MANUAL

ENVIRONMENTAL IMPACT ASSESSMENT

Edited by

A. K. GHOSH
J.R.B. ALFRED
J.K. JONATHAN

ZOOLOGICAL SURVEY OF INDIA
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PREFACE

The post-independence period in India has witnessed an unprecedented pace of development activities. While admitting that such activities only could usher in a new economic era, the Government of India has also been aware of the vital need for conservation and management of the environment. With the setting up of a National Committee under the Department of Science and Technology in 1972 for planning and co-ordination on environmental issues and later establishing a new Department of Environment in 1980 (now the Ministry of Environment & Forests), the Government of India has made it emphatically clear that developmental activities must ensure environmental conservation. In order to fulfil this objective, 'Environmental Impact Assessment' (or EIA) became an obligatory exercise for major development sectors to get clearance from the Government. The EIA exercise being a multi-disciplinary study, appropriate understanding of the natural system and possible impacts that may occur due to proposed projects is essential. Besides, every EIA exercise has also to provide an Environmental Management Plan (EMP) suggesting mitigatory measures.

Considering the need for trained expertise in the field and lack of appropriate training programmes in the area, the Zoological Survey of India, a premier institution under MoEF, organised the first EIA training programme in 1993 and a second one in 1995. Participants were deputed by industrial houses and other agencies and the faculty was drawn from a list of well-known institutions.

The present volume is based on the contributions made by members of the faculty of the EIA courses and is aimed at catering to the needs of the much larger user community.

We express our sincere thanks to all members of the faculty and to the scientists and colleagues who have shared their expertise by way of delivering lectures and contributing articles for the training programmes. We are thankful to Dr R.K. Varshney, Additional Director, ZSI; Dr G.S. Arora, Emeritus Scientist, ZSI and Dr S. Santra, Kalyani University, for helping us in various ways.

We are specially thankful to Mr Dilip Biswas, Chairman, Central Pollution Control Board (then Advisor, MoEF) and Dr N. Bagchi, Advisor, MoEF for their support in organising the training programme and to the authorities of the Ministry of Environment & Forests, Government of India, for providing all support to the programme.

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ENVIRONMENTAL IMPACT ASSESSMENT

A.K. GHOSH*

Introduction

Historically, one may trace the genesis of alternative technology for environmental protection in the introduction of terraced agriculture, contour cultivation, irrigation canal system, storm water sewers, etc. Decades ago, William Blake castigated England's dark "Satanic mills".

However, it is admitted that incorporation of environmental protection 'as a component of administrative, planning, legislative and executive arms of Government' is a recent phenomenon. In general, the hypothesis of environmental control carries the negative connotation of preservation and rather costly measures for protection, conflicting with urgent need to develop; hence it is view as 'an inappropriate extravaganza for developing countries' (ESCAP, 1985).The apparent conflict between those who view resource exploitation as serving the basic human needs and the ones who consider wasteful use of resource will only lead to decreasing productivity in future.

As such, the system of Environmental Impact Assessment originated from the concept that better method and more organised information flow, if generated in a timely, accurate and complete manner and presented in useful format will help decision makers balance the demand for immediate gain from exploitation of resources with the necessity to maintain ecosystem for sustainable development.

The EIA differs from conventional cost benefit analysis aimed at reviewing economic parameters, including the ones with pollution control measures. A host of environmental parameters are "intangible" and no monetary price-tags are available for such parameters; (e.g. social disruption resulting from relocation, destruction of rare habitat or environmental impact over a long time-scale or in geographical location remote to a particular project area.)

By designing a scheme which may include (i) statement of development objectives (ii) techno-economic feasibility (iii) vetting by agency on economic and technical ground (if necessary with corrective measures), (iv) proposed action and alternatives (v) identification of impact (vi)alternative technical/engineering plan (vii) re-identification of impact. Environmental Impact Assessment arrives at the point of understanding that the primary role of EIA is to efficient utilization of natural and human resources in economic development (Evans, 1980).

Since, EIA requires input from different disciplines/sectors, under the coordination of an agency, it provides an unparalleled ground for inter-agency cooperation, EIA, has also been widely adopted as an information gathering and analytical tool to aid economic development (Sammy, 1982).

However, the most commonly voiced objections to EIA are the prohibitive cost and also that idea that this practice retards development (Sammy, op. cit.). A summary, based on response to an international questionnaire which was distributed to 139 developing

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and 25 industrialised countries, indicate the EIA invariably increase project cost but enhance national development and project planning, (Table 1, source Sammy, *op. cit.*).

Table 1

Effect of EIA on Project Cost, National Development and Project Planning

Region or group	Effect of EIA on project cost		Effect of EIA on national development		Effect of EIA project planning	
	Percentage of respondents giving each answer					
	Increase	No effect/ decrease	Enhance	Retard	No effect	Retard
Developing:					(%)	
Africa and the Middle East	84	16	79	21	80	20
Americas	71	29	88	12	81	19
Asia and the Pacific	83	17	60	40	78	22
Europe	100	0	20	80	33	66
Industrialised:						
United States	75	20	41	59	71	29
Canada	70	30	44	56	70	30
Europe	63	34	41	59	57	43
Developing	80	20	74	26	78	22
Industrialised	70	30	42	58	66	34

Environmental Concept and Impact Assessment

Coming back to the basic parameters of EIA, let us look at the concept of environment. In the broadest sense 'the environment is the sum of all social, biological and physical and chemical factors which composes the surrounding of the man. The natural environment of man consists of soil, water, solid waste, noise, biotic components, habitat for wildlife, while the self (man) made environment include work environment, housing, technology, disposal system of noxious air, effluent and garbage, aesthetics, etc. One can therefore, rationally expect that EIA should consider all the parameters cited above along with objectives of minimising impact on short-term and long-term perspectives.

Limitations on EIA arise form complexities of data collection resulting in the delays in implementation and lack of manpower and expertise for assessing the impacts (in developing countries). EIA become more expensive in developing countries due to limited technical and social data-base available at present (Evans, 1982). Large amount of base line data collection become imperative and 'this is perhaps the single most expensive and time-consuming endeavour'. In order to cut down the time and expense, it is often advocated that EIA should be incorporated into the overall development plan of a region (Ludwig, 1984).

Recent efforts initiated by Government of India has been directed towards this logical approach. While urban centres were largely developed through usual planning process drawing data from basic sectors, environmental impact of such development scheme were never considered; now, since 1990, one can witness at least some exercises being suggested towards this goal. Elsewhere, say in mining sector, future mining plan for every major coalfield area in India, now incorporates an environmental management plan based on regional factors.

The impact assessment procedure can only be based on data presented in the project feasibility report and Environmental Impact Statement (EIS) both to be submitted by the proposer of the project. The substantive content of the EIS may be comprehensive but resulting documents often appear to be long on description but short on analysis and becomes of little use in decision making. US Council of Environmental Quality recognised the term "Scoping" (in 1978) to 'describe the process used to determine in an EIS and to what detail'. Earlier, issues and choice of alternatives were largely completed outside the public view but now, the process in USA, has been open to public, affected federal agencies and government.

EIS, as such, forms an integral part for assessment process by the authorised agency (such as Department of Environment in India).

The base line data required for EIS, as mentioned earlier, are to be collected, in most of the cases, in developing countries, a new, from the proposed site and its surroundings.

The weakest part of EIS is often noted with regard to ecological and biological information and analysis. This becomes more critical when rapid assessment is carried out based on one-time, one season data; use of secondary data, (not necessarily on area-specific study but regional, broad based survey data, often dated) creates further confusion at a time when introduction of appropriate procedure is advocated for 'projects which are likely to have significant adverse effects on biodiversity' (IUCN, 1994).

Lastly, while EIA studies in the developed countries have provisions and scope for public hearing and participation, absence of such scope in many developing countries, often lead to public discontent and resentment at a later period of time.

Impact Assessment Studies in India

In India, such data are being asked from identified agencies (Table 2) directly by the Project authorities. When preparation of the report [for submission of Department of Environmental is assigned to a consultant, group/individual the agencies identified may not always be forthcoming considering the role of private profiteering scope of the consultant. But a major question remains, can the identified agencies reply to the questions on the impact statement without any field visit/data collection If not, will the agencies be interested to comply with the requests of number of public-sector clients (without charging any fees for such service) to generate essential data and suggested mitigating measures? Since each of the identified agencies listed in (Table 2) have their own programme of work and priorities, the man-month/days required for such data generation are to be met by deviating a part of expertise from departmental work.

Table 2

India: Agencies responsible for input to EIS	
Agencies	*Area*
1. State Forest Department	Forest data
2. Indian Meteorological Deptt.	Climatological data
3. State Fisheries Deptt.	Fisheries - data
4. Zoological Survey of India	Faunal data
5. State Wildlife Deptt.	Wildlife data
6. State Health Deptt.	Health data
7. Botanical Survey of India	Flora - data
8. Geological Survey of India	Geological - data

The conceptual framework (Table 3) for conduct of EIA in developing countries indicates the Status and Environmental Impact Statement, are to be prepared by an 'Environmental Team' This team has featured from the very beginning to the last but two steps, of the 9 steps in the framework scheme.

Table 3

Conceptual Framework for the conduct of EIA in Developing Countries		
Assessment step	**When ?**	**By whom ?**
1. Preliminary activities	During feasibility study	Project management and environmental team
2. Impact identification (Scoping)	Between feasibility study and preliminary design	Environmental team
3. Baseline study	During preliminary design	Environmental and engineering teams
4. Impact evaluation	Between preliminary and final design	Environmental team and technical specialists
5. Mitigation measures	Between preliminary and final design	Environmental team with input from engineering team
6. Comparison of alternatives	Before final design	Environmental team
7. Documentation	Before final design	Environmental team
8. Decision-making	Before final design	Project management
9. Post audits	After the start of operation	Project O & M

It is evident that no such teamwork functions in India in the impact evaluation, mitigation-measure steps. However, once the project document, primary questionnaire for initial environmental examination (IEE) and/or Environmental Impact Settlement (EIS)/EIA are received (in part from different agencies and compiled by the client department) the Department of Environment (DOEn) takes up the responsibility of examining EIA/EMP clearance or rejection. DOEn has provisions for constitution of expert teams for actual field visit, if necessary. At this stage, it must be mentioned that, for each of the 29 sectors of development project for which environmental clearance has been made compulsory in India, separate committees (with fixed tenure), constituted by DOEn, function independently. Recommendation (EAC) is put up to the Secretary, DOEn, for his consideration.

The demand for development in each of the 29 sectors from almost every state and union territory, *vis-à-vis* the time-fame proposed by concerned client department, can really put pressure to each individual nodal organizations. Above all, in the absence of environmental team at the first 5 steps and variable methodology adopted by different organization, the assessment procedure may not be easy exercise at EAC level.

On the other hand, alternatives are difficult to find out. The efforts on the part of national government to register consultant firms or data generating laboratories often end up in specialised agency list. There is hardly any centre in India, either at non-governmental/governmental level, who can undertake total responsibility of generation/ compilation of data (if available) interpretation for impact statement and suggestion of mitigative measure. Many of the consultant group may be qualified to prepare report on socio-economic-geotechnical/geotechnical parameters but then again, most of these group lack expertise in fisheries/flora/fauna/wildlife ecology. As such, functioning of multi-disciplinary "environmental team" appears remote, but not impossible if such teams are formed by drawing experts from different discipline as a routine matter. Some statement can be made for the case where a Environmental Management Plant (EMP), it to be submitted along with other documents, detailing out reclamation process (e.g. mining). Three vital questions crop up, *viz.*, as to the credibility of data on which present status is based and thereby possible impact assessed; secondly, as the workability of the management plan and thirdly as to the implementation of monitoring system. Specially, identification of expertise/agencies with proven credibility for undertaking reclamation and monitoring work appears to be most difficult, at least at present.

Having the brief overview of the genesis of EIA, its scope and limitations, problem of its application and implementation in developing countries, especially in India, one can now look at the list of sectors where preparation of status report and EIA are prescribed for each of the 29 sectors by Government of India (Table 4).

Before concluding, it would be worthwhile to mention that the cost involved for EIA in other developing countries has been estimated to vary between 0.01 to 0.48 of the total project cost depending on project size and nature (Escap, 1985). In India no such data is available to this author but it has been noted that in order to implement environment management plan (say for instance in coal-mining sector) 5% of the total project cost may be sufficient.

Table 4

List of Projects Requiring Environmental Clearance from the Central Government (1994)

1. Nuclear Power and related projects such as Heavy Water Plants, nuclear fuel complex, rare earths.
2. River Valley Project including hydel power, major irrigation and their combination including flood control
3. Ports, Harbours, Airports (except minor ports and harbours).
4. Petroleum Refineries including crude and product pipelines.
5. Chemical Fertilisers (Nitrogenous and Phosphatic other than single superphosphate).
6. Pesticides (Technical).
7. Petrochemical complexes (Both Olefinic and Aromatic) and Petrochemical intermediates such as DMT, Caprolactum, LAB etc. and production of basic plastics such as LDPE, HDPE, PP, PVC.
8. Bulk drugs and pharmaceuticals.
9. Exploration for oil and gas and their production, transportation and storage.
10. Synthetic Rubber.
11. Asbestos and Asbestos products.
12. Hydrocyanic acid and its derivatives.
13. (a) Primary metallurgical industries (such as production of Iron and Steel, Aluminum, Copper, Zinc, Lead and Ferro Alloys).
    (b) Electric arc furnaces (Mini Steel Plants).
14. Chlor-alkali industry.
15. Integrated paint complex including manufacture of resins and basic raw materials required in the manufacture of paints.
16. Viscose Staple fibre and filament yarn.
17. Storage batteries integrated with manufacture of oxides of lead and lead antimony alloy.
18. All tourism projects between 200m–500 metres of High Tide Line or at locations with an elevation of more than 1000 meters with investment of more than Rs. 5 crores.
19. Thermal Power plants.
20. Mining projects (major minerals) with leases more than 5 hectares.
21. Highway Projects.
22. Tarred Roads in Himalayas and/or Forest areas.
23. Distilleries.
24. Raw Skins and Hides
25. Pulp, paper and newsprint.
26. Dyes.
27. Cement.
28. Foundries (individual)
29. Electroplating.

It can also be stated that while, more than 100 methods are reported to be available for carrying out EIA (Ludwig, 1985) most of these can be divided into 8 broad classes as listed below.

(1) Check-list
(2) Environmental evaluation
(3) Matrices

(4) Network
(5) Overlays
(6) Environmental indices
(7) Cost benefit analysis
(8) Simulation modelling

The checklist is basically involved in preparation of a list of environmental social and economic factors which are likely to be affected by the proposed project. Environmental evaluation may be made by comparing checklist of environmental resources against thresholds of concern and when impact exceeds TOC values, the evaluation process calls for further critical analysis.

The matrix methods may be of different types but all such methods focus on the links between project components and activities and possible impact on environmental components. A two dimensional matrix or interaction matrix is often used as a sample too. While matrix deals with a two dimensional system, Network method expands further into cause-condition-effect relationship. All these methodologies are obviously directed towards identification of possible impacts. The identification process further leads to a process of predication based on magnitude, extent and duration of impact; a system of simulation modelling may be most useful for such an exercise.

The Indian system incorporates at least 5 of the 8 classes (*viz.*, 1,2,3, 6,7) in different sectors. Ideally speaking, the review agency should use critical assessment criteria. Typical questions for such exercise may include (Davies and Mueller, 1984) the following:

1. Will the project result in environmental issues that are likely to be highly controversial and if so, how will this be managed?
2. Will the project result in loss of previous/irreplaceable natural resources, and if so, is this justified?
3. Will the project sacrifice important long-term environment resources and values in favour of immediate gains?
4. Does the project fit into the regional development plant of the region in which the project is to be sited, if such a regional development plan exists?
5. Will the project endanger species survival, and if so, how is this justified?
6. Will the project establish a precedent for future actions involving sensitive environmental issues?
7. Will the project, while in itself not exercising serious impacts, will be related to other actions where the total accumulated effects could be serious?
8 Whether the project is consistent with the national policies?
9. Whether the project is consistent with national foreign exchange policies?
10. Whether due consideration has been given, to alternative project which could realise the desired development objectives, and whether any of these alternatives might represent a better overall solution including consideration of all applicable project constraints including environmental effects?

It is advocated that in case of big project, where the effects of environment affect many sections of pollution, public hearing should be organised and views of various interest group should be heard. this may expose the decision makers to the views of diverse interest group on one hand, educate the public opinion and stimulate public awareness on the other hand.

At the end, EIA study is to be followed by Environmental Management Plan (EMP) with suggestive mitigation measures to reduce, avoid or offset potentially adverse consequences of the proposed project. This may include change of siting, route for transportation of raw material and discharge of effluent, operational methods, introduction of proper pollution control technology at source point, restoration of damaged ecosystem, compensation for lost forest land and rehabilitation of displaced population with an appropriate scheme acceptable to the oustees.

The EIA and EMP exercise however often becomes futile unless a process of monitoring of basic parameters, physico-chemical and ecological is ensured during construction phase and later operational phase of the project. While standards of emissions and discharges of air and effluent are set up and ecological restoration plan are recommended through legal instrument, a strict process of both in-house monitoring and external monitoring become essential component to deliver the goods of EIA and EMP to the community at large. The recent introduction of Environmental Audit (since 1993) system in India is yet to take off the ground but with availability of a cadre of environmental managers and stricter imposition of the law, such a process seems to achievable.

EIA, Biodiversity & Biosystematics

In the context of impact assessment, the biological resources play one of the most significant role; it has been realised that sustainable development can only be ensured through maintenance of biological diversity (McNeely, 1988). The entire foundation for such study of bio-diversity invariably is based on taxonomy and systematics. (Ghosh, 1990)

The Association for Systematic Collections and Smithsonian Institute, in USA in a recent report (January, 1989) entitled "Systematic collections resources for 1990's" pointed out that "We are at a turning point in which biodiversity mapping and comparative studies will play a central role; a total of 1.4 million species of all kinds of organisms have been described to date" The actual number of species is certainly much higher largely because the tropics are biologically so rich and so poorly known: a widely accepted minimum figure is 10 million and nearly three fourth of the invertebrates are believed to be unknown as yet; some zoologists, including the authors of the above mentioned reports and experts opining in the report on "World Resources" (1986) suggested that there could be as many as 30 million insect species in the tropical forests alone (Erwin, 1983).

Due to demand of development processes and ever growing population in the tropical countries, it is estimated that 80,000 square km. of tropical forest are being converted to other uses annually. At the same time few scientists are qualified to describe new tropical species and a 1986 report states that worldwide, only 1600 taxonomists and systematists study tropical organisms, whereas 66 percent of all species occur in the tropics which occupy 42 percent of earth's surface.

The environmental impact assessment study demands precise knowledge of taxonomy related to plants and animals and specifies that the scientists reporting on the proposed site must opine as to whether the area harbour any rare or endangered species, or whether it supports such biodiversity which should be given a shelter under wildlife sanctuary. Ecological condition underline the basic concept of animal diversity, including biology and other phenomenon like animal migration etc. The impact assessment study, therefore, also demands information on possible migration route of terrestrial animals (e.g. elephants), birds and fishes. As such the entire exercise needs a serious scientific study by competent taxonomists and biologists.

Interestingly, while it is acknowledged that systematics appeared early in biological research, the number of specialists, the training facilities, importance of reference collections and funding for systematic research based on taxonomic principles follow a downward trend in recent decades. And this trend continues even at a time when a huge demand for conservation data base on check-lists is evident. The 'old' science of systematics becomes synonymous with "out of date"

The danger that may rise due to inappropriate survey and identification of resources in land area or waterbody is never fully appreciated. But the finding of 16 new rice varieties in Silent Valley area of Kerala (which would have been submerged had the proposed hydel power project been implemented), amply demonstrate the point.

The present system of environmental impact assessment putting only 20 percent weightage on assessment of living natural resources (wholly dependent on taxonomic knowledge), in the matrix analysis calls for a change; specially in view of the fact that both physical environment (45%) (surface water, hydrology and quality, ground water quality, physiography, etc.) and human environment (35%) (agriculture, water supply, health etc.) largely depend on ecology and environment *per se*. But for the present, the question remains as to how many taxonomists in a country like India, are available to identify and assess the fauna and flora, that are likely to be affected due to various developmental projects. The pace of such projects being very fast and the number of experts being too inadequate, such exercise of impact assessment remains highly unsatisfactory in many cases. One is inclined to agree with Bramwell (1988) that "We are allowing a major impoverishment of both ecological and biological diversity to take place under our noses with the inventory incomplete and with probably millions of unknown and undescribed species in the tropic. We have allowed planners and grant committees to ignore, for example, the need for both basic taxonomic, training for taxonomic research, in favour of more glamorous sophisticated trivialities"

Even the "International Biological Programme (IBP) when emphasising on the conservation of terrestrial biological communities, pointed out to be urgent need for extensive taxonomic training to meet the demand (Worthington, 1975) of development.

In summary, the study of biological diversity provides the base line data for genetic resources on which human society "depends for virtually all its food, nearly half of its medicines much of its clothing and in some regions virtually all its fuel and building material" (Fitter, 1982). Much of such diverse genetic resource remain in the yet unexplored, un-mapped areas (biologically) but being continuously converted for other uses. Without appropriate support for taxonomic work, a close estimate of the country's total number of species can never be attained. The pursuit for a basic truth will sadly suffer from lack of empathy in and world of esoteric concepts.

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ENVIRONMENTAL IMPACT ASSESSMENT OF DEVELOPMENT PROJECTS

DILIP K. BISWAS*

Introduction

Over the recent years, Environmental Impact Assessment (EIA) has come to be recognized as an important tool for integrating the objectives of environmental management with the requirements of economic growth and social development. The purpose of environmental impact assessment is to evaluate the beneficial and adverse effects of a planning activity on the environmental system which could be integrated with the economic analysis of the project costs and benefits. It is desirable that this exercise is undertaken early enough in the planning stage so that adequate and appropriate preventive measures can be incorporated into the project at the least cost.

EIA helps in understanding the physical and ecological effects on social, cultural and aesthetic concerns. It involves multi-disciplinary expertise in identifying, evaluating and interpreting the potential impacts. EIA also helps in identifying alternatives to sites of projects, choice of technology and alternatives to the proposed development projects. While EIAs are not always precise, quantitative optima on all environmental issues, they do focus attention on the major ones and thus help in examining options for choosing an environmentally acceptable course of action.

In recognition of the role that EIA could play, Government approval towards investment decisions and selection of sites for projects in various sectors is accorded on the basis of environmental impact assessment and clearance thereof.

The Government of India has assigned the responsibility for appraisal of projects with regard to their environment implications on the Ministry of Environment & Forests. Based on environmental impact assessment and issues arising thereto, decisions are taken by the competent authorities in respect of the projects including selection of sites.

Apart from environmental clearance, clearance from forestry angle is required, if forest land is involved in the project. Under Forest (Conservation) Act, 1980, diversion of forest land for non-forest use requires the prior approval of the Central Government. For such diversion, the Ministry of Environment & Forests considers the proposals on recommendations of the State Forest Departments.

Single Window Clearance

When a project requires both environmental clearance and approval under the Forest (Conservation) Act, 1980, proposals for both are required to be simultaneously given to the corresponding Divisions in the Ministry. The processing is done simultaneously for clearance/rejection, although separate letters may issue in each case. If the project does not involve diversion of forest land, the case is processed only for environmental clearance.

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Information Required For Environmental Appraisal Of Projects

The project authorities are required to furnish the following documents for environmental appraisal of a development projects:

1. Detailed Project Report (DPR)
2. Filled–in Questionnaire on environmental aspects.
3. Environmental Impact Assessment Report along with Environmental Management Plan.

The Detailed Project Report is necessary to seek information on the technical and financial aspects of the projects.

The questionnaire is meant for providing information on specific queries for determining the likely environmental impacts of a development project. The Environmental Impacts Assessment Report (EIAR) is an exercise of self assessment on the part of the project authorities regarding the likely impacts (positive and negative) of their projects. For environmental impact assessment, some of the issues that need to be dealt, which include the following:

1. Impact on soil, water (hydrological regime, ground water and surface water) and air quality.
2. Impact on land use, forests, agriculture, fisheries, tourism, recreation etc.
3. Socio-economic impacts including short and long term impact on population.
4. Impact on Health.
5. Impact on flora and fauna (wildlife) particularly endemic and endangered species.
6. Cost benefit analysis including the measures for environmental protection.

The Environmental Management Plan (EMP) needs to cover the following aspects:

1. Safeguards and control measures proposed to prevent or mitigate the adverse environmental impacts.
2. Plans for rehabilitation of project oustees.
3. Assessment of risk and plans for dealing with accidents/disasters.
4. Monitoring and feed back mechanism on implementation of necessary safeguards (e.g. setting up of Environmental Management Cells).

For filling up the questionnaires and also for furnishing the Environmental Impact Assessment Report and Environmental Management Plan, the project authorities are expected to collect and collated information on various environment aspects which are not normally required in preparing the Detailed Project Reports (DPR) for clearance from techno-economic angle. In respect of such information as needed for the purpose of environmental appraisal, the project authorities may commission studies for baseline data on existing environmental conditions and assessment of the likely impact from the proposed project. Such studies could be carried out through the R&D institutions and consultant organizations with requisite expertise. The project authorities may also seek relevant information from the concerned agencies such as the following:

1. State Departments namely, Environmental, Forests & Wildlife, Agriculture, Fisheries, Health, etc.
2. Indian Meteorological Department.
3. Zoological Survey of India.
4. Botanical Survey of India.
5. Geological Survey of India.

Environmental Regulations & Guidelines

The major environmental regulations which are required to be referred to include the following:

- Water (Prevention and Control of Pollution) Act, 1974 as amended in 1978 and 1988.
- Water (Prevention and Control of Pollution) Cess Act, 1977 as amended in 1991.
- Air (Prevention and Control of Pollution) Act, 1981 as amended in 1987
- Environment (Protection) Act, 1986 and Environment (Protection) Rules, 1986.
- Factories Act,1984 (As amended by Act 20 of 1987).
- Public Liability Insurance Act 1991.
- Environmental Guidelines for Siting of Industries, 1985, and Environmental Impact Assessment of Development Projects: Background note, February 1989, Ministry of Environment & Forests.
- Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989, Ministry of Environment & Forests.
- Forests (Conservation) Act, 1980.

To help the project proponents for in-house evaluation of their projects from environmental angle and to elicit specific information on environmental aspect, the Ministry of Environment & Forests has prepared guidelines for developmental projects in various sectors. The guidelines broadly deal with the issues that need to be considered during the implementation of projects. These include the siting criteria and important environmental parameters such as meteorological conditions and air quality, hydrology and water quality, occupational safety and health effect and impact on surrounding areas.

Environmental Standards

The standards as enlisted in the following tables are usually followed and controlled in regard to effluent, emissions and noise:

	Standard	Coverage	Publisher
1.	IS-2490 Part-I	Effluent Standard General.	Bureau of Indian Standards.
2.	IS-2296	Surface water quality subjected to pollution	
3.	Gazette of India September 1988 (As per Environment (Protection) Act, 1986) and Environment (Protection) Rules, 1988.	Effluent Standard General	Bureau of Indian Standards
4.	Ambient Air Quality Standard Notification	Ambient Air quality various zones.	Central Pollution Control Board (CPCB).
5.	Gazette of India December 1989 (As per Environment (Protection) Act, 1986.)	Ambient air quality standards for noise.	MOEF
6.	Permissible level of certain chemical substances in work environment.	TLV in Work Zone.	Factories Act (Amendment of 1987).
7.	Permissible level of noise in work zone.	Noise pressure level and exposure time.	Central Labour Institute, Bombay (also OSHA norms).
8.	Minimal National Standards (MINAS)	Limits of effluents.	CPCB
9.	Emission regulations	Emission limits and stock heights	CPCB

Procedures for preparing EIA & EMP Reports

A comprehensive EIA and EMP report must contain chapters on –

— Identification
— Prediction
— Evaluation
— Mitigative measures through Environmental Management Plans
— Disaster Management Plan

For preparation of comprehensive EIA & EMP, following are essential:

— Generation of baseline data on quality of air, water, soil, noise, flora and fauna, socio-economic condition, demography, meteorology, hydrogeology and hydrology and other physical parameters and land use pattern likely to be affected by the project. Number and location of monitoring sites for baseline data are to be carefully selected based on suitable models and prevailing meteorology and topography.

— A statement of process technology, flow sheets, water and energy balance, sources of emission, effluent, solid wastes and noise, layout and location – with alternatives, if any, in the form of a feasibility or project report.

— Prediction of impacts using suitable mathematical models, dispersion models, river models, green belt models, etc.
— Evaluation of impacts among alternatives and/or among various stages of project.
— Remedial measures to minimize adverse impacts through technological improvements, proper organization and contingency plans for emergency situations.

In some cases, a rapid EIA and EMP may precede the comprehensive EIA & EMP with baseline data of seasons having worst impact.

Indigenous Availability of Know-how, Plant and Machinery in the field of Environmental Engineering

The preparation of EIA & EMP needs specialized know-how. Many public and private sector consultancy units have the required know-how. Also, for conducting field monitoring, there are a number of laboratories in both public and private sectors. Facilities exist for engineering and project management of pollution control systems and there are small and large manufacturing houses for pollution control equipment. Thus, facilities and know-how for environmental control systems are indigenously available from concept to commissioning.

Incentives for Pollution Control and Initiatives for Clean Technologies and Prevention of Accidents

The existing standards are based on the concentration of pollutants in effluents and emissions. The norms are being revised to formulate mass based standards for reducing the wastes, encouraging recycling and reuse as well as conservation of natural resources.

Traditionally, pollution control measures have been dependent on "end-of-the-pipe" treatment technologies which allow the wasteful use of resources and then consume further resources to deal with environmental problems. With the increasing crunch of raw materials and energy coupled with tightening of pollution control norms, the industries are being persuaded to look for cost-effective alternatives in terms of raw materials and energy conservation as well as cleaner production technologies. Small Scale Industries (SSIs) are a special feature of Indian economy. A scheme has been launched to encourage installation of combined waste treatment facilities in clusters of small scale industries. Subsidy is given to clusters of such industries for setting up Common Effluent Treatment Plants (CETPs).

Initiative has been taken for control of pollution and waste management by conversion of the waste into raw material for various uses. A National Waste Management Council has been constituted for suggesting ways and means for effective utilization of wastes from various sectors including industries.

A Central Crisis Group has been constituted to ensure coordination of necessary action in the event of accidents. A red book on "Central Crisis Group Alert System" has been prepared to provide guidance for management of crisis pertaining to chemical accidents. Risk assessment has been made a pre-requisite for environmental impact assessment and clearance of projects handling hazardous substances. Efforts are being made to create and maintain a data bank for hazardous chemicals and accidents. Data bases like CCINFO (a Canadian database), ETEC5 and POISINDEX in microfiches have been procured for this purpose.

To create awareness among consumers, a scheme for environment-friendly labeling of products has been initiated. The scheme is for the twin purpose of encouraging the manufacture and use of such products. National Awards have been instituted for recognition of outstanding activity for prevention and control of pollution.

Suggested Readings

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CONCEPT OF METEOROLOGY

S. MISHRA*

Introduction

The weather has always been a subject of universal interest. Man has been concerned about its fickle ways and geographical variation since the earliest days of recorded history. He has observed the fury of mighty storms, the freshness of gently falling raindrops, the burning sun over a drought-stricken land, and the refreshing breeze of a spring afternoon. He has observed the lands of perpetual ice and snow, the middle latitudes with rhythmic yet somewhat erratic annual cycles, and the tropics with perpetual warmth. These things have caused him to wonder about the powers that control the elements. What can cause a pleasant summer afternoon to be changed into a frightful display of wind, hail or flood? Only recently have we begun to understand these secrets well enough to permit advanced planning and intelligent action, based on what the weather is going to be.

The planet Earth on which we live falls into four broad categories that include the solid *LITHOSPHERE*, the liquid *HYDROSPHERE*, and gaseous *ATMOSPHERE* and the life forms the *BIOSPHERE*.

The atmosphere which is vital to terrestrial life, is a thick blanket basically of gases and suspended liquids and solids that entirely envelops the earth and is held to the earth by gravitational attraction and is divided into layers (Fig. 1) with distinct characteristics. We all live in the bottom of the vast ocean i.e. the atmosphere.

Although the study of weather and climate focuses on the envelop of gases, continuous interchanges among the "spheres" produce an integrated environment and no component can be understood adequately without reference to the others. An interaction of land, water, air and plant and animal life constantly uses and renews the atmosphere. For example, the weathering of rocks, burning of fuel, decay of plants and breathing of animals all use oxygen and release carbon dioxide. Nitrogen follows a complex cycle through bacterial activity in the soil, animal tissue, organic processes in decay and back into the air. Plants, animals, bacteria and chemical interaction in soil and water all help to maintain an intricate balance among land, water, life and the air.

An analysis of meteorological parameters of weather and climatic information is one of the basic requirements in any kind of project/industry in any area to examine and monitor the following aspects:

a) What is the existing weather and the climatic condition of the area or general meteorological condition and weather in the said areas it allows the particular industry/project to be developed? If so what should be appropriate site with respect to other locations;

b) During the operational stage a systematic recording and analysis of meteorological data will indicate how the industry/project is effecting the environment.

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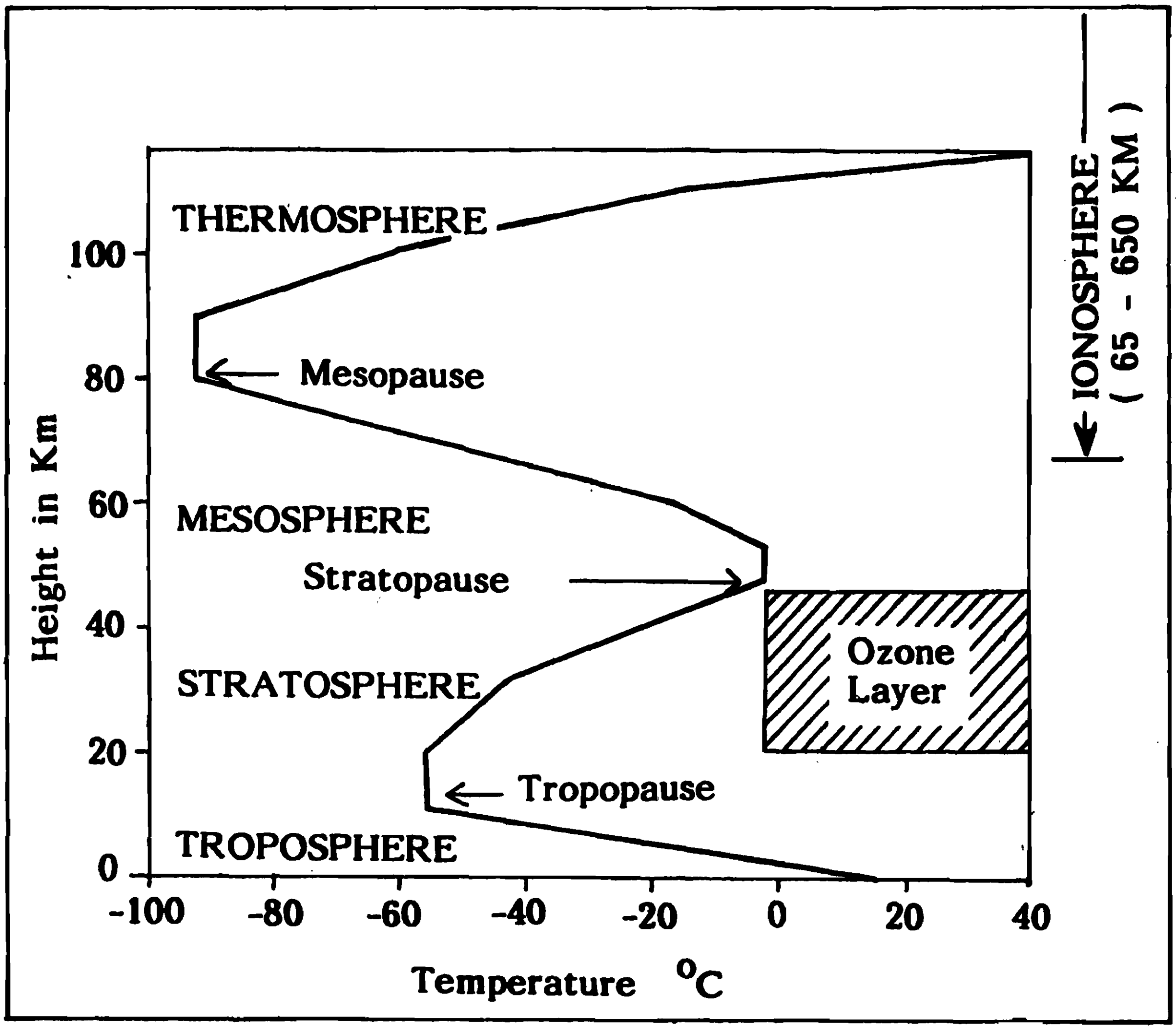


Fig. 1

c) Solution to the problem if any will have to be found out based on observed data and their distribution and variation.

The whole gamut of meteorological environment essentially involves a larger number of parameters and their interaction. Some of the parameters are very important for some endeavour while others are less significant and the picture may also differ from one project to another.

Monitoring of Weather and General Climate

Weather has been described as the sum total or general characteristics of the atmospheric condition of any place for a short period of time. The climate on the other hand implies the totality of weather condition over a period of years. Meteorological parameters are monitored both through instruments and by naked eye (Tables 1 & 2). Since meteorological parameters are very important factors with wide range of bearing and application, one should, in the initial planning stage, study the climate of the proposed site with specific relevance to the specific aspect. An easy method to get a general idea of the climate of a place is the preparation of a climograph.

Table 1

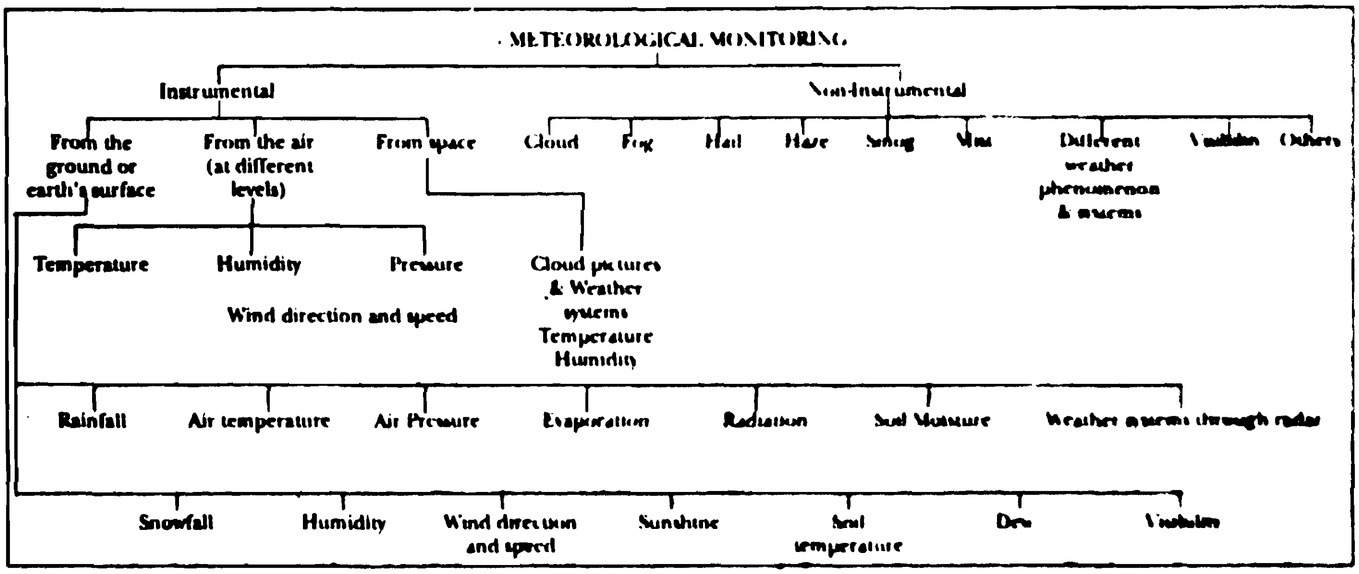


Table 2

	Name of the Instruments	To record
1	Ordinary raingauge	Rainfall
2	Self-recording raingauge	Time of occurrence and cessation of rain with intensity
3	Maximum and Minimum thermometer	Maximum and minimum temperature in a given interval of time
4	Thermograph	Time of occurrence of maximum and minimum temperature and duration of any desired or critical value of temperature which has any special relevance to any phase of crop growth or occurrence of pest and disease
5	Dry and wet bulb thermometer	Humidity and dew point temperature of any selected hours
6	Hygrograph	Time and occurrence of maximum and minimum humidity and duration of any desired or critical value of humidity which has any special relevance to any phase of crop growth, occurrence of pests and disease, etc.
7	Windvane	Wind direction
8	Anemometer	Wind speed
9	Evaporimeter	Potential evaporation
10	Sunshine recorder	Bright sunshine hours
11	Dew gauge	Amount of dew
12	Soil thermometer	Soil temperature at diferent depths at selected hours
13	Grass minimum thermometer	Temperature of air immediately above ground
14	Soil moisture meter	Soil moisture
15	Pyranometer	Radiation

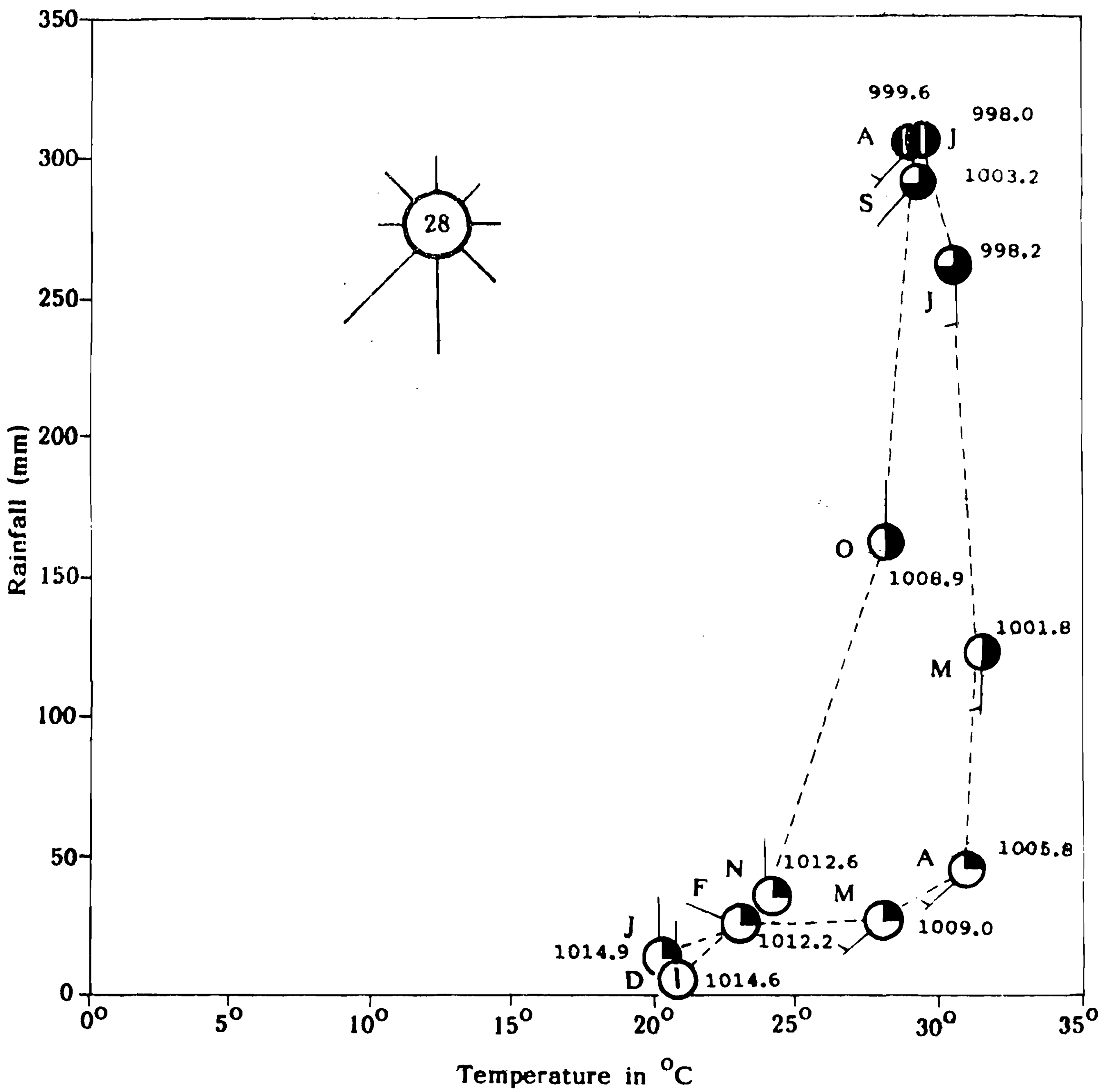


Fig. 2: Climograph – Calcutta

Preparation of a climograph : A climograph may be prepared in a number of ways depending on specific purpose. The most popular way of preparation of a climograph to represent maximum number of elements are as follows (Fig. 2). Y and X axes of the diagram represent the rainfall and temperature. The circles are representative of each month on the basis of rainfall and temperature. The covering of the circles represent average cloud cover of each month. Predominant wind direction and average speed of each month is shown by the straight line attached with the circle and feather at the end of each line. Station level pressure and number of rainy days also represented on the top and bottom of the right hand side of each circle by figure and symbol respectively. This diagram gives a fair idea about the general climatic condition of the station.

Comfort analysis : Where a large number of people will be working in different spheres the planner have to study the climate with specific emphasis on the degree of human comfort. One such model has been designed by Victor Olgyay. Mean monthly values of dry bulb temperature and relative humidity are required for this purpose. In case the records are not available at the site, such data of a nearby station may be used (Fig.3).

The mean monthly values of relative humidity and dry bulb temperature are plotted along X and Y axis of the graph. Twelve points corresponding to twelve months are joined to get a twelve sided polygon. The position of the polygon on the model will indicate the type of climate which will prevail in different months at the project site. There may be some month with fairly comfortable climate; while others may be unbearable.

Precipitation : Precipitation, in meteorology, means either the failing of moisture to the earth in any form, or the quantity of water so deposited, expressed in depth of water. Precipitation takes various forms, such as rain, snow, slit, hail and other special formations like dew, frost and fog although these are not regarded as precipitation Amount of precipitation always means the liquid content. The word *rainfall* is often used as synonymous with precipitation, meaning the amount of water in whatever form it may have fallen. However, precipitation is the fundamental aspect in any kind of planning on land. The object of rainfall measurement is to obtain the thickness of the layer of water that has fallen, assuming it to be evenly distributed over the surface in the vicinity of the measurement. Any open vessel of the same cross section throughout the exposed vertically will serve as a rain gauge.

Evaporation

Water is lost from the earth's surface by evaporation from sheet of water, ice from soil surface and by transpiration from vegetative cover. The rate of evaporation from a surface can be expressed as a volume of liquid water evaporated from unit area in unit time. The rate of evaporation or evapotranspiration depends upon the ability of the atmosphere to evaporate it. The unit of time is generally the day and the unit of depth is millimeters.

Open pan evaporimeter : The open pan evaporimeter is an instrument for the measurement of the evaporating power of the air near the ground. The value of evaporation obtained from an open pan evaporimeter do not give directly the evaporation from a surface, representative of natural condition. They indicate, however, the order of mag-

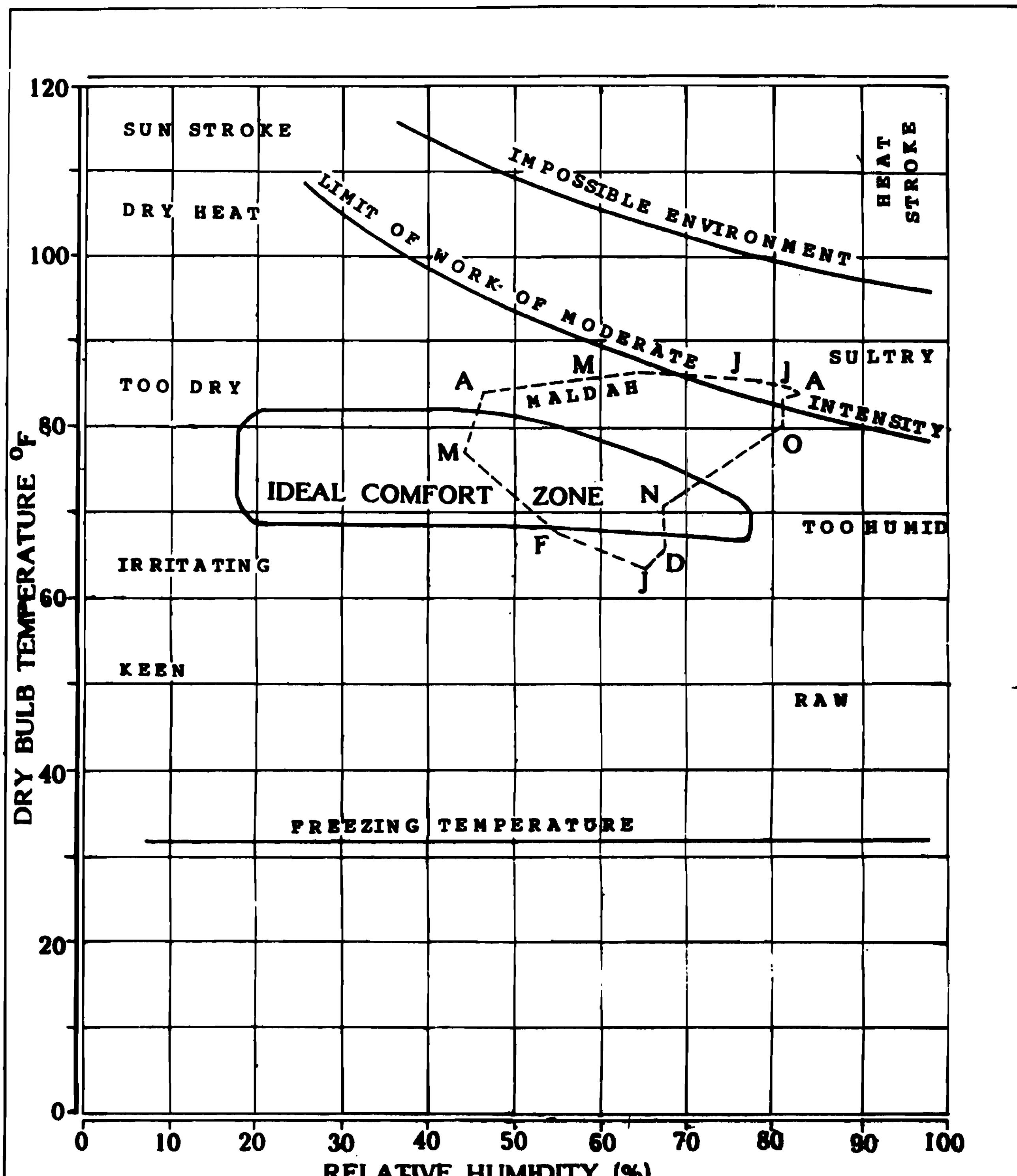

120
100
80
60
40
20
0
DRY BULB TEMPERATURE °F
0 10 20 30 40 50 60 70 80 90 100
RELATIVE HUMIDITY (%)
SUN STROKE
DRY HEAT
TOO DRY
IRRITATING
KEEN
FREEZING TEMPERATURE
IMPOSSIBLE ENVIRONMENT
LIMIT OF WORK OF MODERATE INTENSITY
HEAT STROKE
SULTRY
TOO HUMID
RAW
IDEAL COMFORT ZONE
MALDAH
A
M
J
J
A
O
N
D
J
F
M

Fig. 3

nitude of evaporation from such surfaces and comparative results over different areas can be obtained by using intentional instruments and similar exposure.

Principle : The evaporimeter consists of a large circular pan and a fixed point gauge, which serves as a reference point for the level of the free water surface in the pan. The amount of water lost by evaporation from the pan after any given interval of time is measured by adding known quantities of water to the pan from the graduated cylinder till the water level touches the surface point. The amount of water added equals the amount of water lost by evaporation from the pan and this divided by time interval gives the rate of evaporation. Rain falling into the pan is allowed on the assumption that the catch of a nearby rain gauge represents the added depth of water due to the rain.

Monitoring of effective rainfall

To get an idea of the effective rainfall, a study of the water balance in the area has to be made. Rainfall minus evaporation is the effective rainfall. Mean monthly values of rainfall and evaporation are plotted on a graph on the same scale (Fig 4).

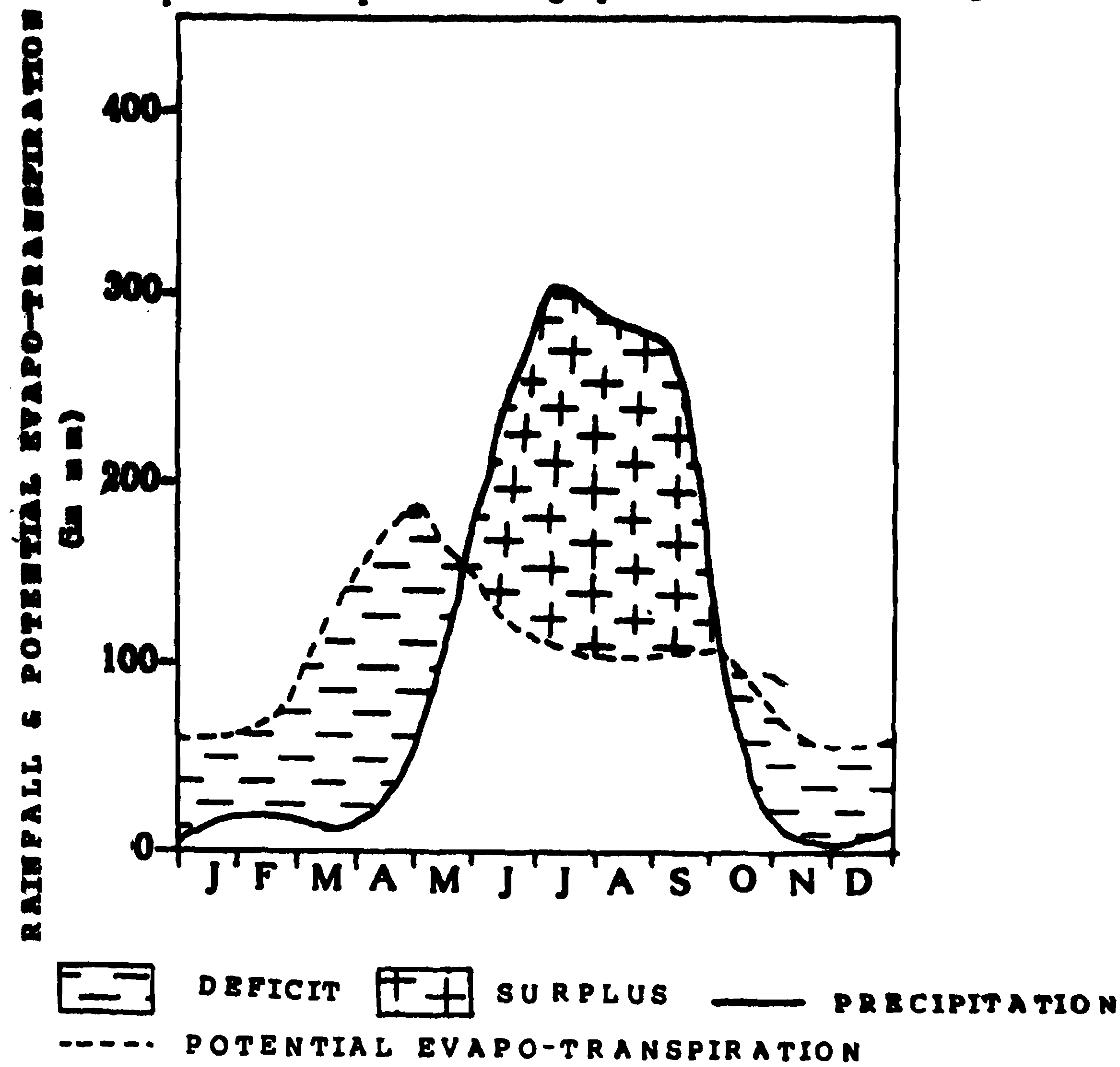


Fig. 4: Average Water Deficiency and Surplus - Maldah

A study of the figure will show the new water available in different months. Continuos lines show the distribution of rainfall while the dotted ones show the evaporation. Positive areas are the months when rainfall is in excess; while the negative areas are the period when rainfall is in deficit. One has to take proper precaution in deficient months. Water use for soil moisture recharge and soil moisture utilization have not been considered in this simple diagram.

Monitoring a rainstorm : A rainstorm is a disturbance which gives fairly widespread rainfall in the area affected by it. For study of a long duration rainstorm the data from an ordinary rain gauge are useful; while study of a short duration storm the data are to be extracted from the records of the self-recording rain gauge.

Short period rainfall intensity : When the project area is being developed, one has to bear in mind the problem of disposal of rain water in a short time. From records of self recording rain gauge, maximum intensity of rainfall(R) in short period, say 15 minutes, which has occurred in association with a rainstorm during the past few years has to be found out. The volume of water accumulated in 15 minutes over the project area (A) is R × A. Hence, the arrangement for disposal of storm water will have to be made in 15 minutes so that there is no accumulation of storm water. Such discharge arrangements lose their efficiency as the time passes, as has happened in case of Calcutta which can now discharge rainfall occurring at the rate of 6mm. per hour only.

Probable maximum precipitation (PMP) : As the discharge arrangement will be a permanent feature of the project area, a safe guard is necessary. Instead of depending on the actual value of short period rainfall that has occurred, it is advisable to work with the P.M.P value, which is calculated in the following way. If the storm had the maximum moisture charge in its system, what would have been the precipitation in that event. Let us assume that from the analysis of the records of the self-recording rain gauge, the rainfall intensity in a short period was observed as 'R' in 15 minutes when the relative humidity was 80%. There are other occasions when in the same area humidity of the other of 95% had occurred. Let us now calculate what would have been the amount of rainfall if the storm has occurred at the time of maximum moisture charge of 95%. This value is:

$$R \times 95/80 = \text{'R'}$$

Hence, an arrangement for disposal of rainfall of ('R') in 15 minutes will meet all emergency situations.

Temperature

One of the weather elements of primary concern is the temperature of the air. Temperature in many parts of the world is subject to wide extremes and sudden changes. It is a weather element to which human life, plant and animal life, are sensitive. It is an important factor in determining the condition of life and the productivity of the soil in different regions of the world. The varying temperature of the air is responsible for many other weather changes. Temperature of a place changes both in vertical and horizontal direction.

Thermometers: Thermometers are instruments designed to respond accurately to changes of temperature. The usual type of thermometer is the mercury-in-glass pattern Changes of temperature are registered by changes in the length of a mercury thread in a glass capillary tube. An increase in the temperature causes upward expansion of the mercury in the tube, while decrease in temperature brings about a contraction of the mercury thread down the tube.

Scale of Temperature: Temperature may be expressed in degrees on one of the following scales with different freezing and boiling points of water.

Scales	Freezing point	Boiling point
Celsius(°C)	0°	100°
Fahrenheit(°F)	32°	212°
Réaumur (°R)	0°	80°
Kelvin (°K)	-273°	373°

Numerous recordings are made for meteorological purpose but the following are the ones usually made when recording the temperatures at stations:

1. The ordinary air, or dry bulb temperature.
2. The 'Wet bulb' temperature'. This is used in humidity determination.
3. The day maximum and minimum temperature,
4. The minimum night temperature near the ground 'the grass minimum'.

Humidity

Water vapour is the most variable of the gases of the atmosphere, ranging from almost zero to a maximum of about 4 per cent by volume. The variability in the water vapour content of the atmosphere, in both place and time, is of great significance for several reasons:

i) The amount of water vapour present in a given volume of air is an indication of the atmosphere's potential capacity of precipitation,

ii) Water vapour in its power to absorb radiation, is a regulator of heat loss from the earth,

iii) The amount of water vapour present decides the quantity of latent energy stored up in the atmosphere for the growth of storms,

iv) The amount of water vapour present is an important factor affecting comfort feeling,

v) It also regulates the rate of evapotranspiration,

It is extremely important to mass existence on the earth and constitutes one of the primary elements of weather.

The humidity of the air is expressed in three different ways.

Absolute humidity of the air is the actual mass or weight of water per unit volume of air, usually calculated in grams per cubic metre. This is a direct way of expressing humidity. Specific humidity on the other hand is the ratio of the weight of water vapour (grams) to the weight of the moist air (kilograms) (g/kg).

Relative humidity is a very common parameter for expressing water vapour content of the air. It is the percentage of water vapour present in the air in comparison with saturated condition at the same temperature.

$$R.H. = \frac{\textit{Actual amount of water vapour present in the air}}{\textit{Possible amount of water vapour when saturated at the same temperature}}$$

Measurement of Humidity : The type of instrument normally used is the wet-and dry bulb thermometer for constant observation hygrograph is used.

Wind direction and Speed

Wind is the air in horizontal motion. Vertical movements in the air are commonly called currents. Wind at the place of observation is caused as a result of:

(i) pressure gradient force;

(ii) coriolis force due to the earth's rotation and

(iii) frictional force.

The wind at any place is never steady. At the time of observation, the mean wind direction and speed are read from the wind vane and anemometer, which are erected at a height of 10 metres above the ground.

Monitoring the general wind pattern : For planning purposes, the wind data are to be summarized and the most predominant wind direction and speed have to be ascertained. This is done by calculating the percentage frequency of the number of occasions wind was blowing from different directions and the same plotted by appropriate length of the line from the direction around a circular station model. The speed is indicated by the number of arrows attached to each direction. The p.c. frequency of calm wind is shown by a figure inside the station model. This method of depiction is termed a wind rose.

Monitoring of wind data round the clock : Both the wind direction and speed are recorded continuously by the Dine's pressure tube anemograph. Wind data at any instant may be picked up from the graph. There are other instruments which record wind data continuously on a running strip chart with facility for digital display. The exact time, direction, and the speed when a station is hit by a squall (very high wind) are obtained from such records. This is useful in structural designing etc. Further analysis of such continuous data may help the scientist/engineer to study the feasibility or otherwise of a station for erection of a wind mill for power generation. Wind direction and speed are also essential to understand the drift/ transport of smoke, pollution etc.

Monitoring of vertical component of wind : The lift of a balloon in an upper wind observation either by a pilot balloon ascent or by a ratio wind flight in the vertical direction in a given time gives a measure of the vertical component. The dispersal of the pollution from a chimney top i.e. its horizontal speed and vertical mixing height will depend on the horizontal and vertical components. and they will determine the shape of the cone of dispersal. Both these parameters are to be included in the preparation of a dispersal model.

Monitoring of Upper air : Briefly it may be stated that temperature of air decreases with altitude up to a height called tropopause. The height of tropopause is about 9 km over the poles and about 18 km over the equator. Beyond the tropopause the temperature of air either remains constant or increases with height in a layer known as stratosphere. Fall of temperature with height in the lower layer is called Lapse rate. Lapse rate varies with respect to time and space. It is determined twice daily by releasing the Radio-Sonde balloon. The balloon is fitted with a Baroswitch for measurement of pressure of altitude: a Thermister for measure of temperature; and a Hydrister for measurement of relative humidity. It has also a transmitter sending signal of pressure, temperature and relative humidity which are received at the ground station.

Assessment of lapse rate of the atmosphere

An analysis of the radio sonde data will reveal the rate of fall of temperature with height. This is called the environmental lapse rate (Y) the value of which is not constant and has to be determined each time by releasing a radio sonde balloon in the air from the station where the value of lapse rate is required.

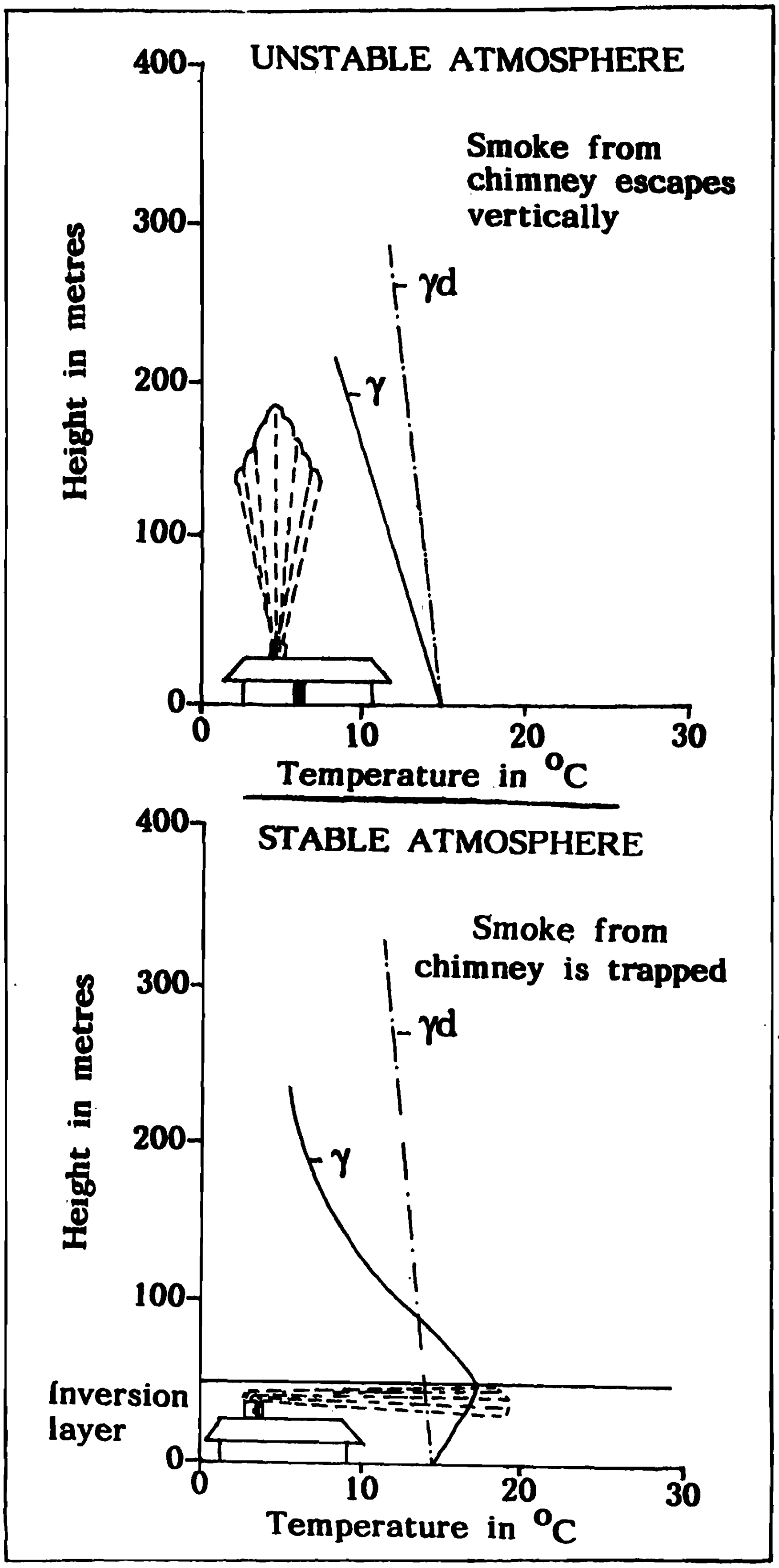
In this connection it may be worthwhile to mention also the dry adiabatic lapse rate (γd). When an air mass remains in contact with the heated earth, it becomes heated and lighter. The air mass then leaves the ground and comes to a higher level. The barometric pressure at this higher level is low, hence the lifted air mass at this level will try to expand. Expansion means cooling. The rate of cooling by this process is called Dry Adiabatic Cooling (γd). Its rate is 1°C per 100 metres and this is constant.

Assessment of stability and instability of the atmosphere

The atmosphere is said to be unstable if it allows vertical motion to develop. An unstable atmosphere means it helps vertical lifting of air *i.e.*, the released pollutants will escape vertically upwards. The atmosphere is stable when it does not allow vertical motion. A stable atmosphere means it retards verti-lifting i.e. the released pollutants will remain stagnant and never escape upwards.

Condition for instability : When the environmental lapse rate (γ) is greater than the dry adiabatic lapse rate (γd), the atmosphere is unstable. The air and the pollutants will escape vertically upwards (Fig. 5).

Condition for stability : When the environmental lapse rate (γ) is less than the dry adiabatic lapse rate (γd); or when the environmental lapse rate (γ) is negative (i.e. a rise of temperature with height), the atmosphere is stable. The air and the pollutants cannot escape upwards - rather they will be trapped and remain stagnant in the lower layer. This helps in the formation of smoke. This type of stagnation of pollutants and their consequent ill effects will continue until the above phenomenon (i.e. the rise of temperature with height called Inversion) is wiped out later in the day due to the ground heating. Fortunately in our country, this type of Inversion occurs only in certain months



UNSTABLE ATMOSPHERE
Smoke from chimney escapes vertically
γd
γ
Height in metres
400
300
200
100
0
0
10
20
30
Temperature in °C
STABLE ATMOSPHERE
Smoke from chimney is trapped
γd
γ
Height in metres
400
300
200
100
Inversion layer
0
0
10
20
30
Temperature in °C

Fig. 5

and for a short period, when sufficient care has to be exercised by the project officials in releasing chimney smoke. The best way will be to release the smoke above the top of the inversion layer from where it will escape vertically upwards.

Visibility of air

Visibility means the transparency of air. At times due to fog, mist or suspended dust, objects at some distance cannot be seen clearly. The maximum distance up to which an object can be seen clearly by a normal eye is a measure of the visibility of air. For purpose of selecting site for a new aerodrome or to meet the operational requirements of landing/take-off of an aircraft from an aerodrome the value of visibility is extremely important. Before landing the value of visibility is passed on to the pilot from the control tower over R/T. If the value falls below the landing value of minimum prescribed for the aircraft it has to be diverted to another airport having better visibility.

Duration of bright sunshine and its observation

Duration of bright sunshine is of fundamental importance for different stages of plant growth and for solar energy using instruments. It has also paramount importance in many other spheres. The sunshine recorder is an instrument for recording the duration of bright sunshine.

Hydrological radar

The intensities of the echoes will show the isohyetal pattern i.e. the distribution of rainfall pattern in distant or unapproachable areas. From this, one can compute the run-off and the expected flood hydrograph at a downstream point in a river. This is helpful for flood forecasting. The person in charge of dam operation may also know the expected inflow and the level of water in the dam at peak flood. This is useful for reservoir operation.

Cyclone warning radar

A 10 cm radar can detect a cyclonic storm at a distance of 400 km from the station. It can track the cyclone round the clock till the landfall. By studying the echoes, one can find out its centre, calculate its rate of movement and the expected time of its landfall. It takes at least two days for a cyclone to travel a distance of 400 km. Hence it is possible for the personnel to take precautionary measures two days in advance.

Weather Satellites

A cyclone warning radar cannot see a cyclone beyond a distance of 400 km. For detection of a cyclone at greater distance and other weather systems like advance of the monsoon front well out over the ocean areas, the imagery received from the satellite is extremely useful. Satellite imagery thus helps in tracking a weather system from distance ocean area. Satellite imagery now received in India covers all the neighbouring countries and the surrounding seas and the ocean. Today it is a very useful tool for medium and long range forecast prognostication.

Monitoring of daily weather

For certain operational purposes in a project, it may be necessary for the personnel to know the changes in weather expected daily over some areas. In such events, it is also advisable to install a meteorological station to record essential parameters on the spot. It is also advisable to maintain a constant liaison with the nearest meteorological centre and take their briefing periodically. It is also advantageous to make an arrangement for the reception of a few important weather charts at the site by facsimile transmission.

Climatic change

In recent years climatic change or trend has become a very important aspect of scientific interest. The pattern of climatic change is very important in policy making at various levels. This can be studied by analyzing systematically observed climatic data of a considerably long period for which standard statistical method are applied.

Conclusion

Role of specific climate parameters should be analyzed in details for specific purposes like agriculture, forestry, animals, humans, buildings, hydrology, urban environment, industry, communications, transport, military operations, expeditions, etc.

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LAND USE SURVEY

G. K. DUTT*

Introduction

Land use is an abbreviation of the term 'Land utilisation'. Land use studies are aimed at making on objective assessment of the use to which each parcel of land is being put at a given point of time in a defined territory, large or small.

The land being the most important natural resource of a country, proper and optimal use of the land is essential for gaining maximum economic return from the land. Land management planning is to be based on information on the present use and potentiality of the land. Land use studies provide basic data for management planning.

History

The concept of land utilisation studies was first initiated by the celebrated British Geographer Prof. L. Dudley Stamp in 1930s.To meet the necessity of finding out fresh land areas in England for increasing food production and supplementing of other farm products Prof. Stamp innovated the idea of making plot to plot enumeration and survey of land; make a record of the type of uses that are being made of each plot on the basis of a standard index and finally prepared a map depicting land use of the territory surveyed after following a standardised method of depiction. The concept was universally accepted initially by geographers all over the world and land use studies were made mostly out of academic interest in a variety of territories. Prof. Stamp and his followers and students, however, carried out survey of land use for most parts of England and Wales and land use maps of the region on a scale of 1: 250,000 were prepared and published for general use of academicians, planners and Administrators. Analytical studies were made of the land use maps of some of the countries (districts) and monographs containing details of such analysis were also published. Academic bodies, voluntary organisations, Government sponsored efforts followed the example of England in several other countries of Europe and land use maps of parts of their territory were published at various scales. In India before independence land use studies were confined to academic circle only. Immediately after partition the influx of Bengali Hindu refugees from the then East Pakistan got the administration in West Bengal worried about finding suitable vacant land for settling those refugees. The then Chief Minister of West Bengal, Dr. B. C. Roy asked late Prof. S. P. Chatterjee of Calcutta University if he could be of help in locating suitable land for the purpose. Prof. Chatterjee with the help of his students and colleagues conducted detailed land use survey of several districts of West Bengal and the results in the form of maps and statistics were made available to the Govt. of West Bengal.

Official Statistics

The Revenue Department of Govt. of India under the British administration had

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adopted a standard classification of land for the purpose of indicating the quality and use of the land down to the village level. After independence the task was taken over by the Bureau of Economic & Statistics set up by Govt. of India. The existing classification of land use was adopted with minor corrections and records of land and land revenue right down to village papers were maintained as per the standard proforma. The situation, as per rules, was reviewed every year and relevant land use statistics for each year were prepared and they were published at Districts State and National Levels by Agencies existing at various levels. The classification was as follows:

1. Area under forest
2. Area not available for cultivation
    i) Area under non-agricultural uses
    ii) Barren and uncultivable land
3. Other uncultivated land (excluding fallow land)
    i) Permanent pasture and other grazing land
    ii) Land under miscellaneous tree crops and groves not included in net area sown
    iii) Cultivable waste land,
4. Fallow Land
    i) Fallow land other than current fallow
    ii) Current fallow
5. Crop land
6. Intensive crop land
7. Multiple crop land

The classification of land adopted by the Directorate of Economics and Statistics is available in village papers. The definition of the various types of land are not very clear and in many cases are overlapping and contradictory. Moreover, the comprehension of village level Patwaris of the classification and definition in different parts of the country varies to a great extent and therefore, statistics based on their reporting can never be very dependable. The very theoretical approach of the classification is further endorsed by the fact that most of the categories are not clearly identifiable on the ground and have thus proved to be misleading.

Land use information Maps

The approach of the mapping agencies in the Public Sector is field Oriented and is therefore, more realistic. The Survey of India, the premier mapping Agency of the country, since its inception more than two centuries ago demarcated some uses of land along with other topographical and man-made features on the topographical sheets of various scales published by them. This was done not with the specific purpose of producing land use maps as such but were included in the topographical sheets perhaps as useful information for assessment and collection of revenue and other related purposes.

However, for obtaining reliable information on land use based on ground realities conducting a land use survey using a reliable base map as frame of reference is essential. The International Geographical Union has suggested a classification of land use which has been adopted by different countries with modifications to suit the conditions prevailing in those countries. The thematic mapping agencies of India namely National Atlas and Thematic Mapping Organization, National Remote Sensing Agency, National Bureau of Soil Survey & Land use Planning, etc. have adopted various schemes of land use classification.

Land Use Classification

As stated earlier, adopting a land use classification depends on two main factors – (a) Scale of the land use map to be produced (b) Source of land use information. The traditional methods of collection of information by Field Survey have now been supplemented in a major way by information on land use available by analysing Air photos and Space Imageries. Larger scale of the map to be produced provided scope for elaboration of land use information in greater detail and their depiction.

The National Atlas and Thematic Mapping Organization in the public sector was a pioneer in the matter of compilation and publication of land use maps covering the entire surface of the country. The first series of maps on land use that were included in the National Atlas of India were on a scale of 1:1 million (1cm:10km). In view of the scale of the map, land use classification was suitably generalised.

The features depicted in the 1:1 M series are as follows:

1. Town/cities and settlements, related urban.
2. Rural settlements.
3. Other uncultivated land – mining areas, brick fields, etc.
4. Settlement with trees and groves.
5. Garden and Plantations.
6. Arable land.
   (a) Irrigated.
   (b) Non-irrigated.
7. Pasture land.
8. Forest.
   (a) Dense.
   (b) Light.
   (c) Scrub.
   (d) Mangrove.
9. Waterbound areas.
   (a) Perennial.
   (b) Seasonal.
   (c) Marsh.

10. Wasteland.
    (a) Rocky outcrop.
    (b) Sandy.
    (c) Usar:alkaline.
    (d) Ravines.
    (e) Rann.
    (f) Others

They are under different categories of land use and were demarcated primarily on 1:1 inch or 1:50,000 toposheets. These were then photographically reduced in stages to finally take shape in the form of multi-coloured maps on land use on a millionth scale. Field checks were carried out in samples and information available from Air photographs was widely incorporated.

At a second stage National Atlas & Thematic Mapping Organization took up the task of preparing land use maps on a scale of 1:50,000 for 40 odd selected backward districts of the country. The land use classes were suitably elaborated. Information on arable land were further enriched by demarcation on such areas crop Combination Zones. Crop Combination Zones were worked out on the basis of predominant crops grown in an area. Such information would prove to be useful tools for agricultural planners. The same Scheme of Classification was adopted for producing land use maps on a scale of 1: 50,000 of each Development Block occurring in those districts. It may be mentioned here that base maps of each Development Block were compiled making use of topographic sheets and thereafter on those maps were incorporated land use information available from ground truth, Air photo and Space Imagery analysis.

N.R.S.A Maps

The National Remote Sensing Agency functions as the custodian of space imageries and as a Govt. Agency, has exhaustive coverage of the country by Air photographs of various scales. The NRSA has adopted two schemes of land use classification based on source of information namely Air photos and Space Imageries. Of late, particularly in the United States of America the term "land cover" is also used in place of "land use" The two terms are not quite synonymous but are not much different either.

Air photographs of various scales ranging from 1: 5000 captive ground information are available in greater detail. The resolution if adequate enables a map analyser to identify land use classes and their characteristics in a more precise manner. The classification that has been adopted by the NRSA for land use maps to be produced on the basis of Air photographs is more ambitious. The Scheme follows on page 35.

It may be appreciated that all the levels of information as laid out above can not be obtained directly from Air photographs. Air photo analysis is to be supplemented elaborately by Field Work. Moreover, the scale of the Land use maps to be finally produced on the basis of information collected as per the above proposition has to be fairly large, 1: 50,000 or above.

First Level	Second Level	Third Level
1. Urban areas	a) Residential	- one family
		- multi-family
		- separate houses
		- scattered houses
		- mixed types
	b) Commercial Services	- types of services
	c) Industrial	- types of Industries
	d) Transport and other Services	- rail, road and trucks
	e) Recreation areas	- playgrounds, stadia, gardens
	f) Religious	- temples, mosques, churches, others
	g) Other open spaces	- open commons
2. Arable land	a) Cropped areas	- types of crops
	b) Wasteland	- new areas
	c) Plantations	- gardens
	d) Wetlands	
	e) Shifting cultivation	- extent of area
3. Forest land	a) Evergreen	- various types
	b) Deciduous	- tree types
	c) Mixed	- dry and wet types
4. Water Bodies	a) Rivers	- all types
	b) lakes	- ponds
	c) Reservoirs	- waterbody
	d) Bays	- dried channels
5. Pastures	a) Types of vegetation	- scattered trees on grass
	b) Thorny Pastures	
	c) Permanent Pastures	
	d) Mixed Pastures	
6. Useless/Waste lands	a) Bare rocks	
	b) Salt encrusted zones	
	c) Open cast mines and quarries	
	d) Beach/river line sand	
	e) Desert	
	f) Dissected land	
	g) Others	
7. Ice covered areas	a) Permanent ice cover	

The limitations of the space imageries which are available originally on a scale of 1:1 Million (1cm: 10km) are very much reflected in the scheme for land use classification based on Space imageries that have been adopted by NRSA.

The land use classes are as follows:

Level One	*Level Two*
1. Settlement areas	a) Urban
	b) Rural
	c) Roads and Railways
2. Arable land	a) Crop land
	b) Waste land
	c) Jhum/Terraced land
	d) Wet land/crops
	e) Plantations
3. Forest land	a) Evergreen forests
	b) Deciduous forests
	c) Mixed forests
	d) Thorny forests
4. Water Bodies	a) Rivers and Channels
	b) Lakes/Ponds
	c) Reservoirs
	d) Lagoons
	e) Estuary
	f) Sea
5. Waste lands	a) Deserts
	b) Rocky out crops
	c) Cultivable waste
6. Others	a) Grass lands
	b) Icebound areas
	c) Riverine sands

The quality of analysed information is very much dependent on the resolution of the colour composites of the Imageries. Moreover, unless adequate ground information and ground knowledge are possessed by the interpreter it would be difficult to demarcate the different land classes. Enlargement photography of the imageries of large scales have not proved to be successful.

However, the quality of Imageries is gradually improving, particularly with the availability of INSAT imageries and that brings hope about the effectiveness of those sources for obtaining information on land use in future.

About the classification adopted by NRSA there appears to be some inherent confusion regarding placement and classification of waste land, cultivable land and pasture land, etc.

Sources of Information

The traditional avenues of land use information in the form of source maps, field surveys, etc. were certainly time-consuming. Keeping in view the vast land surface of the country such methods were slow and time consuming. Moreover, since the objective information collected was true for a certain time frame because outdated by the time the land use maps based on collected information were produced. The planners, therefore, found those maps of not much use. Compared to that the capability of providing information on land use by the modern sources of Air photographs and Space imageries are quite remarkable. The analysis is possible to be done more speedily and, if matched with an efficient printing of system maps, could also be produced without delay.

Visual analysis of imageries is loosing ground to computer processing and analysis which are much faster in every respect. In case of small areas – a district or a State computer processing matched with digital mapping would produce remarkable results. Maps need not be printed in the traditional manners. Hard copies of land use maps could be obtained from the standing tapes of the computer as and when needed.

There is one word of caution that has to be essentially kept in mind in this connection. Imageries, at time, reflect confusing situations regarding various types of land use. To make sure adequate field checks must be carried out. The interpreter should check and compare the imageries with ground realities before giving a final shape to the land use information. The same caution is applicable in case of Air-photo interpretation as well. Compared between the two sources viz. Air photo and Space Imageries, for small scale maps imageries are faster and less amenable to mistake depending upon its quality. Air photos are more effective for large and medium scale maps although it is a fact that interpretation and transfer of information to the base map are tedious and tend to be comparatively slow.

Other Agencies

The All India Soil and Land use Survey have also produced land use maps for some selected areas that were intensively studied by them. They have chosen natural regions like River basins, Reservoir catchment areas or watersheds attempting to draw a correlation between physical characteristics with soil and land use.

The National Bureau of Soil Survey and Land use Planning have adopted a Land use classification scheme for compiling land use maps of selected areas. The guiding factor in this classification had been, to some extent, the quality and depth of soil on land. Soil and its varieties being the main concern the land use maps produced by these Agencies are patchy and differ from those produced by other National Mapping Agencies.

Land Planning

Obviously, the best use of the land use maps could be made for proper planning and optimum use of land. The Mapping Agencies as mentioned above have produced land use maps at various scales – the largest series being in the scale of 1: 50,000 published by NATMO for some selected Development Blocks of the country. The NRSA has taken up a project for publishing land use maps on a scale of 1:250,000 for the entire country. The

Survey of India has adopted a policy of showing more land use details in its toposheets on a scale of 1:50,000. All these would provide useful basic information for planning and monitoring up to a certain level – perhaps State or District, but when it comes to village level planning, which actually is the base for national planning as per the policies of Panchayat System, the existing land use maps prove to be inadequate. An average village on a map of scale 1:50,000 covers a small area. Thus intricate details of land use varieties in each village get obscured in the process of generalisation.

Maps for Action Plan at Village Level

As discussed above the largest scale maps available on land use would only be able to indicate, in a very generalised form, the location of land types. Although these would be useful information and would serve as sound source of reference, they would prove to be inadequate towards chalking out action plans. The limitation imposed by the scale of the map would not make it possible for the planner to get all the information he needs about the patches of land under different uses for determining line of action for their development.

Obviously, maps of large scale, for example the mouza maps on a scale of 16":1 mile prepared by the State Revenue Department for each Mouza or Village are the ideal base maps for plotting land use details.

The greatest advantage of these maps is the fact that they provide boundaries of each individual plot of land along with several land related information in detail.

Methodology

Revenue maps on a scale of 16":1 mile are to be procured for the villages to be surveyed. Field Surveys are then to be conducted utilizing appropriate maps for plot to plot enumeration and survey of the actual uses that are being made of each plot of land. Supplementary information like ownership of the plots, and soil depth, moisture conditions, water table, slope, existing vegetation are to be noted for different land use patches.

Most of the Revenue maps are fairly old and outdated. Therefore while conducting the Survey details like the present condition of water bodies new dams and reservoirs created, new communication network, the present pattern of drainage network etc. are to be incorporated.

The field notes prepared on the basis of survey conducted on the basis of standard index of Land use classes are then to be transferred onto a set of final maps. In these patches of land having similar land use adjacent to each other are to be lumped together and thus final pattern of land use of the village as a whole would emerge. The final maps on land use if prepared in Black/White using Craft tint could be reduced to a suitable handy size without compromising with the details. Other related information collected, as stated above, could then be incorporated at actual locations of the maps using standard symbols. Place names, river names, etc. may then be incorporated as points of reference. It would be worthwhile to use a digitized planimeter to measure the area under each type of land use. The total area of the village may also be measured. The data on areas thus obtained may not tally with the village Revenue papers; but that need not be worried about since this is a common feature of Indian land records.

Once these maps and data are compiled that could be transferred on to computer compatible tapes. With suitable programming it would then be possible to have print outs in the form of hard copies of the stored data and maps, and also to incorporate corrections and update quickly as and when needed. The Govt. of Madhya Pradesh has initiated such a project sometime ago and is reported to have made good progress.

Unfortunately, the process is going to be slow. Air photographs at very large scale 1:5000 could be of help in speeding up the process but they are not available to common uses. The Imageries would not have the resolution. However, once the maps are compiled they would make permanent records for valuable uses.

Wasteland Maps

Wastelands have been getting special attention these days. They are, more or less, spin-offs of the land use maps. The National Wasteland Development Board has provided detailed classification of wastelands and have got prepared wasteland maps on a scale of 1:50,000 for 140 odd wasteland scourged districts of the country. The village land use maps on a scale of 16":1 mile as proposed above could also provide detailed information on wastelands as per the NWDB specification. Thus, composite maps on land use and wastelands, could be produced which would be of interest to a wide range of users.

Urban Land use

Urban areas do not get adequate treatment in the Rural Land use maps. The scale of the maps is the main limiting factor in restricting depiction of land use details of urban area. Moreover, urban functions are very different from Rural,: therefore, urban land use remains neglected in a common land use map. Urban studies have been gaining popularity since independence and with that the urge for compiling Urban Land use Maps has also grown. During the 6th and 7th Plan NATMO undertook a project for making studies of the Headquarters towns of selected districts and as a part of the study several urban maps of each district were compiled. The Urban Land use map of the Calcutta Metropolitan district (Scale 1: 100,000) has been compiled based on the following Urban land use classification:

1. Urban Settlement
2. Industrial area
3. Commercial area
4. Open area
5. Gardens
6. Transport
7. Rural Settlement
8. Agricultural land

In case of smaller towns the scale of the maps could be larger and several other categories of use like Central Business district, Educational areas, recreational areas, slums, newly developed areas, railway yard, transport depot, etc. could be identified and depicted.

Geographers in academic institutions have made studies of several towns and cities. Along with the maps they also collected a wide range of data.

Suggested Readings

1. DUTT, G.K. 1990. Classification of Wastelands: Rational Ecological Development of Wasteland.

2. DUTT, G.K. 1992. *Gramer manchitra: Parichiti O Prayog*. Paribesh Bhavna.

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SOIL QUALITY : ASSESSMENT AND SIGNIFICANCE

S. K. GUPTA*

Part A: Some fundamental concepts of soil systems

Soils are complex biogeochemical materials on which plants may grow. They have structural and biological properties that distinguish them from the materials from which they normally originate. They are dynamic ecological systems providing plants with support, water, nutrients, and air for growth and support a large population of macro-and micro organisms that recycle materials of life. Soils also support the entire human population. So understanding soils and managing them well are essential to human welfare.

Two approaches – *pedagogical* and *edaphical* – have been used in studying soils. A pedologist studies, examines, and classifies soils as they occur in their natural environment whereas an edaphilogist considers the various properties of soil in relation to plant production. He has ultimate goal for production of food and fibre. To achieve that goal he must determine the reasons for variation in the productivity of soils and find means of conserving and improving productivity.

Four major components of soils: (a) *Inorganic or mineral matter* and (b) *Organic matter* (solid component), (c) Water (liquid component) and (d) air: (gaseous component). The solid mineral particles comprise about 45% of the solid volume and organic matter 5%. At optimum moisture for plant growth, the pore space is approximately half ie, 25% being water space and 25% air. These four components occur in a thoroughly mixed condition in soils. The mixture encourages interactions within and between the group and permits marked variation in the environment for the growth of plants.

Solid components: Soil has two kinds of solid components: *minerals* derived from weathering of rocks and *organic* matter derived from plant, animals and micro organisms. The weathering of rocks form the *parent materials* from which the mineral soils develop by various soil forming processes.

Soil organic matter comprises an accumulation of partially disintegrated and decomposed plant and animal residues and other organic compounds synthesized by soil microbes as the decay occurs. *Humus*, the decomposed organic matter, is very important because it has properties of water retention, nutrient retention and cohesion that complement those of clay (soil separates having diameter <0.002 mm).

Soil separates consist of sand (diameter 2.0 to 0.02 mm), silt (0.02 to 0.002 mm) and clay <0.002 mm. *Soil texture* involves the size of individual mineral particles and specially refers to the relative proportions of various-sized particles in a given soil. *Soil structure* refers to the grouping or arrangement of both primary soil particles and secondary groupings called aggregate or peds.

Clay and humus are the seats of soil activity. Both of them have a large surface area per unit weight and they exhibit surface charges which attract negatively and positively

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charged ions and water (ion exchange phenomena: Cation exchange and anion exchange). In addition, their charged surfaces permit them to act as '*contact bridges*' between particles thus helping to create and maintain the stable aggregates of soil particles. On a weight basis, humus particles have greater nutrient and water holding capacities than do clay particles. However, since clay is generally present in large amounts, its total contribution to the chemical and physical properties of the soil will usually equal or even exceed than that of humus. The most inherently productive agricultural soils contain a balance of these two important soil solid components.

Liquid component: Soil water: Polarity is important to water and to soils. Water molecules attach themselves to one another to form clusters that are larger than single H_2O molecules. The hydrogen (+ve) end of one water molecule bonds to the oxygen (–ve) end of an adjacent water molecule. This is called *hydrogen bonding*. Polarity and hydrogen bonding result in *cohesion*, the attraction of one water molecule to another. Likewise, *adhesion* involves attraction of water molecules to solid surfaces. Hydrogen bonding between water molecules produces surface tension.

Water in the soil is referred to as the soil solution because it is not pure. The soil solution contains *solutes* including cations, anions, organic and inorganic components, and gases.

Solid liquid interaction: Many interactions between the solid and liquid phases occur at the surface of the solid phase. One of these is *ion exchange*. Others are dissolution of the solid phase in the solution phase: *precipitation*, ligand exchange, covalent bonding, hydrogen bonding and surface chelation.

The most important interaction in soil is cation exchange (expressed as C mols/kg of soil) in which positively charged ions are attracted to the negatively charged surfaces of clays and organic matter when they are loosely held. These cations are the major sources of plant nutrients. Hydrogen ions are abundant in many soils and the concentrations of H^+ ions is controlled by the interactions between the soil's solid and liquid phases.

Soil air: Composition of soil air is similar to, but not identical with, the air we breathe.

Average composition

Component	Soil air (%)	Atmospheres (%)
N_2	73.2	79.0
O_2	20.6	20.9
CO_2	0.25	0.03

Air and liquid compete for the same pore space.

A soil is a three-phase system containing solids, liquids, and gases which are in intimate contact and interactions among themselves are continuous.

The soil – a tremendous biological laboratory: Soils harbour a diverse population of living organisms both animals and plants. Activities of soil organisms range widely. They largely include the physical breakdown of plant residues and ultimately the formation of humus. The biological transformation of soil nutrients particularly nitrogen, phosphorus and sulphur to available forms to plants and atmospheric fixation of nitrogen by soil micro organisms are classic examples of rich and varied biological laboratories.

Soils are three-dimensional systems: Soil scientists call the three-dimensional body a pedon. The upper part of the pedon – most influenced by rainfall, roots and organism is the solum. The part below the solum is usually the parent material from which the solum developed. At time, the solum may sit directly on the geological materials.

A soil is not uniform with depth but consists of layers called horizons. The master horizons are O, A, E, B, C, & R horizons.

Characteristics of Master Horizons

Master horizon symbols	Horizon property or characteristic
O	Surface layers dominated by organic material.
A	Mineral horizons formed at the surface or below an O horizon and containing accumulated decomposed organic matter.
E	Mineral horizon whose main feature is the loss of silicate clay, Fe or Al, leaving a concentration of resistant sand and silt particles.
B	Horizons formed below an A, E, or O horizon and dominated by the obliteration of the original rock structure and the accumulation of silicate clay, Fe, Al, humus, carbonate, gypsum, or Si.
C	Horizons excluding hard bedrock and little affected by soil genesis.
R	Hard bedrock like basalt, granite, or sandstone.
'E' represents *eluviation* and 'B' *illuviation*.	

Soil formation and classification: Weathering or igneous sedimentary and metamorphic rocks and soil forming processes are vital phases of soil genesis. Five soil forming factors (parent material, climate, relief, biota and time) can combine in endless ways. Indeed there are over fifteen thousand kinds of soil individuals in the world. In soil taxonomy, eleven soil orders are designed to contain all the soils of the worlds. Each order is a broad grouping of similar soils separated by particular morphological characteristics. Within these broads groups are more specific groups – suborders, great groups, subgroups and families. The soil series is the lowest and most specific level. Thus soil taxonomy has 6 categories:

— Order

— Suborder

— Great group

— Sub-group

— Family

— Series

Definitions of Soil Orders

Order name	Diagnostic characteristics
Entisol	Simple soils, no subsoil diagnostic horizon.
Inceptisol	Soils with minimum development, little or no subsoil clay accumulation.
Aridisol	Soils of hot dry regions.
Vertisol	No subsoil diagnostic horizons
Mollisol	Thick, soft, dark mineral soil of grasslands.
Alfisol	Subsoil accumulation of clay, not strongly leached.
Spodosol	Subsoil accumulation of iron.
Ultisol	Subsoil accumulation of clay, strongly leached.
Oxisol	Extreme leaching; Fe, Al oxides, and quartz left.
Histosol	Dark organic soil, little mineral matter.
Andosol	Mineral soil formed on volcanic ash parent material.

Soil–plant relationships: Soil is the main resource for growing plants for food and fibre. Four basic needs of plants from soils are: Support, Nutrients, Water and air.

Soil survey & land capability classification: Information about soils in totality is found in soil survey reports which are made by soil scientists who dig and examine pedons describing horizons physically, chemically and biologically including the assessment of fertility status of soil. Such information is used for land use planning. Land capability classification has been prepared for the sustained production of common cultivated crops. It has eight classes, four sub–classes and ten units.

Classes: Each class contains soils with similar broad limitations. Class I soils have few permanent limitations for cultivated agriculture. They are greater than 100 cm deep and well drained and have medium surface textures (loams and sandy loams), good water-holding capacity, no alkali or toxicity limitations, and no moderate or severe salinity. To be in Class I, soils must be on level parts of the landscape and in a climate where the rain is sufficient and the frost-free season is long enough for common cultivated crops to be grown. Class I soils require ordinary good management such as fertilizer, lime to reduce acidity, animal manures, or rotations to maintain productivity.

Class II, III and IV soils have progressively more limitations for sustained crop growth. Class II soils have some limitations and require careful management and some special management to maintain productivity. For example, Class II soils may require erosion control practices such as contour cultivation or nontillage. Class III soils have severe limitations that restrict crop and require special practice to maintain productivity. Soil in this classification may require erosion control practices such as contour cultivation, nontillage, strip cropping, or terrace construction. Water is also important to soil Class, as they may require artificial drainage.

Class IV soils have very severe limitations that require very careful management and restrict the choice of crops. Limitations such as shallowness to bedrock, steep slopes that increase the risk of soil erosion, low water-holding capacity, and wetness during the growing season distinguushes Class II to Class IV soils. Class IV soils are the lowest-capability as arable soil.

Class V soils are the best non-arable soils. They have fewer slope and soil thickness limitations than Class IV soils do but are excluded from cultivation because of limitations such as climate or wetness. Soils in Class VI and Class VII are range soils with increasing limitations. Management practices may be successfully applied to Class VI soils, but Class VII are so severely restricted that no management is possible. Class VIII soils are unsuitable for cultivating agriculture and severely limited for range and pasture but are often important scenic, recreational, and watershed resources that require careful management.

Subclass: Within Class II through VIII are the subclasses e (erosion), s (soil morphology), w (wetness), and c(climate), which specify a kind of limitation or hazard.

Units: Units group soils with similar management responses and specify the most limiting characteristic or predominant problem within the subclass. There is no standard for the numbering system, but 0 to 9 appear to be the common range of unit designations. The complete classification of a soil series includes the class, subclass, and unit, such as IIe-1 or IVs-5.

Part B: Assessment of Soil Quality

I. The physical properties of soils are extremely important in determining soil quality. Among the important physical properties, the following are worth mentioning:

- Soil texture
- Soil structure
- Soil colour
- Soil consistency
- Soil densities and porosity

Soil texture: This is evaluated by particle-size analysis. The principle involved is simple. When soil particles are suspended in water, they tend to sink. Because there is little variation in the density of moist soil particles, their velocity (V) of settling is proportional to the square of the radius(r) of each particle. Thus $V = Kr^2$ when K is a constant. The equation is referred to as Stroke's law. The percentages of each size fraction in the sample are used to identify the soil texture class, such as sand, silt or loam.

A less quantitative but common method of determining soil texture in field is the feel method – guidelines are as on the following page.

Soil Structure: This is assessed by aggregated shape, size and grade. Structural strength in terms of grades refers to (i) how many of the primary particles are aggregated and (ii) how strongly they are held together. Three grades: Weak structure, moderate structure and strong structure are the common classification for assessing the stability of soil structure.

Guidelines for Estimating Texture by Feel

Texture	Guidelines
Sand and loamy sand	Individual grains easily seen and felt. When squeezed moist, forms a cast that crumbles when touched.
Loam	Somewhat gritty feel but fairly smooth. When squeezed moist, forms a cast that can be freely handled without breaking.
Silt loam	Soft and floury when dry. Forms a cast when dry or moist, but when squeezed between thumb and forefinger, will not ribbon when moist.
Clay loam	Forms a thin ribbon that barely sustains its own weight. Moist soil is plastic and forms a cast that can be handled.
Clay	Sticky and plastic when wet. Forms a strong ribbon.

Soil Colour: This is the most obvious and easily determined soil characteristic. It is also an indirect nature of many qualities of soils that are not so easily determined. Soil colours are most conveniently measured by the Munsell Colour Chart.

Soil density and pore space: Density is usually defined as the mass of a unit volume of soil *solid* and is called *particle density* (Dp) where *bulk density* (Db) is defined as the mass of a unit volume of dry soil. The volume includes both solid and pores.

$$\text{Percent pore space} = 100 - \left(\frac{Db}{Dp} \times 100\right)$$

In recent years, conservation tillage practices, which minimise plowing and association soil manipulation have been widely adopted in different countries.

Soil consistency: This is a composite expression of those forces of mutual attraction among soil particles that determine the ease with which a soil can be reshaped. It is commonly measured by feeling and manipulating the soil by hand or by pulling a tillage instrument through it. In conclusion, the above physical parameters of soil play very important role to maintain excellent *soil tilth.*

II. Physico–chemical and chemical properties of soil that determine its quality are mostly controlled by: Soil pH; Ion–exchange properties; Cation and anion exchange capacities; Buffering properties and Salinity hazards.

Ion–exchange properties: The charges associated with soil particles attract simple and complex ions of opposite charges and hence soil exhibits both *cation* and *anion exchange phenomena.* The ion exchange properties of soil are evaluated in term of cation exchange capacity (CEC) and anion exchange capacity and are expressed in terms of Centimols per unit mass of soil. The *percentage base saturation* is an important soil property which indicate tendency towards neutrality and alkalinity.

$$\textit{Percentage base saturation} = \frac{\textit{Exchange base - forming cations (C mols / ka)}}{\textit{CEC (C mols / ka)}}$$

Soil pH: Soil reaction is assessed by measuring soil pH which not only indicates the intensity of soil nutrients, but it significantly influences many soil chemical properties as well as biological organisms.

Soil Salinity: This is estimated by methods based on the ability of the salt in the soil solution to conduct electricity. Laboratory measurements of the electrical conductivity (EC) of the soil solution extracted from a saturated sample of soil give an indication of the salt levels. EC is expressed in decisiemens per meter (ds/m).

III. Soil testing. This is used to evaluate the fertility status of soils. It involves in the determination of the following parameters of surface soils:

(a) pH, (b) EC, (c) Organic carbon, (d) available P, (e) available K, (f) D.T.P.A. extractable micro-nutrients like Fe, Mn, Cu and Zn, (g) Lime requirement in case of acidic soil; (h) Gypsum requirements – in case of alkaline soil.

Soil test values are rated in 6 different categories and fertilizer schedules are prepared on the basis of rating classes and requirement of the field crops.

Part C: Problem soil, soil degradation and chemical pollution

Acid soil: two absorbed cations – hydrogen and aluminium – are largely responsible for soil acidity. The mechanism by which these two cations exert their influence depends on the degree of soil acidity and on the source and nature of the soil colloids.

Soil acidification is continuous in most well-drained soils with high rainfall. So sustainable agriculture must include regular liming. Atmospheric pollution with sulphuric and nitric acids is increasing the prevalence of acid precipitation. Acid rain damages forest, mountains and probably humans.

Research suggested three types of acidity: a) active acidity due to the H^+ ion in the soil; b) exchangeable acidity or salt replaceable acidity represented by the H^+ and A^{+3} that can be easily exchangeable by other cations and c) residual acidity which can be neutralised by limestone or other alkaline materials. Such type of acidity is generally associated with aluminium hydroxy ions and non-exchangeable forms of H and Al bounded by organic matter and silicate clays.

Effects of acidity on plant and soil are enormous – particularly due to Al toxicity, Mn toxicity, Ca and Mg deficiency.

Relative Acid sensitivity in some agricultural crops

Highly sensitive	Alfalfa, common bean, pea, red clover, crown vetch, Leuacaena, spinach, cotton.
Sensitive	Cabbage, wheat, soyabean, white clover, sorghum.
Moderately tolerant	Peanut, potato, oats, rice rye, corn
Tolerant	Styloeanthes, kudzu, pineapple, tea, coffee, blueberry.

Soil acidity is commonly decreased by adding carbonate, oxide or hydroxides of Ca and Mg compounds which are referred to as agricultural limes. Efficiency of liming materials depends on (a) correct measurement of quantities needed (Lime requirement measurement) (b) chemical guarantees, (c) buffering capacity of soils and (d) fineness of the liming materials.

Chemical guarantee is tested by neutralising power ($CaCo_3$ equivalent) of the liming materials.

Liming not only maintains the level of Ca and Mg but , also provides a chemical and physical environment that encourages the growth of most common crops.

Salt-affected soils: Saline, saline-sodic, and sodic soils.

Saline soils contain a concentration of neutral soluble salts of Na, Ca and Mg sufficient to interfere seriously with the growth of plants. Ec of saturated extract >4 ds/m. Exchangeable sodium percentage (ESP) <15 and pH is less than 8.5. Popularly known as white alkali soils because of surface encrustation.

Saline – sodic soils: pH 8.5 or less; Ec is more than 4 ds/m. ESP >15 and sodium absorption ratio (SAR) is at least 13.

Sodic soils: (ESP) >15; SAR >13; Ec <4 ds/m.>10pH. Black alkali soil due to deposition of dispersed humus on soil surface.

Reclamation and Control: Reclamation of soil means treatment to correct a severe excess of salinity, sodicity or alkalinity. It is the drastic fix needed if thing are bad. 'Control' is the preventive practices and management needed to keep problems from developing, recurring or worsening. Reclamation and control depend on the same principles and use similar processes and practices. They both require:

— Amendments that provide cations to displace exchangeable Na and flocculate soil colloids.

— Leaching of salts and displaced Na.

— Drainage for leaching.

— An acceptable sink to receive drainage water.

With luck, these are provided naturally. But more often, deliberate action is necessary to correct and control salt and Na in irrigated soils.

Amendments for Sodic Soils: Exchangeable sodium cannot be leached unless something is done to displace it into solution and to keep soil flocculated. Both objectives are achieved by maintaining a sufficient concentration of other cations in solution. In practice, the critical cation is calcium. It is abundant, and being divalent and little hydrated, it replaces Na readily and flocculated clay at quite low total salt concentrations.

Gypsum-$CaSO_4$, $2H_2O$- is soluble enough to maintain Ca at a useful concentration. Saline soils whose surface horizons already contain gypsum need no amendments to leach readily. To other soils, gypsum is added, either by spreading it on the surface or dissolving it in the water applied for irrigation or leaching.

Reclamation of sodic soil requires large amount of amendment, sometimes several tons per hectare. Even the periodic additions to control Na accumulation can be costly if the irrigation water has a high salinity and sodium absorption ratio.

Leaching Methods: The purpose of leaching is to lower the salt concentration and sodicity in the root zone and keep it low. Drip irrigation offers a temporary, local control of salt, water trickling from properly laced emitters keeps salts moving away from the plant. Frequent conventional irrigation achieved the same thing, albeit less well. But the salts accumulated around the wet zone tend to move back into it, especially when the soil surface and root zone dry out. Accordingly, conventional leaching practice aims at deep leaching to move salts well below the root zone

Leaching Requirement (Leaching Fraction): The long-term or steady-state leaching requirement (LR) is important to planning irrigation and drainage systems, as it suggests how much water in addition to crop requirement will be needed to control salinity. The leaching requirement (LR) is the amount of drainage water that must be produced (DW), as a fraction of the amount of water applied to the land (IW):

$$LR = DW/IW$$

The LR depends on the amount and salinity of water sources being applied and the level of soil salinity that can be accepted, tolerated, or permitted. Under the simplest conditions, LR equals the ratio of salinity (salt concentration) in the irrigation water (Si) and the acceptable salinity in the drainwater (Sd), so that

$$LR = DW/IW = Si/Sd$$

In reality, conditions are seldom simple enough for this equation to hold. Nevertheless, exploration of the underlying ideas is instructive.

Drainage and Disposal: Long-term salt control requires drainage into a suitable sink. Sometimes natural drainage and disposal are satisfactory. Political, legal, and ecological constraints on drainwater disposal can also inhibit the use of saline land and water. Disposal into rivers adds salinity and sodium to afflict other users down-stream. Nitrate, pesticides, or toxic substances such as selenium, leached with the salt, further limit the dumping of drainage into natural waters sensitive to such pollutants.

Soil degradation: Soils are neither permanent nor indestructible but may be altered or destroyed by mismanagement. The degree of alteration or mismanagement destroys a soil.

Physical degradation: Erosion, surface crusts and seals, and compaction lead to physical degradation of soil. Erosion by water, wind and gravity occurs continuously, but soil formation rates exceed or equal the natural (or geological) rates of degradation. Therefore, when mismanagement increases erosion rates beyond the geological rates, a serious problem is created.

Water erosion occurs when raindrops strike bare soil, detaching particles, and overland flow carries the detached soil form the field. Water erosion takes several forms, depending on the concentration of water flow. Sheet or splash erosion occurs when there is little or no concentration of water flow over the soil surface. Rills form as water concentrate in small channels, and when the rills deepen they become gullies.

Wind moves soil by rolling, bouncing, and lifting particles. Rolling and bouncing move large- and medium-size particles to short distances. Lifting suspends fine particles and may carry them to long distances.

Mass wasting such as landslides and soil creep are caused by gravity, assisted by water that lubricates and adds weight to the soil being pulled downslope.

Soil crusting and sealing of the surface for a few millimetres reduce the rate of water penetration into soil. A seal or crust forms when water disperses clay that moves into the pores, plugging them. This may be a natural process or may be accelerated by management. Soils with a high exchangeable sodium percentage are most susceptible to this problem.

Soil compaction also reduces water penetration. Compaction is often caused by excessive traffic or loading, especially when the soil is wet. While supporting the load, the soil particles can be rearranged to reduce total pore space and pore size.

Chemical degradation and soil pollution: Chemical soil degradation is most frequently a problem of soil contamination, which occurs when sufficient quantities or concentrations of harmful substances accumulate beyond their 'natural' or background level in soil. A constant danger is that contaminated soils may also contaminate drinking water supplies. Soil contamination occurs when useful chemicals are added to the soil in excess or through the accumulation of chemicals added in small amounts over time. Although waste may not be dangerous when first buried, it may produce dangerous chemicals when it decomposes. Improper disposal and accidental spills and leaks may also contaminate soil.

Contamination may present a risk of explosion, fire corrosion, or chemical toxicity. The toxicity reduces crop yields and the usefulness of soil for agriculture and is dangerous to humans and animals through direct contact, through drinking contaminated water, or through eating contaminated products grown on contaminated soils. Such contaminants include:

1. Elements such as lead, mercury, cadmium, copper, chromium, selenium, and arsenic and their compounds.
2. Organic chemicals such as pesticides, plastics, solvents, oils and tars.
3. Radioactive materials.
4. Asbestos and other hazardous materials.
5. Sodium salt and acids.

Few contaminants are so inert that they remain in soils unchanged. Elements and their inorganic compounds may be absorbed on clay and organic matter surfaces as exchangeable ions, may be fixed in non-exchangeable forms, or may be precipitated in the soil. These processes may prevent the movements and plant uptake of the contaminant but may not reduce its toxicity. Organic chemicals, including oils and tars, are frequently susceptible to micro-biological decomposition in soils.

In addition to solid phase interactions, contaminants in soils may be dissolved in the soil solution or simply occupy space in soil pores, along with the soil solution and soil gases. In general, the solubility of hydrocarbons in water decreases with the increasing number of carbon atoms in the compounds. The mobility of contaminants that do not interact with the solid phase is a major concern because of the possibility that they move from the soil into the groundwater.

Unwanted accumulation of pesticides is one example of contamination caused by the regular use of agricultural chemicals. Pesticide persistence is sometimes a useful chemical property because a persistent chemical does not leach into water and has a long useful life in the soil.

The role of a cover cap is to (1) prevent human or animal exposure to contaminants through either blowing or erosion of contaminated soil, (2) to sustain vegetative growth on the cover, and (3) to fulfill any engineering function. A cover must control the movement of gas generated within the contaminated soil. This is particularly important in old sanitary landfills in which the decay of organic debris produces carbon dioxide and methane (which is explosive).The advantage of soil cover is that it is relatively inexpensive; it may be installed rapidly; and contaminated material need not be excavated. Excavation leads to further contamination and greater costs.

Mine soils: Significant areas are being mined for coal, oil shale and gravel by surface mining (strip mining). Environmental laws (and good sense) dictate that when the mining is finished, the areas be returned to a condition that will permit a continued use similar to the original uses.

Mine soils are created after the overburden is removed during strip or open–pit mining to uncover ore. The overburden consists of 'natural' soil, parent material, and underlying geological materials. It may be many meters thick. Once removed, it is deposited somewhere near the mine, often in a former mine area. Initially, the overburden looks like parent material for the 'natural' soil, and it is the parent material for the new minesoil that forms over time.

The practice used in most strip mine today is to stockpile either the A horizon or all of the natural soil materials and to use it to topdress (cover) the overburden. Plant establishment is more rapid on natural soil material. This is important because soil erosion on bare overburden or fresh mine soils can be extreme.

Mine soils inherit their properties from the material used to create them. They have a different distribution of C, N, pH, clay, and micro - organisms than do natural soils. Over time, as the natural soil–forming processes act, the mine soils take on the characteristics of more 'natural' soil. Most mine soils have two properties in common. They have many more rock fragments than natural soils do and they lack the structure of natural soils. This lack of structure may decrease infiltration and increase runoff and erosion, but studies have shown that properly prepared mine soils can be productive, some even more productive than the natural soils destroyed during the mining.

The soil is a primary recipient, intended or otherwise, of many of the waste products and chemicals used in modern society. Once these materials enter the soil, they become part of a cycle that affects all forms of life. At least a general understanding of the pollutants their reactions in soils and available means of managing, destroying or inactivating them is essential.

Suggested Readings

1. HESSE, P.R. 1971. A Text Book of Soil Chemical Analysis, John Murray, London.

2. JACKSON, M.L. 1958. Soil Chemical Analysis, Prentice Hall, Englewood Cliffs, NJ, USA.

3. BLACK, C.A. (Editor). 1965. Methods of Soil Analysis (American Society of Agronomy, Madison, Wisconsin, USA.)

WATER QUALITY IMPACT ANALYSIS AND STANDARDS

R.N. BHATTACHARYA*

Preamble

Water Uses: Inherently water is a multiple use resource. Thus, the uses and purposes of most rivers and lakes are multiple, often conflicting, and will generally include most of the following:

1. Public water supply;
2. Water as a recreational asset (primary contact, such as bathing and swimming; secondary contact, such as boating and indirect, such and scenic beauty);
3. Propagation of fish and other aquatic life;
4. Stock and wildlife watering;
5. Water for agricultural use, principally irrigation;
6. Water as raw material or coolant in industry;
7. Water as power producer in hydro-electric power plants;
8. Water as supporting medium for ships and other commercial vessels (navigation);
9. Water as a sink for wastes.

In order for any water body to function adequately in satisfying any one of the above purpose, it must have corresponding degree of purity - the list is ranked approximately by decreasing purity requirements, i.e., public water supply employing disinfectant as the only treatment must be of highest quality, while wastes can discharged into any type of water body (with fire consequences).

In recent years, as the demand for water has nearly approached in magnitude the available supply, the concept that management of quality of water is quite as important and obligatory as its physical management has since been widely recognized and strongly advocated throughout the world. This has led to a profound expansion of the goals of water quality management. First it was protection of public heath – growing out of the disasters of less sanitary times, protection of the public health was the chief target of the control agencies, and control of pollution by human and/or animal wastes was the primary objective of watershed management.

Protection of multiple beneficial uses became an added objective of water quality management in the middle of the current century in the context of:

1. Intensifying competition for the limited water resource arising mainly from the many-sided needs of a burgeoning population.
2. Emergence of industry as a major producer of wastes.
3. Lengthening the spectrum of wastes for beyond organic residues of life processes – refractory compounds in particular.
4. The growing problem, in some regions of mineralized agricultural return waters.

Recently, aesthetic or social goals of water quality have been added to the growing list of objectives of water quality management.

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Water Quality: The term *water quality* is a widely used expression which has an extremely broad spectrum of meanings. Each individual has vested interests in water for his particular use. The term *quality,* therefore, must be considered relative to the proposed use of water. From the user's point of view, the term *water quality* is used to define "those physical, chemical, biological or radiological characteristics by which the user evaluates the acceptability of water"(1)*.

In the above context, it is worthwhile to mention that McGauhey has noted, "A need to quantitative, or give numerical values to the dimension of water known as quality derives from every aspect of modern industrialized society. For the sake of man's health we require by law that his water supply be pure, wholesome, and potable. The productivity and variety of modern agriculture require that the sensitivity of hundreds of plants to dissolved minerals in water be known and either water quality or nature of crop controlled accordingly. ....Textiles, paper, brewing and dozens of other industries using water, each have their own peculiar water quality needs. Aquatic life and human recreation have limits of acceptable quality. In many instances water is one of the raw materials the quality of which must be precisely known and controlled"(2)

Thus, the uses that have specific quality requirements which the management must seek to protect are:

1. Public water supply;
2. Recreation and aesthetic;
3. Fish, other aquatic and wildlife;
4. Agricultural uses
   i) farmstead water supplies;
   ii) livestock water supplies;
   iii) irrigation water supplies;
5. Industrial water supplies.

The other beneficial uses of water cited earlier but not included in the above list, such as navigation and receptacle of wastes do not demand any quality requirements but these uses should be carefully controlled so as not to impede the higher uses.

Hence, the minimum objective of the quality control procedures is to maintain the quality of the resource pool at such a level that it can support the in-stream uses such as recreation, aesthetics and aquaculture, can be directly used for irrigation and stock-watering, or upgraded for industrial or domestic use by current technology of water purification. Thus, both the objectives and engineering of water quality management depend upon a knowledge, what concentrations of each can be tolerated by the various beneficial uses which management seeks to protect.

The discussions that will appear in the subsequent sections of the present chapter are essentially on the water quality criteria for the various beneficial uses, but before that enunciation of the concepts of criteria and standards in water quality management appear pertinent.

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*Figures in brackets ( ) refer to suggested readings at end of chapter

Criteria and Standards

Criteria: A scientific requirement on which a decision or judgement may be based concerning the suitability of water quality to support a designated use[3]. McKee and Wolf[4] in their monumental work "Water Quality Criteria" noted the need for applying numbers to criteria but warned against letting them into rigid standards.

The criteria should be based on findings from fundamental and applied researches and also careful and scientific interpretation of any catastrophe steaming from any disorder in the water environment. Setting of water quality criteria, therefore, gets involved with epidemiology, fish-kills, statistics, sanitary and micro-biological surveys, and aquatic ecosystems as well.

Obviously, criteria should reflect the latest scientific knowledge on all identifiable effects of pollution on human health, fish and aquatic life, plant life, wildlife, shore lines and recreation. It must, however, be recognized that there is lack of adequate knowledge concerning many of the quality characteristic upon which criteria should be based. The unknowns still outweigh the knowns. Hence, criteria are amenable to revisions from time to time with newer information and knowledge coming up through further research, however, at any time and within the framework of available wisdom water quality criteria represent the ideal requirements and constitute one most important facet of the many-sided lines setting standard pertaining to water quality management.

National Technical Advisory Committee (NTAC), and Environmental Protection Agency (EPA)[3,5] have provided numerical criteria with the limits for each pollutant followed by scientific rationale. The Canadian Working Group[6] has restricted the domain of criteria to descriptive expressions on the effects of pollutants and has proposed guidelines in numerical terms on the basis of the descriptive criteria for formulation of water quality standards. In India, IS 2296-1974[7] published by the Indian Standards Institution provides numerical tolerance limits for inland surface waters subject to pollution as discussed subsequently. It is worthwhile to mention that in contrast to standards, criteria have no connotation of authority.

Standards: These are legally prescribed limits of pollution and/or deterioration which are established under statutory authority[6]. Standards also include the plan that is established by governmental authorized as a programme for water pollution prevention and abatement[3]. In totally, therefore, standards reflect:

i) use designations for each water body or portion thereof;
ii) water quality standards to support the designated uses;
iii) implementation plans for achieving the desired quality objectives.

i) Use of designations: The task of use designations involves balancing conflicting interests and defining a management programme which can satisfy multiple objections and criteria with the least total cost of the society. This calls for modern management methods embracing problems of costs and benefits with respect to public health, aesthetics, recreation, and other productive uses, to arrive at some optimal set of decisions. However, it is felt that the physical and economy data needed for such comprehensive approach satisfactorily economy passing all relevant elements are much more that we now have. Hence, decisions pertaining to use designation/s of any waterbody or portion thereof, at the present time, have to be make on a subjective basis with a sense of balance and caution to assure disruptive or adverse effects on the various segments of economy dependent on water for their existence are minimized.

ii) **Receiving water quality standards:** Once the use designation or so-called best usage of any water body is decided, the receiving water quality standards may be set on the basis of the water quality criteria for the best usage envisaged. Thus, criteria give way to receiving water quality standards. In practice, ideal would it be if the water quality criteria for a particular use could be translated to stream standards in total for any natural body of water classified for that best usage. This is, however, hardly possible in reality owing to widely varying ambient quality levels of natural bodies of water resulting from natural quality interchange factors, and man made modification well. Moreover, other extenuating conditions may also warrant exemptions from the ideal requirements as dictated by the scientific criteria. The pattern is, thus, becoming established for determinants stream standards according to the social and economical classifications of their rivers. Such approach must, however, recognize and applicable overall state or national policies pertaining to water quality objectives, and should stress upon the joint management programme and cooperation across state lines which will be necessary in most instances.

iii) **Plan of implementation and enforcement:** The third major component of comprehensive water quality standard programme is enunciation of the plan of implementation and enforcement. Of the many facets of the implementation plan, the one paramount importance and obviously the technical under gird of the entire planning system is the *effluent standards* or *standards limitations.* Such standards specify the maximum permissible concentration of pollutants in effluents from municipal, industrial and agricultural pursuits, and discharging into the surface water sink. It may be noted that the control of diffused not-point source of pollutants (primarily agricultural return waters) is in a primitive stage, however, the point sources comprising the municipal and industrial waste water outfalls are amenable to control. The task of setting effluent limitations for point-sources and be approach in two ways as stated below:

a) Uniform effluent standards – Such uniform standards may be set for sewage effluents, industrial effluents in general, also for individual effluents industries. The relevant Indian Standards as published by the Indian Standards Institution are listed in Appendix - I. Uniform effluent standards for any type of effluent are invariably based on quality that can be attained by employing the best practicable wasted treatment technology currently available. Though, there are many advantages of uniform effluent limitations, nevertheless, the system definitely lacks adequate flexibility and does not provide much scope for equitable allocation of the self-purification capacity of the surface water sink.

b) Situation – This system based on maintaining the stipulated quality standards of receiving water presupposes the technological ability to predict the effect of waste discharges on the quality of water under varying conditions. It implies that discharge limitations should be based on local receiving water standards taking into account the self-purifying capacity of natural water bodies. Such capacity should be allocated, with appropriate safety factors, to existing discharges. conservation and recreation reserves, and a reserve for future discharges in accordance with applicable land use and comprehensive water quality plans. This requires a knowledge of physical, chemical and biological phenomena in the water environment and expression thereof mathematical in models. Specific models are needed for a specific pollutants and specific locations.

It is felt that both the policies for effluent limitations cited above are workable and, in practice, unanimous superiority of any one over the other at all places and at all times can neither be claimed nor established. Thus, one should not be dogmatic in recommending effluent limitations either on a uniform basis or on situation-specific theory, and such decision making should read with the level of the government nearest to the problem.

Other essential facets of the plan of implementation of water quality policy serving simultaneous attention and consideration are:

1. Introduction of waste discharge permit system;
2. Imposing a cost of polluter;
3. Information collection pertaining to water quality and effluent quality through vigorous monitoring and inspection programs;
4 Promotion of research and development, and training of environmental man power:
5. Feasibility of providing partial subsidies for pollution control measures;
6. Initiation of attack on problems from non-point sources;
7. Creation of interstate agency to settle problems arising from interstate pollution endangering the health or welfare of persons in a state other than the state where from pollution stems;
8. Providing adequate means at interstate levels so that enforcement reaches its full potential.

The Concept of Water Quality Criteria Since 1950

Use-Specific Criteria and Standards: Determining water quality criteria for various uses is an important step in solving water pollution problems. This concept received overwhelming recognition after publication of "Water Quality Criteria" by the California State Water Pollution Control Board in 1952[(8)] prepared under the direction of Professor J.E. McKee of California Institute of Technology. The 1952 publication includes among many other things:

- A thorough consideration of dilution, mixing, self-purification, synergism, and other such factors in the disposal of pollutants.
- Water quality criteria promulgated by state and interstate agencies.
- Quality criteria for the major beneficial uses of water embracing domestic water supply; industrial water supply; agricultural water supply (irrigation); and swimming and bathing waters. Potential pollutants and their effects on the major beneficial uses.

In addition, some coverage on the survey of judicial aspects of water quality criteria was provided in the original publication. Recognizing that any literature survey is outdated shortly after its publications and that it becomes less useful with each passing year as significant new data become available, the California State WPC Board resolve to sustain the usefulness of "Water Quality Criteria" by the preparation of an addendum comprising a resume of the literature that appeared in the two years since the original volume was published. Accordingly, an addendum was brought out in 1954[9]. In the subsequent years the original compendium underwent further updating and the total outcome was the valuable and monumental publication entitled "Water Quality Criteria" by McKee and Wolf[4] published by the California State WPC Board in 1963 with a subsequent reprint in June 1976. In 1976 the first National Technical Advisory Committee of Water Quality Criteria was established in U.S.A. The Committee's principal function was to collect in one volume a basic foundation of water quality criteria. The Committee identified and developed criteria for five general areas of water use:

i) Recreation and aesthetic;
ii) Public water supply;
iii) Fish, other aquatic life and wildlife;
iv) Agriculture;
v) Industry.

The final version of the NTAC Report came out in 1968[3] under the title "Water Quality Criteria". Subsequently, the Environmental Protection Agency (EPA) was created in U.S.A., the famous "Blue Book" which is more correctly titled "Water Quality Criteria – 1972"

Almost concurrently came out "Guidelines for Water Quality Objectives and Standards – Environment Canada"[6], which is essentially a compilation of technical and scientific data. The Canadian working group has at the outset emphasized that in the development of any comprehensive plan to control the present and future use of quality of water, the following facts must be known:

i) the existing water uses;
ii) future water uses;
iii) what must be done to provide both the quantity and quality of water for these uses, including recreational use and the maintenance of aesthetic characteristics;
iv) the level of environmental quality to be maintained.

The U.S.A. EPA of 1973, the Agency, pursuant to the provisions in the Federal Water Pollution Act Amendments of 1972 prepared and circulated "Proposed Criteria for Water Quality" in October 1973 for comment.[5] The compendium is mostly based on the NAS recommendations in the "Blue Book" with minor modifications, and is probably the latest of the water quality criteria series. The volume encompasses numerical criteria together with scientific rationale thereof for:

i) Agricultural Constituents
   a) General
   b) Irrigation
   c) Livestock

ii) Fresh Water Constituents
   a) Aquatic life
   b) Wildlife
   c) Public water supply intake

iii) Marine Water Constituents
   a) Aquatic life
   b) Wildlife

iv) Recreational Waters
   a) Aesthetic considerations
   b) Recreational waters

In India, Indian Standards Institution published the "Tolerance Limits for Inland Surface Water Subject to Pollution – IS 2296", for the first time in 1963 which has so far undergone its first revision in 1974[7]. This Indian Standard is a praiseworthy document compiled by the Indian Standards Institution and encompasses tolerance limits for:

i) Raw water for public water supply and bathing ghats – 17 constituents;
ii) Fish culture – 8 constituents;
iii) Irrigation – 9 constituents.

The identified best usages as mentioned above are traditional, although industrial water use has not been included. In fact, most varied spectrum of quality requirements is found in industrial water needs and this leads to the conclusion that the requirements of industry cannot possibly become the criteria by which quality of the fresh water resource is managed. Therefore, it would seem axiomatic that industry will have to continue to treat water in accordance with its own needs for processed water, and to locate its plants where the local source can be suited for its processing and water cooling requirements.

The details of the Indian Standards for various beneficial uses have been presented in Annexure I. However, for the present it is expressed that the water quality constituents considered in specifying the tolerance limits are well chosen and fall under the four categories such as physical, chemical, microbiological and radiological. Nevertheless, it is felt that in consideration of the continuing lengthening of the spectrum of pollutants stemming mainly from increasing extractive and processing industries on the one hand, and consumption activities on the other, further widening of the spectrum of quality constituents to be controlled for effective water quality management needs serious probing. Such enhancement must, however, be compatible with our needs, analytical facilities, and financial ability in the foreseeable future.

Public Water Supply:

i) **Relevant Aspects:** Domestic water supply, being most necessary for the sustenance of human life, is generally considered the highest beneficial of water. Therefore, municipal use seems worthy of first consideration. In fact, surface water bodies completely free from the deleteric influences of modern civilization are rarely available in this last quarter of the twentieth century. Thus surface waters invariably need some treatment to meet drinking water quality standards. In many occasions surface water are used for public water supply without treatment other than disinfection. Such waters at the point of withdrawal should meet Drinking Water Standards as prescribed by Central Public Health and Environmental Engineering Organization (CPHEEO), India, in all respects barring bacterial quality only[10].

It is true that treatment processes exist which can, at a price convert almost any water including sea water and grossly polluted fresh water into a potable product, nevertheless, the large scale feasibility of such an approach is very limited because of economic constraint. Hence, the management should seek to protect the quality of the resource pool at such a level that it can be upgraded to conform to the drinking water standards by the conventional treatment or even lesser.

ii) **Drinking Water Standards:** In the context of the preceding discussion, the

CPHEEO Drinking Water Standards, which have been mostly taken from the WHO International Drinking Water Standards[11] are presented in Table 1. Undesirable effects that may be produced by the constituents if present at higher concentrations have also been indicated in the table.

iii) Quality Criteria for Public Water Supply Intake: In our country, Indian Standards Institute has prescribed the tolerance limits for inland surface water for use as raw water for public water supply as illustrated in Table2.

Aesthetics and Recreation:

i) Aesthetics: Aesthetically pleasing water adds to the quality of human experience. Water may be pleasant to look upon, to walk or rest beside. It may provide a variety of recreation experience. It enhances the visual scene wherever it appears – in cities or wilderness. It may enhance values of adjoining properties, and also provide a focal point of pride in the community. The appearance of pollution or fear of pollution reduces aesthetic value, whereas, the knowledge that water is clean enhance both direct and indirect aesthetic appreciation. The recognition, identification, and preservation of the aesthetic values and qualities of water should be an objective of all water quality management programmes.

General Criteria

A. All surface water should be capable of supporting life form of aesthetic value.

B. Surface waters should be free of substances attributable of discharge of waste as follows:[3]

(i) Minerals that will settle to form objectionable deposits.

(ii) Floating debris, oil scum, and other matter.

(iii) Substances producing objectionable colour, odour, taste or turbidity.

(iv) Materials including radio nuclides in concentrations or combinations which are toxic or which produce undesirable physiological responses in human, fish and other animal life and plants.

(v) Substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life.

Desirable Additional Criteria

A. The positive aesthetic values of water should be attained through continuous enhancement of water quality.

B. The aesthetic values of unique or outstanding waters should be recognized and protected by development of appropriate criteria for each individual use.

ii) Recreation

A. *Primary Contact Recreation* – is defined as activities in which there is prolonged and intimate control with water involving considerable risk of ingesting water in quantities sufficient to pose a significant health hazard. Examples are wading and dabbling by children, swimming, diving, water skiing, and surfing.

B. *Secondary Contact Recreation* – includes those in which contact with the water is either incidental or accidental and the probability of ingesting appreciable quantities of water is minimal, such as boating.
Fishing is, of course, a secondary contact recreational use of water, however, the quality consideration in this case are required for protection and propagation of fish discussed subsequently.

General Criteria

The general criteria of quality for recreational use of water are obvious: "freedom from obnoxious suspended or floating material, objectionable colour or foul odours. Accordingly, the general criteria for aesthetics as listed earlier are applicable in recreational uses also".

Other Essential Criteria

Furthermore, recreational waters should also meet the following quality criteria:

(i) Clarity – For Bathing and swimming water, clarity should be such that a Sacchi disc is visible at a minimum depth of 4 feet.

(ii) Microbiological – None would question the necessity of including microbiological criteria in a mandatory category, thus, the question of what indicators and what limits should apply remains to be decided. The current American trend is toward utilizing fecal califorms as indicators for use in criteria for contact recreation. Indian Standard Tolerance Limits for Inland Surface Waters for Bathing Ghats are presented in Table 3.(7)

Agricultural Uses:

i) **General Consideration:** Agricultural uses of water encompass:

A. Farmstead waters, which primarily include the water used by the human farm population for drinking, culinary and laundry. The other important use is washing of fruits and vegetables in preparation for sale.

B. Livestock watering.

C. Irrigation.

Thus, concern for quality of water is important to modern agriculture not only in determining the productivity of plant and animals, but also because it affects the health and welfare of the farmers.

ii) **Irrigation Water:** Of the three uses delineated, irrigation is the largest, single-purpose beneficial use of water in agriculture. Crop sensitivity to salinity and toxic substances necessitates the need for water quality criteria for irrigation purposes. The quality of water consumed by livestock has far-reaching implications; polluted water can cause death or disease of livestock and contaminate animal products. A dependable source of livestock water of requisite quality is indispensable for the profitable production of animal. Furthermore good water quality is an important factor for the health and well-being of human farm population, and to enhance production by reducing man-days lost in sickness.

iii) Irrigation Water Supplies: Among the multipurpose for which resources are developed and used, irrigation is the largest single-purpose beneficial consumptive use. Therefore, water quality criteria for irrigation becomes more and more significant as water resource developments increase within each river basin. Evaluation of water quality criteria for irrigation uses must take into cognizance the interactive effects of salt, plant, and climate. Each of these factors is highly variable, nevertheless, they are important in determining the quality of water that can be used for irrigation under a specific set of conditions. The physicochemical properties of a soil determine the root environment that a plant encounters subsequent to an irrigation. The soil comprises and organo-mineral complex which has the ability to react both physically and chemically with constituents carried by the irrigation water. The extent to which these added constituents will leach out of a soil, remain available to plants in the soil, or become fixed and unavoidable to plants depends largely on the soil characteristics.

It is axiomatic that favourable salt balance in the root zone is essential for plant growth, which in turn, depends on drainage capacity of the soil. In fact, good drainage is essential to prevent a rising water table, salt accumulation in the soil surface, and to maintain adequate soil aeration. Plants vary considerably in their tolerance of water quality constituents, especially salinity and trace elements. Again, in a saline soil at a given water content, a plant will suffer more in a hot dry climate that in a cool humid one.

Owing to the many variable factors as hinted above, setting of water quality criteria for irrigation uses has become highly complex, nevertheless, McKee and Wolf(4), National Technical Advisory Committee(3) and U.S.A. EPA(5) have made praiseworthy contributions towards development of rational water quality criteria for irrigation use. The factors that limit the usefulness of a water for agriculture and the concentrations at which their effects are felt either in a minimal or a catastrophic way, have been the object of much research and many publications.

The quality factors the invariable come up during evaluating the suitability of water for irrigation often include:

1. Inorganic (ions and free elements/compounds)
2. Solids
   (a) Dissolved
   (b) Suspended
3. Pathogens
4. Pesticides
5. Radioactivity
6. Temperature

The Indian Standard tolerance limits for inland surface waters for irrigation water[7] and for industrial effluents discharged on land for irrigation purposes[13] are presented in Tables 4 and 5 respectively.

iv) Farmstead Water Supplies: Farmstead water supplies for use by the human farm population should conform to the drinking water standards already discussed earlier under public water supplies as far as practicable, farm water supplies can be of ground ore surface origin. Ground sources are generally regarded as providing a more dependable supply as being less variable in composition than surface water. However, it should be recognized that all supplies are subject to pollution and care must be exercised in both the installation and maintenance of water system. In general terms, raw waters should be free of impurities which are offensive to sight, smell and taste. They should be free of any significant concentrations of toxic substances, and should be free also of bacteria and other living forms which can not be controlled or eliminated by simple processing techniques such as chlorination.

v) Livestock Water Supplies: Since the total quantities of substances ingested daily are critical values for animal metabolism, the permissible concentrations of such substances in water will depend, to some extent, on the daily water consumption of the animals. The daily water requirements of animals vary with a number of factors, such as the temperature and humidity of the atmosphere, the water content of the diet, the degree of exertion by the individual with a resulting loss of water as sweat, and the salinity of the available supply.

Industry:

i) Preamble: Modern industry is a dynamic enterprise, ever expanding, constantly changing and an intense water user. In our country, we do not, as yet have adequate information pertaining to water intake and gross water use (intake plus water recycled) in the industry. Nation-wide survey on the use of water in Indian Industry has not been organized so far. However, the estimate (excluding power plants) stands at 11000 million cubic metre (2,42.000 million gallons) per year which is little higher than the estimated industrial water use as mentioned earlier probably lies in between the water withdrawn from resources pool and the gross water use.

Again, generation of 116 x 10(9) kwhr was envisioned in the year 1978-79 out of which one-half might be the share of the steam-electric power plants. A liberal estimate for water use based on once-through cooling system and water requirements of 300 litres per kwhr works out to be 17,400 million cum (3828000 million gallons) per year. With a conservative outlook if we consider the estimates to present the water intake then the total intake for industry and thermal power plants is nearly 3 per cent of the Nation's annual utilisable fresh water resource of 93.5 million hectare metre (MHW). Water quality requirements differ so widely for the hundreds of uses to which water is put industrially that no meaningful criteria for surface water supplies can encompass a majority of such cases. Therefore, it would seem axiomatic that industry will have to continue to treat water in accord with its own needs for process water, and to locate its plants where the local resource can be suited to its process and cooling water requirements.

ii) Industrial Water Use: The manufacturing industry uses water for:

1. Cooling and condensing	May be once-through system, or a recirculating system with cooling towers or ponds.
2. Steam generation	Boiler feed and make-up.

3. Process application	Conveying other materials; washing of production materials; as raw material itself; and numerous uses which may be peculiar to only one industry, etc.
4. Cleaning of equipment and floors and sanitary service.	General use of water

Consumptive use of water has been defined as "..the quantity of water discharged to the atmosphere (evaporated) or incorporated in the products of the process in connection with vegetative growth, food processing or incidental to an industrial process". Industry consumes only about 7 percent of the water it withdraws[15]. This is divided principally between water evaporated and water incorporated in products of manufacture. Table 6 provides information on water consumption in selected U.S. industries.

iii) Cooling Use: A significant proportion of all industrial water withdrawal is used in cooling system as showed in Table 7.[15]

Fish and other Aquatic life:

i) General Approach: In determining water quality requirements for aquatic life and wildlife, it is essential to recognize that there are not only acute and chronic toxic levels but also tolerable, favourable, and essential levels of dissolved materials. Hence, lethal, tolerable and favourable levels and conditions should be ascertained through field investigations, laboratory studies, together with testing laboratory findings in the field to determine their adequacy for the protection of aquatic and wild life resources.

ii) Key Criteria: Criteria for the quality of fresh water that will support a good fish fauna were first presented by Ellis [16] who proposed the following limits [quoted from Mckee and Wolf[4]] —

1. Dissolved oxygen, not less than 5 mg/l:
2. pH, approximately 6.7 to 8.6, with an extreme range of 6.3 to 9.0;
3. Specific conductance at 25°C; 150 x 10-6mhos with a maximum of 1000-2000 x 10-6mhos permissible for stream in ..alkaline areas;
4. Free carbon dioxide not over 3 c.c. per litre;
5. Ammonia, not over 1.5 mg/l;
6. Suspended solids such that millionth intensity level for light penetration will not be less than 5 metres.

Subsequently, Doudoroff and Katz presented an excellent literature review on toxicity of industrial wastes and their components to fish[17,18]. While discussing the effects of alkalies, acids and inorganic gases, the reviewers summarized:

1. Under otherwise favourable conditions, pH values above 5.0 and ranging upward to pH 9.0, at least, are not lethal for most fully developed fresh-water fishes;
2. None of the strong alkalies which are important as industrial wastes [i.e. NaOH, $Ca(OH)_2$ and KOH] has been clearly shown to be lethal to fully developed fish in natural fresh-waters when its concentration is insufficient to raise the pH well above 9.0.

3. A concentration of the non-ionic free ammonia or ammonium base, of 1.2 to 3 ppm (as NH_3) has been reported to be quite rapidly and uniformly toxic to a relatively hardy species in solutions of varying pH and ammonia ion content.
4. The strong mineral acids (i.e. H_2SO4, Hcl and HNO_3) and also phosphoric acid (H_3PO_4) and some moderately weak organic acids (e.g. lactic, citric, tartaric, and oxalic acids), apparently can be directly lethal to fully developed fish in most natural fresh-waters only when the pH is reduced thereby to about 5.0 or lower.
5. A number of weak organic and inorganic acids can impart to some waters pronounced toxicity for fresh-water fish without lowing the pH to a value às low as 5.0.
6. The susceptibility of different species of fish to the lethal action of free carbon dioxide varies greatly;
7. Solution of hydrogen sulfide (as well as other sulfides), free chlorine, cyanogen chloride, carbon monoxide and ozone all are extremely toxic to fish.

iii) Aquatic Life: Table 8 indicating the Indian Standard tolerance limits for inland surface waters for fish culture, may serve to indicate the general criteria by which water can be judged as to its suitability for aquatic life. The characteristics and corresponding tolerance limits prescribed above are likely to function well for the present. However, in near future lengthening of the list may become necessary for incorporating constituents such as pesticides, detergent, phenolic compounds and other tainting substances, cyanides, toxic heavy metals, etc., and we should think in this perspective right from now. For pesticides, while we can have information from Western experiences even then, it is obligatory that the TLm values i.e. Median Tolerance Limit [TLm - The concentration of the tested material in a suitable dilutent (experimental water) at which just 50 percent of the test animals are able to survive for specified period of exposure] for specified period of exposure be determined in our country using the receiving water and the most sensitive important species.

iv) Aquatic Wildlife: Wildlife is defined herein as all species of mammals, birds, reptiles and amphibians. Because of the dependence of waterfowl on aquatic habitats, their needs form primary basis for definition of water quality requirements for wildlife. The water quality criteria for aquatic wildlife are discussed in detail in the reverent literature.

v) Aquatic Life in Marine/Estuarine Environment: Although, detailed coverage of estuarine and marine water quality criteria for aquatic life transcends the scope of the present section, nevertheless, it is worthwhile to mention that the quality management of such water bodies must take careful cognizance of the various constituents of significance in relevant to the numerous aquatic life species, and their favourable levels. The quality factors deserving attention are [3]: Salinity, pH, temperature, D.O., crude oil and petroleum products, turbidity and colour, settleable/floating substances, tainting substances, nutrients, nuisance organisms and toxic substances (e.g. pesticides, heavy metals and other toxicants), pathogenic bacteria and viruses and radio activity. Table 9 may serve as a good guide for water quality requirement of marine and estuarine aquatic life.

Residual Generation and Impact

Residual Generation/Emission Factors:

a) In order to analyse the factor underlying residual/waste generation, their type and extent, it is useful to classify the industrial activities as production or consumption. In the most general way one can say that a residual is a function of the economics and technology of production. Indeed, the volume and characteristics of residuals generated are functions of not only the amount of product, but also, for example, the raw materials used, the production technology and to some extent, the type of containers used, for marketing of products. Technological changes can play an important role. New productions processes can transform what was residual/waste into a useful production input. Some residuals may be recycled as inputs into the same production process or into some production processes. Other residuals may be treated so as to change their form or weight. A relatively small projection of residuals is being currently recycled into some productive process, the remainder being discharged directly into one or another of the environmental media – air, water and land.

b) For a given production technology, the driving force behind residuals/wastes generated is the quantity of production itself i.e. the society's final demand for the product. Given any final demand, the nature, quantity and the time rate of residuals/wastes generated are determined as functions of the nature of raw materials used, the nature of the production, the operating level, the product output mix, and the control of gaseous, liquid and solid residuals/wastes. Final demand. reflected in the volume and variety of products consumed, is a function of population size, standard of living, and social tastes and values. The complex inter relationships between production technology, consumers choices/limitations, and residuals generation can be illustrated by the simple example of the residuals/wastes generated by household.

c) Obviously, then, there is a wide range in the quantity and character of residuals/wastes generation even in a single type of activity. For example, generation of gaseous residuals varies with time – daily, weekly seasonally and from year to year – according to the type of activity. These time variations can be linked to variations in demand for a specific product, variations in the quality and quantity of raw materials input suited to the production process etc. Variations also exist among areas, depending on the mix and spatial pattern of economic activity. Of course, a region where heavy industries are concentrated is likely to bear a higher impact from residuals/wastes generation than an area devoted to tourism or administrative activities. Such a variability in both time and space implies that, to be operational, the analyses for residuals/wastes generation should be made at a higher disaggregated level. However, it is important to bear in mind that information at a micro-level can still be highly valuable, from both a methodological and practical point of view.

Residual Generation Measurements:

a) Standard economic theory (or one-dimensional model) has been concerned mainly with services that yield flows of positive utilities, not with physical substances. Residuals/wastes generation such as, which does not yield any utility to society, does not appear in the traditional theoretical and applied models of the economic system

Recently attempts have been made to include residuals/waste generation in the traditional framework of the economic system*. Leontief has extended his basic input–output economic model to include pollutants as outputs of the production sector, and pollution control activities among the various usual production sectors. For this purpose, Leontief assumes the availability of pollutant generation coefficient (i.e. emission factors) as well as of input-output coefficient for the pollution treatment activities. The usual final demand vector is supplemented by the vectors of residuals/waste discharged, and the resulting total vector expresses simultaneously the final demand for usual goods and the final demand for a clean environment, through the explicit limitation of the amounts of the various pollutants produced.

b) The following matrices and sectors are defined:

A11 = [aij]	input of good *i* per unit output of good *j*
A21 = [agi]	output of pollutant *g* per unit output of good *i*
A12 = [aig]	input of good *i* per unit of eliminated pollutant *g* (pollutant *g* eliminated by sector *g*)
A22 = [agk]	output of pollutant *g* per unit of eliminated pollutant *k* (eliminated by sector *k*)
X1 = [xi]	total output of good *i*
X2 = [xg]	total amount of pollutant eliminated
Y1 = [yi]	output of good *i* delivered to the final demand sector
Y2 = [yg]	amount of residual pollution (delivered to the final demand sector)

The following balance conditions are delivered:

Y1 = X1 - A11 X1 - A12 X2	i.e. The final demand for goods (Y1) equals the total output of goods (X1) minus the intermediate of the economic sector (A11 X1) minus the intermediate demand of the treatment sector (A12 X2) .. (4.1)
Y2 = A21 X1 - X2 + A22 X2	i.e. The total amount of pollutant residuals (Y2) equals the output of pollutants from the production of goods (A21 X1) minus the total amount of pollutants eliminated (X2) plus the output of pollutants from treatment activities...(4.2)

These conditions are expressed in matrix form as:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} 1 - A_{11} & -A_{12} \\ A_{21} - 1 & +A_{22} \end{bmatrix}^{-1} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix}$$

The usual input-output computations reveal the amount of various usual goods and of the pollution treatment goods that must be produced to meet the exogenously given final demand. The above model is adequate to assess the effects of technological changes in the production processes or changes in the final demands and to point out the possible incompatibility between demand for usual goods and demand for environmental quality under given production possibilities and resources availability. Its main limitations are the data requirements, the high level of sector aggregation, and the lack of input

* W. Leontief, "Environmental Repercussions and the Economic Structure: An Input-Output Approach", Review of Economics and Statistics, 70, August, 1970.

substitutability inherent to input-output analysis. However, its formal simplicity can make it a valuable tool in macro–analysis.

c) A useful way to look at the residuals generation is to consider the difference in weight (and energy) between the input of fuel, food, and raw materials to production and consumption activities and the output of these activities. In terms of 'material balance', the weight of residuals discharged into air, water and land must be approximately equal to the basis fuels, food and raw materials entering the processes of production land consumption, including the weight of the oxygen drawn from the atmosphere. Therefore, the weight of residuals requiring disposal is larger than the weight of basic materials produced. Provided below is a methodology to apply material balance concepts formally which assumes a hypothetical region with no import – export movements, and to connect the economic exchange system to the physical flow of materials, they add two new sectors to the ones generally in input–output models:

i) An environmental sector whose output X_0 provides physical inputs to the production processes and which receives the waste flows from the production and consumption sectors;

ii) A final consumption sector, which emits physical output to the environmental sector, in amount X_l.

There are N productive processes and X_k is the output of process k. The production functions are of the Leontief type, and C_{kj} is defined as the amount of produce k to produce one unit of product j. All flows and outputs are measured in physical units, that is C_{kj}. X_j is then the physical quantity of product k transferred as input to product j. Final demand and total output of product k are respectively noted as Y_k and X_k. They are linked by the classical inverse matrix coefficients so that:

$$X_j = \sum_{K=1}^{N} A_{jk} Y_k \qquad ..(4.4)$$

Furthermore, X_l is defined as the total aggregate final demand:

$$X_i = \sum_{j=1}^{N} Y_j \qquad ..(4.5)$$

Then, since mass is conserved, the flows in weight from and to the environmental sector must be equal:

$$\underbrace{\sum C_{\theta k} . X_k}_{\text{sum of all raw material flows (inputs from the environment)}} = \underbrace{\sum C_{k\theta} . X_\theta + C_{f\theta} X_\theta}_{\text{sum of all returns to the environment (waste flows)}} \qquad ..(4.6)$$

Furthermore, material flows to and from the final sector must also balance:

$$\underbrace{\sum_{k=1}^{N} C_{ki} X_i}_{\text{sum of all final goods}} = \underbrace{\{\sum_{k=1}^{N} C_{fk} X_k\}}_{\text{sum of all materials recycled}} + \underbrace{C_{f\theta} X_\theta}_{\text{waste residuals}} \quad (4.7)$$

Substituting relationship (4.4), (4.5) and (4.6) in (4.7), we get:

$$C_{f\theta} X_\theta = \sum_{j=1}^{N} \sum_{k=1}^{N} (C_{ji} - C_{fj} A_{jk}) Y_k \quad ..(4.8)$$

The equation (4.8) relates the bundles of final demands Y_k to the weight of waste residuals.

This model is larger in scope than Leontief's model. In fact, it includes the better, and, although it does not deal explicitly with various pollutants, the weight approach permits, at least conceptually, specific residual measurements and a better treatment of the Assimilative capacity of the Environment.

Impacts of Residuals and Environmental Feedback: The generation of residuals/waste affects environmental health in many ways, both through direct exposure and through various indirect effects. The extent of the impacts will vary in relation to many factors, such as the type of the residuals/waste and the time–spatial context of their generation.

It is important to see that people's welfare is not only affected directly by the impacts of economic activities upon the environment (e.g. the impact of air pollution on chronic diseases), but also by the feed–back from the environment into the economy. The latter consideration led researchers to integrate the economic and ecological systems into a type of generalized input–output model that would allow for exploration of the effects of resources utilization and waste generation on the ecological system of natural environment and for establishment of feed–back linkages from ecological to economic system. In its formal structure it is an accounting frame work similar to an inter–regional input–output model, where the two regions are the economic and ecological systems. The ecological system is considered as a very large set of inter–dependent activities, involving as inputs and outputs of many commodities, only a few of which correspond to those of the social system. Not only do these activities feed on each other, i.e. provide each other with inputs, but they also furnish final outputs to the exogenous social system, on which, in turn, they are dependent for various commodities to be used as inputs. From conceptual view point, such an integrated approach seems to be the most rational and comprehensive way to sustainable development i.e. development through conservation of the environment. Presently there are some difficulties uniformly extending the linear analyses to ecological systems as also to build a table or an inventory that includes all the economic–ecological linkages on a regional or national scale. Nevertheless, the approach holds out though promise for further work and advancement.

Appendix I

Indian Standards – Water and Effluent Qualities	
IS: 201–1964	Quality tolerances for water for textile industry.
IS: 2296–1974	Tolerance limits for inland surface waters subject to pollution (first revision).
IS: 2490–1974	Tolerance limits for industrial effluents discharged into land surface waters, part I-V. (first revision).
IS: 2724–1964	Quality tolerance for water for pulp and paper industry.
IS: 2725–1964	Quality tolerance for water for rayon-manufacturing industry.
IS: 3306–1974	Tolerance limits for industrial effluents discharged into public sewers.
IS: 3307–1965	Tolerance limits for industrial effluents discharged on land for irrigation purpose.
IS: 3328–1965	Quality tolerance for water for swimming pools.
IS: 3957–1966	Quality tolerance for water for ice manufacture.
IS: 4221–1967	Quality tolerance for water for tanning industry.
IS: 4251–1967	Quality tolerance for water for processed food industry.
IS: 4700–1968	Quality tolerance for water for fermentation industry.
IS: 4764–1973	Tolerance limits for sewage effluents discharged into land surface waters (first revision).

Table 1

CPHEEO Drinking Water Standards[10]

Sl. No.	Characteristics	Concentrations acceptable *	Causes for rejection **	Undesirables that may be produced
1.	Turbidity (Units on J.T.U. Scale)	2.5	10	Aesthetically pleasing; possible gastro-intestinal irrigation.
2.	Colour (Units on platinum cobalt scale)	5.0	25	Discoloration
3.	Taste and odour	Unobjection-able	Unobjection-able	Taste and odour
4.	pH	7.0 to 8.5	6.5 to 9.2	Taste, corrosion
5.	Total dissolved solids (mg/1)	500	1500	Taste, gastrointestinal irrigation.
6.	Total hardness (mg/1 as CaCo3)	200	1000	Excessive scale formation
7.	Chlorides (as Cl) (mg/1)	200	600	Taste; corrosion in hot water system
8.	Sulphates (as So4) (mg/1)	200	400	Gastrointestinal irritation when magnesium or sodium are present
9.	Fluorides (as F) (mg/1)	1.0	1.5	Cumulative fluorosis with resulting skeletal damage of both children and adults.
10.	Nitrates (as NO3) (mg/1)	45	45	Methemoglobine largely confined infants
11.	Calcium (as Ca) (mg/1)	75	200	Excessive scale of formation
12.	Magnesium (as Mg) (mg/1)	Not greater than 30	150	Hardness, Taste, Gastrointestinal irritation in presence of sulphates.
13.	Iron (as Fe) (mg/1)	0.1	1.0	Taste, discoloration, deposits growth of iron, bacteria, turbidity
14.	Manganese (as Mn)	0.05	0.5	Taste
15.	Copper (as Cu) (mg/1)	0.05	1.5	Astringent taste
16.	Zinc (as Zn) (mg/1)	5.0	15.0	Astringent taste opalescence and sand-like deposits
17.	Phenolic compounds (as phenol) (mg/1)	0.001	0.002	Taste, particularly in chlorinated water
18.	Anionic detergents (mg/1) (as MB AS)	0.20	1.0	Taste and foaming

Table 1 (contd.)

CPHEEO Drinking Water Standards[10]				
Sl. No.	Characteristics	Concentrations acceptable *	Causes for rejection **	Undesirables that may be produced
19.	Mineral oil (mg/1)	0.01	0.30	Taste and odour after chlorination
20.	Arsenic (as AS) (mg/1)	0.05	0.05	Toxic to humans
21.	Cadmium (as Cd) (mg/1/)	0.01	0.01	Can produce nephron and cardiovascular effect; Itai-itai disease has been associated with ingestion of cadmium
22.	Chromium (as hexavalent Cr) (mg/1)	0.05	0.05	Toxic to man
23.	Cyanide (as CN) (mg/1)	0.05	0.05	Toxic to man
24.	Lead (as Pb) (mg/1)	0.1	0.1	Toxic to humans
25.	Selenium as (Se) (mg/1)	0.01	0.01	Selenium intoxicology in man produces ill-defined symptoms but can cause well defined illness in animals
26.	Mercury (Total as Hg) (mg/1)	0.001	0.001	Cumulative poison
27.	Polynuclear aromatic hydrocarbons (PAH) (micro-gram/1)	0.2	0.2	Some PAH are known to be carcinogenic
28.	Gross alpha activity (picocurie/1)	2	3	detrimental effect on health
29.	Gross beta activity (picocurie/1)	30	30	detrimental effect on health

Notes:

* Limits up to which the water is generally acceptable to the consumer.

** Figures in excess of those mentioned under "acceptable" the not acceptable, but still may be tolerated in the absence of alternative and better source but up to the limits indicated under the column "cause for rejection" above which the supply will have to be rejected.

a – Compiled from reference 12 and 13.

b – If there are 250 mg/1 of sulphate, Mg content can be increased to a maximum of 125 mg/1 with the reduction of sulphate at the rate of 1 unit per every 2.5 units of sulphates.

Table 1 (Notes, contd.)

Additional Notes:

It is possible that some mine and spring waters may exceed these radioactivity limits and in such cases it is necessary to analyze the individual radionuclides in order to assess acceptability or otherwise for public consumption.

Bacteriological Standards:

(i) Water entering the distribution system – Coliform count if any sample of 100 ml should be zero. A sample of the water entering the distribution system that does not conform to this standard calls for an immediate investigation into boost the efficacy of the purification process and the method of sampling.

(ii) Water in the distribution system shall satisfy all the three criteria indicated below:

E. Coli count in 100 ml of any sample should be zero.

Coliform organisms not more that 10 per 100 ml shall be present in any sample.

Coliform organisms should not be detectable in 100 ml of any two consecutive samples or more than 50 percent of the samples collected per year.

If coliform organisms are found, re-sampling should be done. The repeated finding of 1 to 10 coliform organisms in 100 or the appearance of higher number in any sample should necessitate the investigation and removal of the source of pollution.

(iii) Individual or small community supplies – E. Coli count should be zero in any sample 100 ml and coliform organisms should not be more than 3 per 100 ml (if repeated sample show the presence of coliform organisms, steps should be to discover and remove the source of pollution. If coliforms exceed 3 per 100 ml, the supply should be disinfected).

Virological Aspects:

0.5 ml/1 of free chlorine residual for one hour is sufficient to inactivate virus, even in water that was originally polluted. The free chlorine residual is to be insisted on in all disinfected supplies in areas suspected to endemicity of infectious hepatitis to take care of the safety from the bacteriological point of view as well. For other areas 0.2 mg/1 of free chlorine residual for half an hour should be insisted upon.

Table 2

Tolerance limits for Inland Surface Waters for Use as Raw water for Public Water Supply[7]. IS-2296-74

Sl. No.	Characteristics	Tolerance Limits
1.	Coliform organisms (monthly average MPN 100 ml)	Not more than 5000, with less than 5 percent of the samples with value greater than or equal to 20,000 and less than 20 per cent of the samples with value greater than or equal to 5,000.
2.	pH value	6.0 to 9.0
3.	Fluorides (as F) mg/l, Max	1.5
4.	Chloride (as Cl), mg/l, Max	600
5.	Cyanides (as CN), mg/l, Max	0.01
6.	Selenium (as Se), mg/l, Max	0.05
7.	Total Chromium (as Cr), mg/l, Max	0.05
8.	Lead (as Pb), mg/l, Max	0.10
9.	Arsenic (as As), mg/l, Max	0.20
10.	Dissolved Oxygen, Minimum	40 percent of saturation value or 3 mg/l whichever is higher
11.	Biochemical Oxygen demand (5 days at 20°c) mg/l, Max	3
12.	Phenolic compounds (as C_6H_5OH), mg/l, Max	0.005
13.	Alpha emitters, micro curies/ml, Max	10^{-9}
14.	Beta emitters, micro curies/ml, Max	10^{-8}
15.	Nitrates (as NO_3), mg/l, Max	50
16.	Oils and grease, mg/l, Max	0.1
17.	Insecticides	absent

Table 3

Tolerance limits for Inland Surface Waters for use as Raw water for Public Water Supply and for Bathing Ghats (IS: 2296–1974, First Revision)

Sl. No.	Characteristic	Tolerance Limit
1.	Coliform organisms (monthly average MPN 100 ml)	Not more than 5000, with less than 5 percent of the samples with value greater than or equal to 20.000 and less than 20 per cent of the samples with value greater than or equal to 5,000
2.	pH value	6.0 to 9.0
3.	Fluorides (as F) mg/l, Max,	1.5
4.	Chloride (as Cl), mg/l, Max	600
5.	Cyanides (as CN), mg/l, Max	0.01
6.	Selenium (as Se), mg/l, Max	0.05
7.	Lead (as Pb), mg/l, Max	0.10
8.	Total Chromium (as Cr), mg/l, Max	0.05
9.	Arsenic (as As), mg/l, Max	0.20
10.	Dissolved Oxygen, Minimum	40 percent of saturation value or 3 mg/l, whichever is higher
11.	Biochemical Oxygen demand (5 days at 20°C) mg/l, Max	3
12.	Phenolic compounds (as C_6H_5OH), mg/l, Max	0.005
13.	Alpha emitters,, micro curies per ml, Max,	10-9
14.	Beta emitters, micro curies/ml, Max	10-8
15	Nitrates (as NO_3), mg/l, Max	50
16.	Oils and grease, mg/l, Max	0.1
17.	Insecticides	absent

Table 4

Indian Standard Tolerance limits for Inland Surface Waters for irrigation[7]		
Sl. No.	**Characteristic**	**Tolerance Limit**
1.	pH	5.5 - 9.0
2.	Electrical conductance at 25°C Max, mhos	3,000 × 10-6
3.	Total dissolved solids (inorganic) (mg/l), Max	2,100
4.	Sulphates (as S04),mg/l	1,000
5.	Chlorides (as Cl) (mg/l), Max	600
6.	Boron (as B) (mg/l), Max	2.0
7.	Percent sodium, Max	60
8.	Alpha emitters, microcurie/ml, Max	10-9
9.	Beta emitters, microcurie/ml, Max	10-8

Table 5

Indian Standard Tolerance Limits for Industrial Effluents Discharged on land for Irrigation Purposes[20]		
Sl. No.	**Characteristic**	**Tolerance Limit**
1.	BOD at 5 day 20°C, mg/l	500
2.	pH	5.5 - 9.0
3.	Total dissolved solids, inorganic, mg/l	2,100
4.	Oils and grease, mg/l	30
5.	Chlorides, mg/l	600
6.	Boron, mg/l	2
7.	Sulphates, mg/l	1,000
8.	Sodium, percent	60

Table 6

Water Consumption in selected industries[15]		
Sl. No.	Industry	Water Consumption (Percent of intake)
1.	Automobile	6.2
2.	Beet sugar	10.5
3.	Chemicals	5.9
4.	Coal preparation	18.2
5.	Corn and wheat milling	20.6
6.	Distillery	10.4
7.	Food processing	33.6
8.	Machinery	21.4
9.	Meat	3.2
10.	Petroleum	7.2
11.	Poultry processing	5.3
12.	Pulp and paper	4.3
13.	Salt	27.6
14.	Soaps and detergents	8.5
15.	Steel	7.3
16.	Sugar cane	15.9
17.	Textiles	6.7

Table 7

Industrial Uses of Water[15]			
Sl. No.	Industry	Cooling (%)	Non-cooling (process and other uses) (%)
1.	All reporting industries	66	34
2.	Automobile	21	79
3.	Beet sugar	95	5
4.	Chemical	65	35
5.	Distillery	84	16
6.	Wheat	25	75
7.	Petroleum	82	18
8.	Soaps and detergents	66	34
9.	Steel	66	34
10.	Sugar	69	31
11.	Textiles	10	90

Table 8

Tolerance Limits for Inland Surface Waters for Fish Culture (IS 2296–1974, First Revision)

Sl. No.	Characteristic	Tolerance Limits
1.	pH value	6.0 to 9.0
2.	Electrical conductance, at 25°C, Max.	1000 x 10-6 mhos
3.	Free carbon dioxide (as CO_2), mg/l., Max.	—
4.	Free ammonia (as N), mg/l	1.2
5.	Dissolved Oxygen, Min.	40 percent saturation value or 3 mg/l whichever is higher
6.	Alpha emitters, micro curies/ml, Max.	10^{9}
7.	Beta emitters, micro curies/ml, Max.	10^{8}
8.	Oils and greases, mg/l, Max.	0.1

Table 9

Tentative Guides for Evaluating the Quality of Water for Aquatic Life

Sl. No.	Determination	* Threshold concentrations	
		Freshwater	Saltwater
1.	Total dissolved solid (TDS), mg/l	2000*	—
2.	Electrical conductivity, micro mhos/ cm @ 25°C	3000*	—
3.	Temperature, maximum °C	34	34
4.	Maximum for salmonoid fish	23	23
5.	Range of pH	6.5 - 8.5	6.5 - 9.0
6.	Dissolved Oxygen (DO), Minimum mg/l	5.0**	5.0**
7.	Flotable oil and grease, mg/l	0	0*
8.	Emulsified oil and grease, mg/l	10*	10*
9.	Detergent, ABS, mg/l	2.0	2.0
10.	Ammonia (free), mg/l	0.5*	—
11.	Arsenic, mg/l	1.0*	1.0*
12.	Barium, mg/l	5.0*	—
13.	Cadmium, mg/l	0.01*	—
14.	Carbon dioxide (free), mg/l	1.0	—
15.	Chlorine (free) mg/l	0.02	—

Tentative Guides for Evaluating the Quality of Water for Aquatic Life

Sl. No.	Determination	* Threshold concentrations	
		Freshwater	Saltwater
16.	Chromium, hexavalent, mg/l	0.05+	0.05+
17.	Copper, mg/l	0.02+	0.02+
18.	Cyanide, mg/l	0.02+	0.02+
19.	Fluoride, mg/l	1.5+	1.5+
20.	Lead, mg/l	0.1+	0.1+
21.	Mercury, mg/l	0.01+	0.01+
22.	Nickel, mg/l	0.05+	0.0
23.	Phenolic compounds as phenol, mg/l	1.0	—
24.	Silver mg/l	0.01	0.01
25.	Sulphide, dissolved, mg/l	0.5+	0.5+
26.	Zinc, mg/l	0.1	—

Source: McKee and Wolf (1963) and compiled by McGauhey[2] — +

* Threshold concentration is value that normally might not be deleterious of fish life. Waters that do not exceed these values should be suitable habitats for mixed fauna and flora.

** Values not to be exceeded by more than 20 percent of any 20 consecutive samples, nor in any 3 consecutive samples. Other values should never be exceeded. Frequency sampling should be specified.

*** Dissolved oxygen concentrations should not fall below 5.0 mg/l more than 20 percent of the time and never below 2.0 mg/l. (*Note* : Recent data indicate also that rate of change of oxygen tension is an important factor, and that diurnal changes in D.O. may in sewage-polluted water render the value of 5.0 of questionable merit.)

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SURFACE WATER QUALITY MONITORING

K.J. NATH*

Introduction

Man's activities on earth are degrading the natural healthy quality of water bodies. The surface water sources are getting polluted due to urbanization, industrialization, agriculture etc. These water bodies have thus become unsuitable for many beneficial users for which they were utilized earlier. The eco-system of the water bodies are getting disturbed due to rapid degradation of the water quality. It is thus now essential to protect as well as to conserve the surface water sources not only as a resource for their present use but for future generation as well. It is imperative to restore and maintain natural water bodies at various stretches to such quality levels as are needed for their designated best uses rather than aiming for a pristine quality which may be ambitious, cost prohibitive and hence impractical.

Source of River Pollution

The following are the general sources of river pollution in our country.

a) Discharge of sewage/sullage from urban areas.
b) Discharge of waste water from industries.
c) Surface run off from agricultural areas.
d) Dumping of solid wastes in river or from leachate through nearby solid waste dumps.
e) Wallowing and bathing of cattle.
f) Dumping of dead bodies.

Use of Surface Water

The surface water is extensively used in our country for various purposes. These are briefed below:

a) Bathing
b) Fishing
c) Recreation
d) Industrial process
e) Agriculture
f) Public water supply.

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Water Pollution Control Strategy

Water pollution control programmes are designed essentially to maintain/restore the natural water bodies to various designated best use. It can be achieved by the following action plan:

a) Control of pollution of the source to the extent possible, giving due regard to techno-economic feasibility and social expectations.
b) Optimal utilization of self purification capacity of natural water bodies keeping eco-system undisturbed.
c) Providing appropriate treatment technology to upgrade the quality of waste water and to take adequate and meticulous measure to utilize the treated waste water for fish-culture/agriculture/industrial purposes etc.
d) Minimization of pollution control requirements by judicious location of industries and relocation of industries whenever necessary.
e) River flow regulation.
f) Organizing motivation and mass awareness campaign.

The strategic administration mechanisms for control of pollution at source are:

— Water quality criteria as ascertained by the scheme of classification and zoning and evolving water quality standards from these criteria.
— Rational evolution of effluent quality criteria for any discharge into one of those classified water bodies and specifying effluent standards.

The exercise of river classification scheme and zoning based on the scheme is explained in the flow sheets (Fig. 1, on following page) which serve as the inter-link between the concepts of stream standards and effluent standards.

Water Quality Management

In order to initiate a water quality management programme the following information is essential:

a) Catchment characteristics and activities.
b) Existing water quality parameters.
c) Criteria for present and planned uses of the water as well as catchment development.

Data pertaining to (a) and (c) above may be collected from relevant agencies, whereas appropriate data on water quality as mentioned in (b) can be obtained by establishing a rational water quality monitoring network.

Water Quality Monitoring Network

Objective: The data on water quality must represent the actual situation of the water bodies in defined locations. Accuracy in collection and analysis need to be given due importance by all concerned. Such network must conform to the present objectives of the performance, necessitating an acute need for visualizing the objectives very clearly.

Location of Sampling Points: It is most critical factor in the collection of water quality data. The selection of location of sampling points should represent the waste water body and if it is not done judiciously the whole exercise may become useless. Various factors e.g. existence of urban set up, industries, potential growth rate, land use planning, climate, accessibility, flow condition etc. have to be taken into consideration while making surveys to establish the sampling stations.

a) Macro-location: Refers to a sampling location relative to an entire river.

b) Micro-location: Refers to the nearest outfalls

WHO Guidelines

Basic stations:	To be operated independently/permanent.
Auxiliary stations:	Related to each other/may be temporary.

Concept of Classification and Zoning as an Aid to Pollution Control

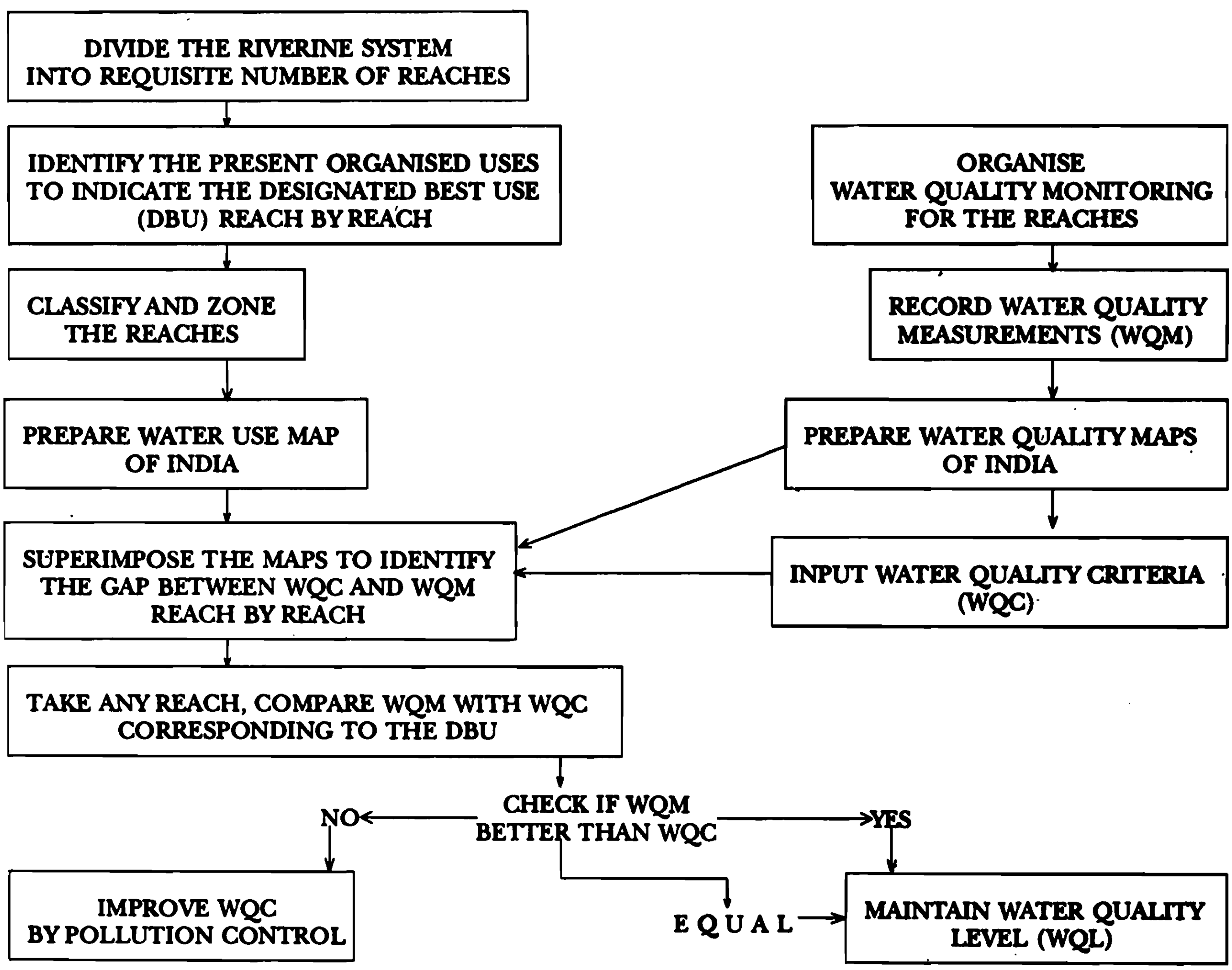

Figure 1

Sampling stations in a river may be selected from following locations:

- — Undisturbed zone.
- — Ghat locations.
- — Down stream of major bathing and burning ghats.
- — Down stream of outfalls and in recovery zone.

At each station cross-sectional and depth of the river need to be examined and sampling points are to be selected according to the local condition.

Sampling Frequency: It depends on:

- — Examining seasonal variation.
- — Flow of river.
- — Professional judgement.
- — Variability of data.
- — Cost constraint.

Water Quality Parameters: The selection of various physical, chemical and biological parameters should be so made that the objectives of the monitoring network are satisfied and their analyses reveal a correct interpretation of water quality.

Recording and Processing of Data: Data collected should be critically evaluated simultaneously to make sure that the data conforms to the requirements of the study, especially in terms of :

a) Detection limits that should meet the study needs.

b) Correlation of various parameters amongst each other at given stations.

c) Net information content of the data from the points of its further meaningful utilization in quantitative studies.

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WATER QUALITY MONITORING AND MANAGEMENT METHODS FOR INDIAN RIVERS

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Introduction

In India, at present, the water quality monitoring and management is performed through physico-chemical evaluation only, which is not sufficient in many cases to justify the need and priority of various pollution control programmes to be implemented in the country. Under the Indo-Dutch collaboration on Environment possibility of introducing biomonitoring methodology in Indian water quality evaluation and management through a three years pilot study was accepted by the Indian and Dutch Governments in 1988. Since the Central Pollution Control Board (CPCB, a central level pollution control authority in India) is responsible for providing national standards according to which water quality management should be performed by the State Pollution Control Boards (SPCBs, state level authorities), it was thought appropriate that the CPCB should perform the pilot study. Yamuna River was selected for this study as it is representative of many rivers in India and is nearer to CPCB's Laboratory. Also the CPCB is monitoring its water quality for the last 15 years. The study was started in October, 1988. With monthly intervals a large variety of biological and chemical parameters were observed at 15 stations along the river from upstream Delhi to downstream Etawah. The main objective for this study was to formulate and test technical and strategic methods which can be acceptable in scientific and legislative framework for water quality evaluation. The outcome of the study was generally applicable yardstick for indication of actual water quality and can be used in water quality management programme in the country.

The Yardstick

The proposed yardstick consists of an "AMOEBA" (A Method of Ecological and Biological Assessment) presentation of 8 different indices:

Pollution Indices:

- Bacterial Pollution Index (BPI)
- The Nutrient Pollution Index (NPI)
- The Organic Pollution Index (OPI)
- The Industrial Pollution Index (IPI)
- The Pesticide Pollution Index (PPI)

Effect Indices:

- The Benthic Saprobity Index (BSI)
- The Biological Diversity Index (BDI)
- The Production Respiration Index (PRI)

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Each of these indices are derived from a set of one or more monitoring parameters which may vary according to regional requirements.

Table 1
Minimum set of parameters included in different indices

Pollution Load Indices					Effects Indices		
Domestic Pollution			Industrial Pollution		Structural Effects		Function Effects
BPI	NPI	OPI	IPI*	PPI*	BSI	BDI	PRI
Thermo-tolerant Bacteria	Ammonia	Temperature	Heavy Metals	Organo-chlorine pesticides CP	BMWP Score	Sequential Comparison Index	P/R Ratio
-	Total Kjeldahl Nitrogen	BOD	Oil & Grease	Organo-phosphorus pesticides PP	-	-	-
-	Nitrites + Nitrates	COD	PAH	Organotin pesticides	-	-	-
-	Total Phosphates	Dissolved oxygen	Phenol	Carbonates	-	-	-
-	Ortho-Phosphates	Ammonia	Cyanides	etc.	-	-	-
-	pH	-	PCB	etc.	-	-	-
-	Chlorophyll	-	etc.	etc.	-	-	-
-	Conductivity	-	etc.	etc.	-	-	-
-	Turbidity	-	etc.	etc.	-	-	-

* *The parameter should be selected on the basis of local importance.*

The relationship between anthropogenic activities, their by-products and corresponding strain and stress indicators are visualized in the Figure 1 (on following page).

Index Calculation

The Concentration Based Indices: From the observed values of the parameters included in Table 1 corresponding indices can be calculated as follows:

Bacterial Pollution Index: The number of Thermo-tolerant bacteria is monthly evaluated according to the MPN or membrane filtration technique. The number counted are transformed to a quality index on a scale of 0 to 100 by comparison with a preset quality function where 100 represents perfect conditions and 0 stands for totally unacceptable conditions. The suggested quality function is based on the primary water quality criteria adopted by the Central Pollution Control Board, Delhi, India for "Designated Best Use" under bathing water quality, as the outdoor bathing is one of the most important use of

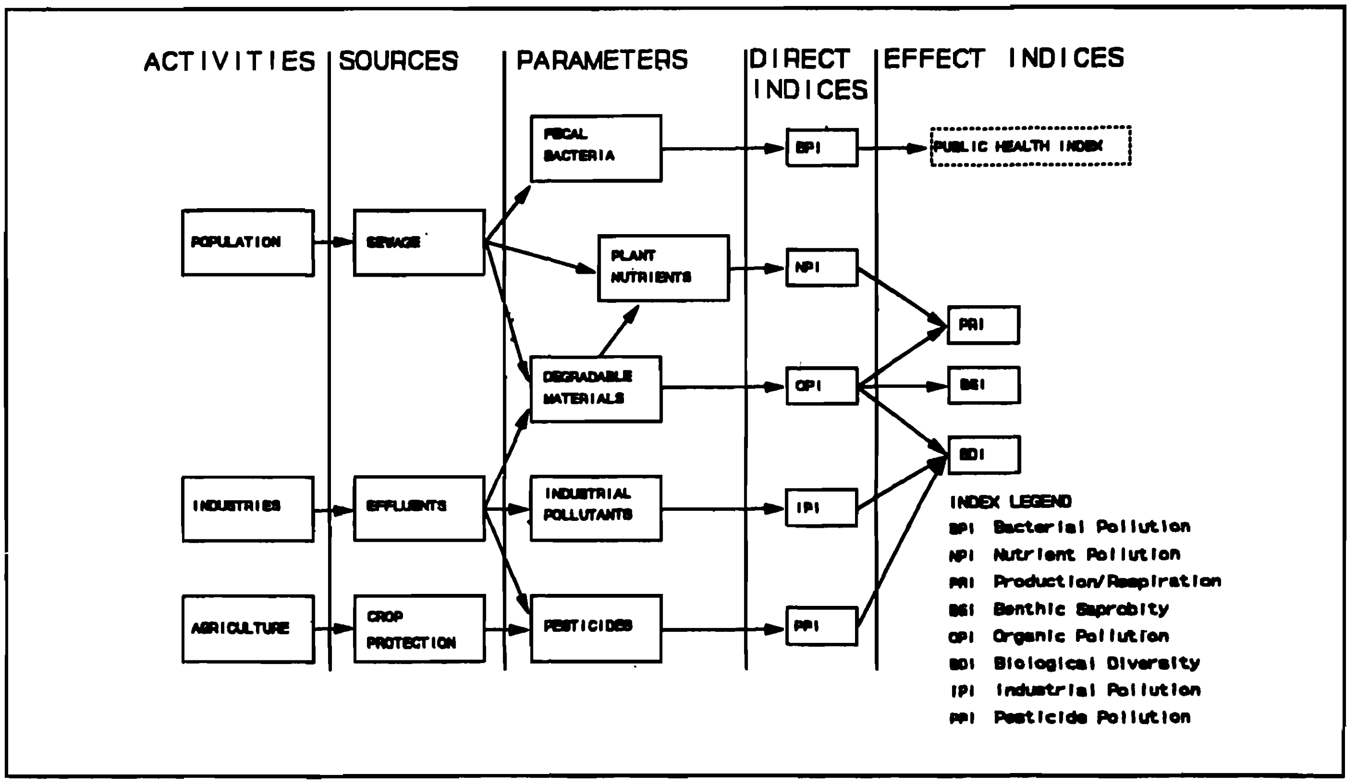

Fig. 1. Cause and effect chain.

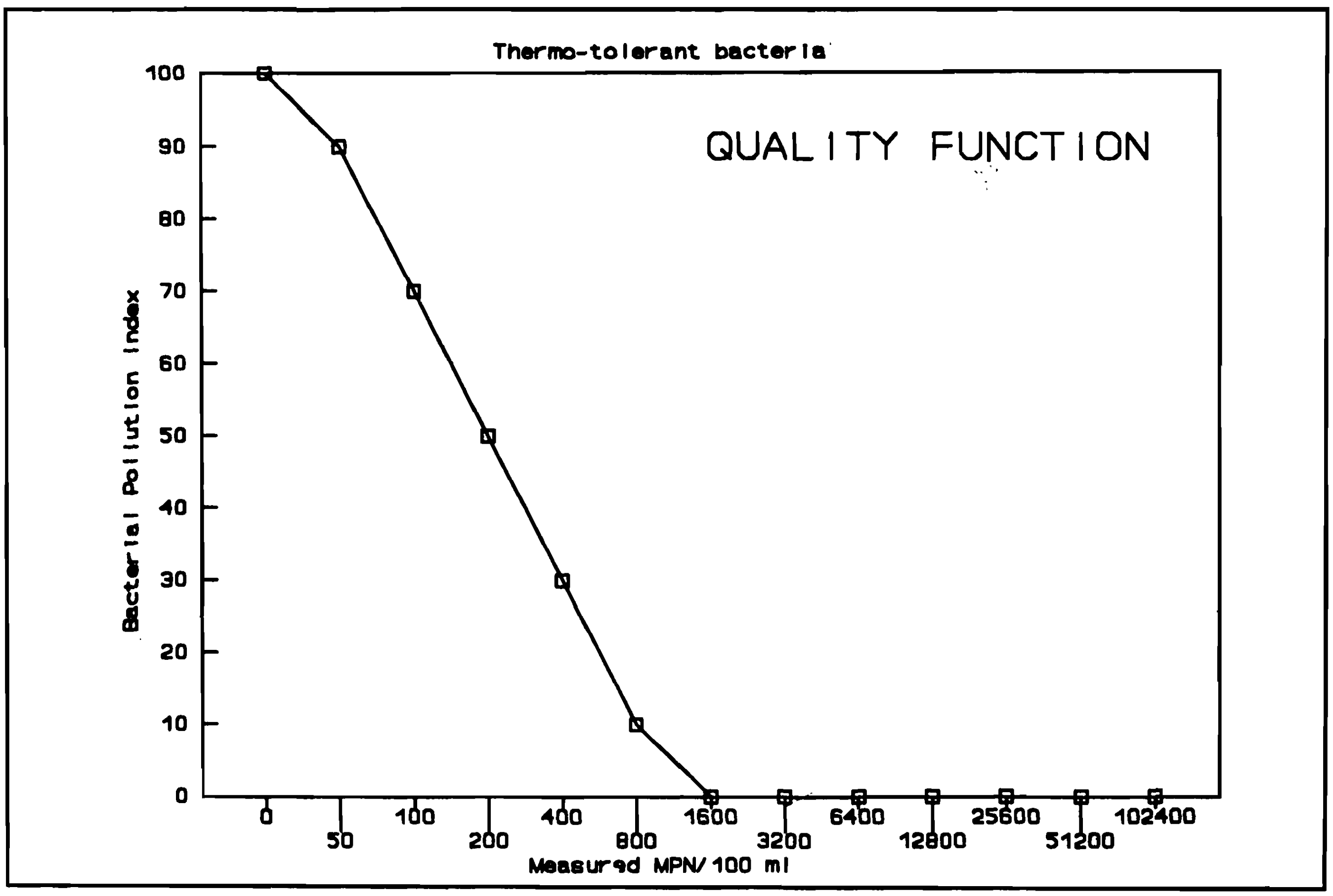

Fig.2. Suggested quality curve for bacterial pollution.

rivers in India. It is suggested to take a Bacterial Pollution Index value of 90 as the target value in the yardstick "AMOEBA"

The suggested quality function is presented in Figure 2 (on previous page).

Nutrient Pollution Index, Organic Pollution Index, Industrial Pollution Index And Pesticide Pollution Index: These indices can be calculated by integrating the corresponding parameters using the following formula:

$$PI = e^{\sum Ln\,(PQI)_n \times Wn}$$

Where:

- PI = NPI or OPI or IPI or PPI
- PQI_n is the quality index for the nth parameters, a dimensionless number between 0 to 100 standing for very poor and excellent quality with respect to the parameter under consideration. These quality indices can be derived from target values and dose-response curve available in the literature or can be constructed by conducting such studies. Suggested curves for the parameters included in the yardstick are presented in Figures 3-6 (on following pages).
- Wn, is the weightage factor for the nth parameter, which is adopted equal for all, for the time being and can be changed in due course based on gathered knowledge on the relative importance of the parameters. In case of missing values, Wn should be calculated according to remaining parameters.

In IPI and PPI, the parameters are to be locally or regionally selected, on the basis of industrial and/or contaminant survey. Hence the Table 1 does not specify the complete set of parameters.

Effect-Based Indices

Benthic Saprobity Index: The BSI can be evaluated according to the method prescribed by the Biological Monitoring Working Party (BMWP), (UK-NWC, 1981). The site score so derived is averaged, which will be in the range of 0 to 10. This score is then transformed into the BSI by multiplying it with a factor of 10 to produce a scale from 0 to 100.

Biological Diversity Index: The BDI is evaluated for the same period for which BSI is evaluated. The BDI is based on Sequential Comparison Index (SCI) methodology (Cairns, et al. 1968). Since the methodology involves a pair-wise comparison of sequentially encountered individuals, no taxonomic skill is required.

The diversity index so obtained has a value between 0 and 1 and can be transformed into the BDI by multiplying with a factor or 100.

Production Respiration Index : The river production - respiration measured according to the method developed by Odum (1957) which is recently adopted by the Standard Methods, (APHA 1986). The method involves 24-hour measurement of dissolved oxygen changes, which can be transformed into photosynthesis and respiration (APHA 1986).

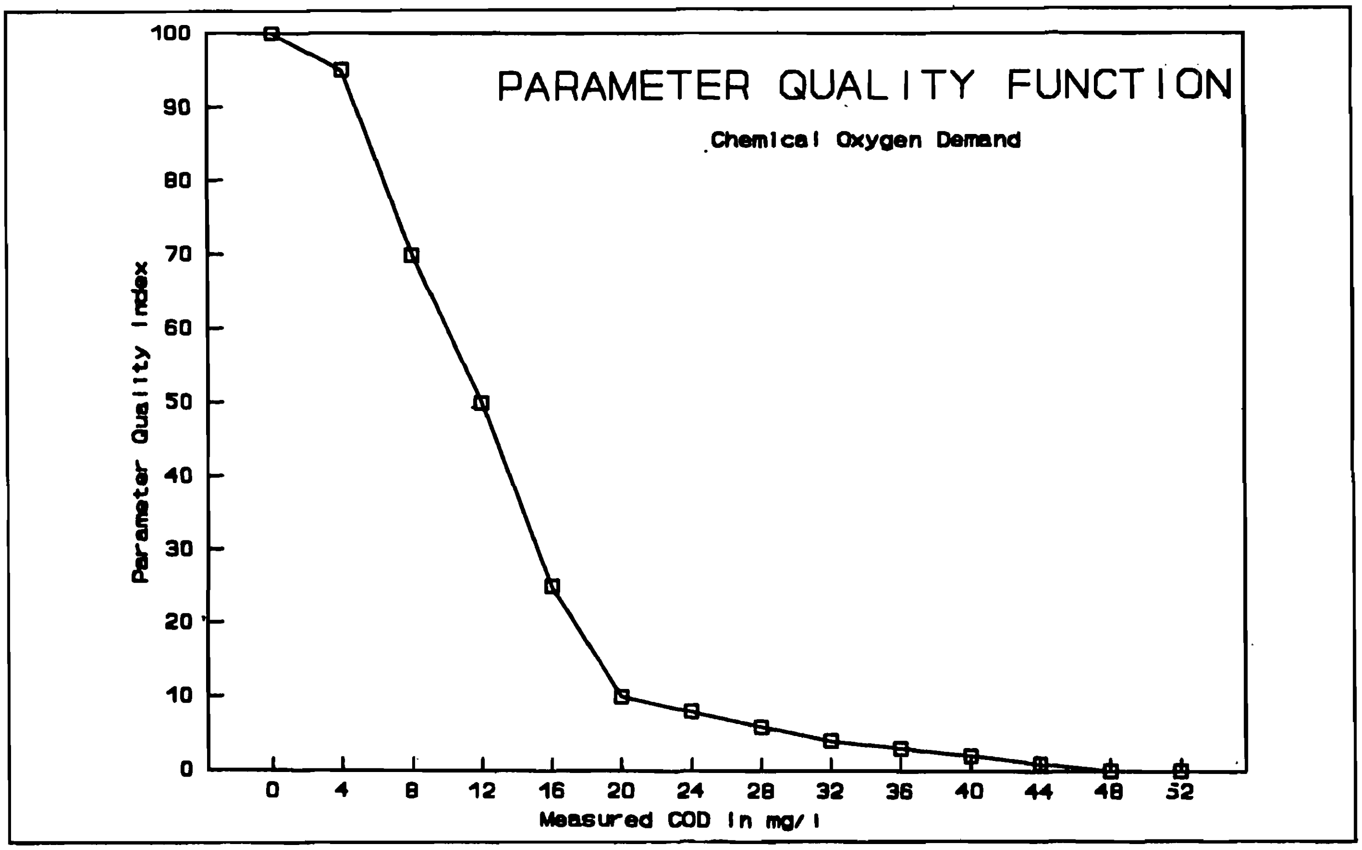

Fig. 3. Quality function suggested for individual parameters.

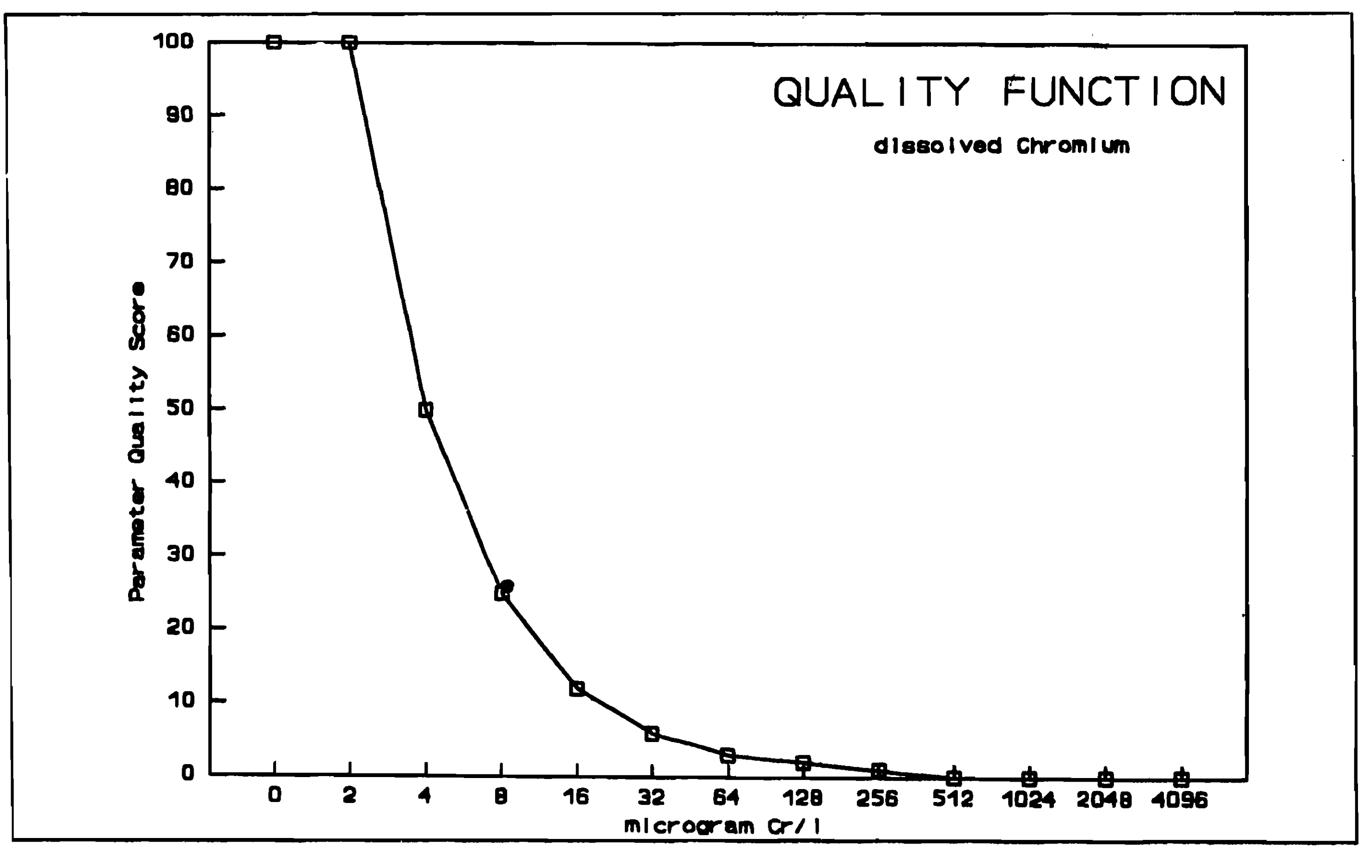

Fig. 4. Quality function suggested for individual parameters.

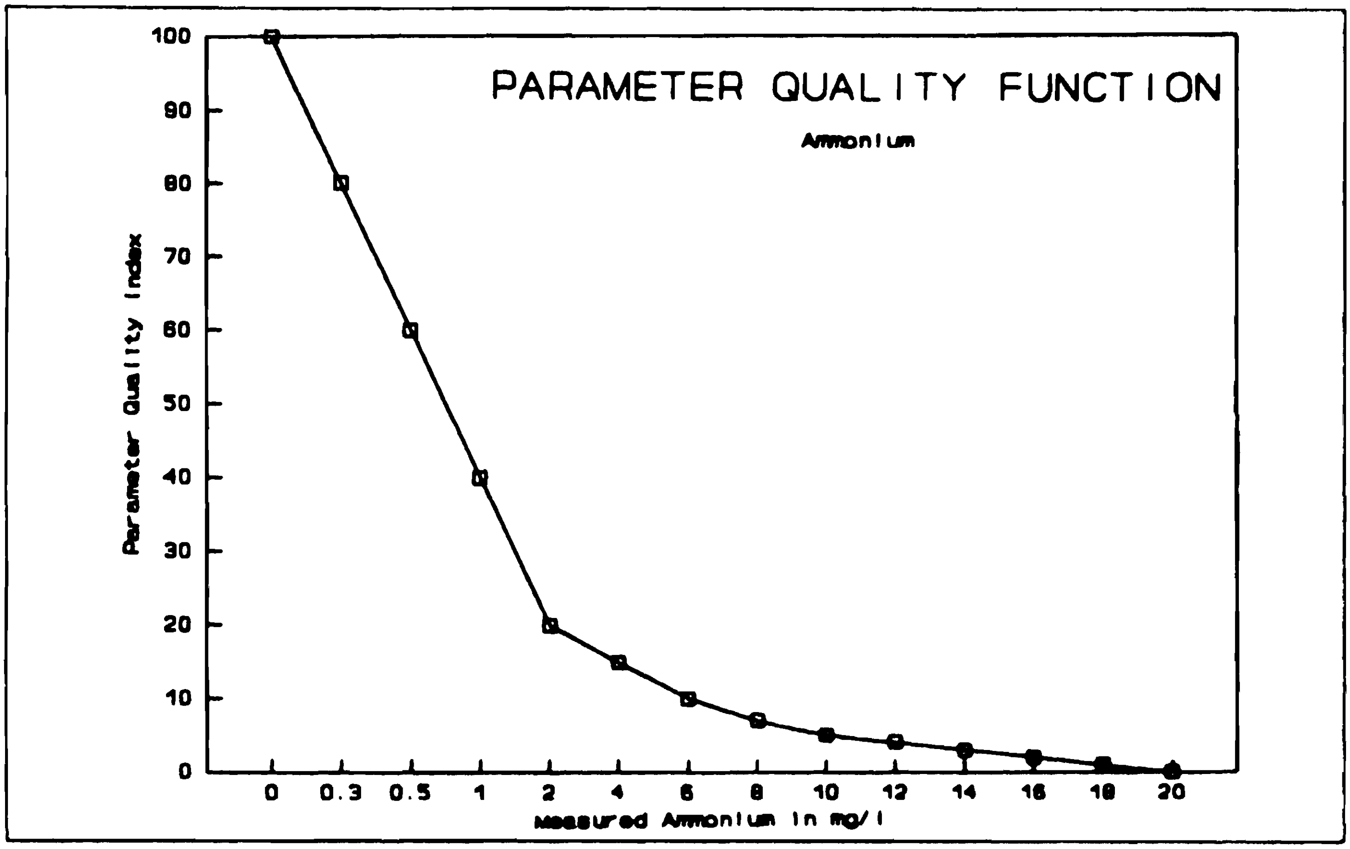

Fig. 5. Quality function suggested for individual parameters.

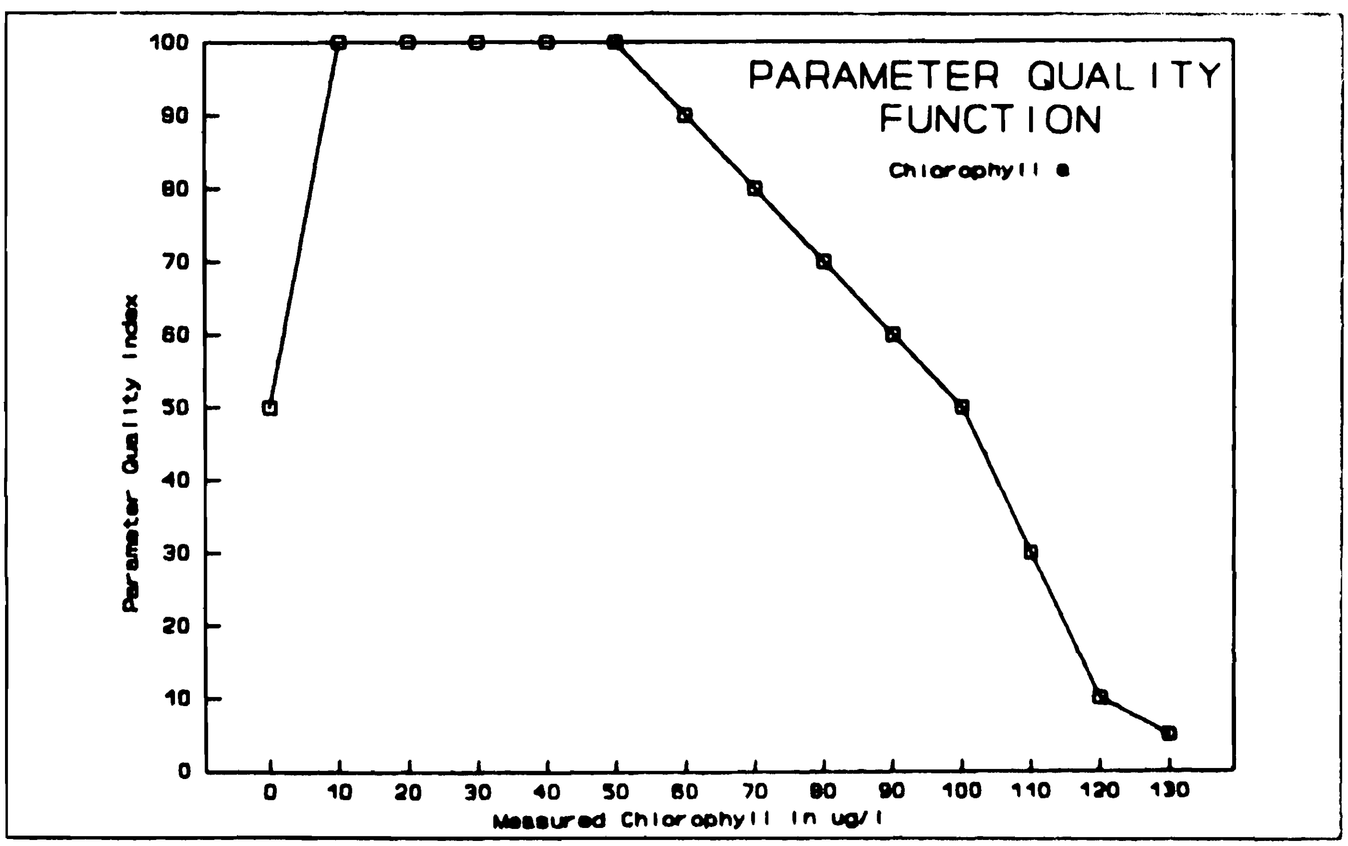

Fig. 6. Quality function suggested for individual parameters.

The P/R ratio ranging from near 0 under extreme saprobic conditions to 3-4 under extreme eutrophic conditions. A P/R ratio of 1 implies a balanced ecosystem. The P/R ratio can be converted into the PRI by comparing with the quality function curve. A suggested quality function curve is given in Figure 7, with optimum (targeted) quality at centre and 0 on extreme left side and 4 on extreme right side.

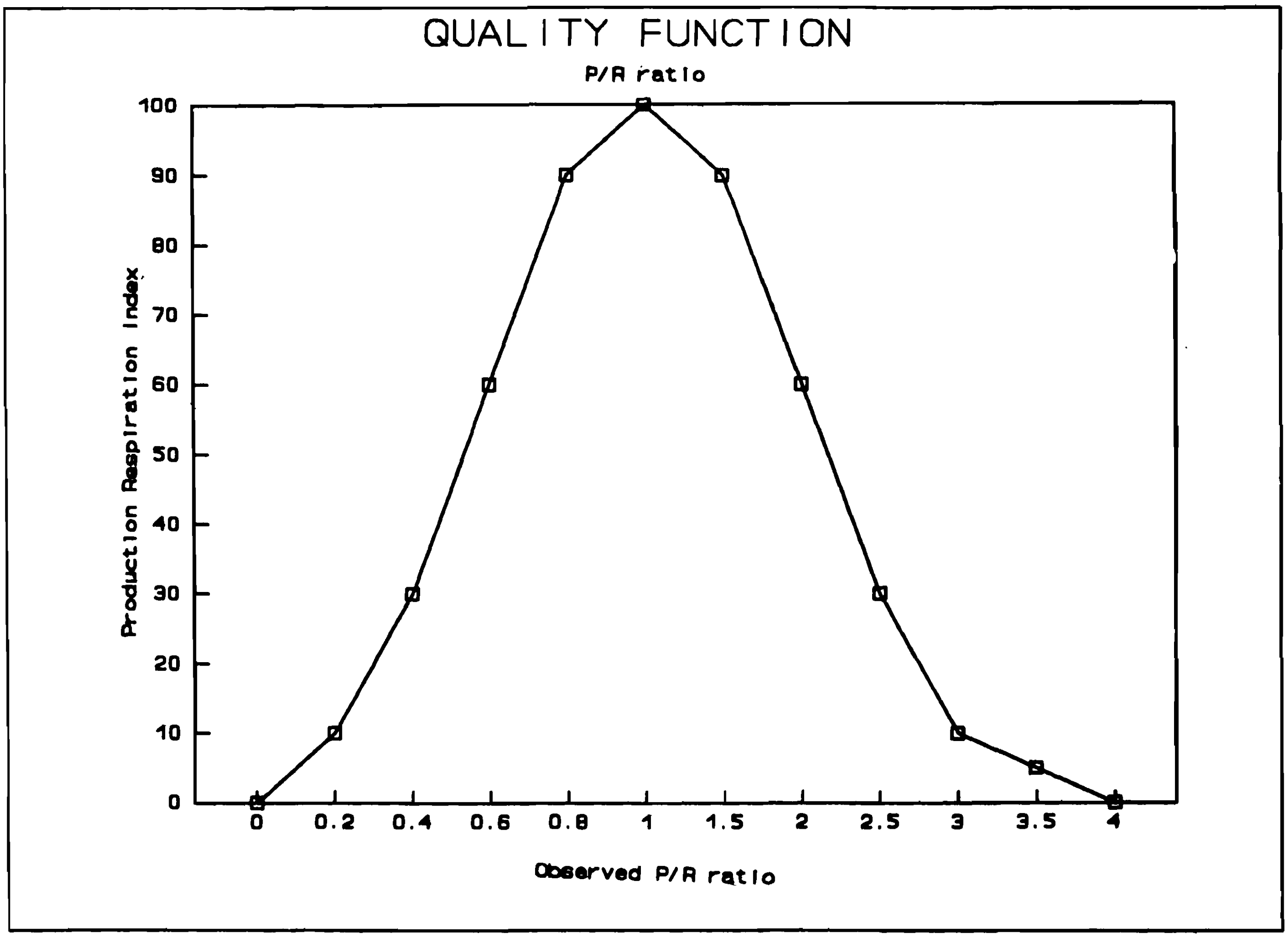

Fig. 7. Suggested quality function curve for P/R ratio.

Amoeba Presentation

All the eight individual indices as explained earlier are expressed on a scale from 0 to 100, where 0 indicates the worst imaginable condition and 100 stands for a totally natural environment. The target level does not necessarily be 100 since compromise between development and environmental protection leads to the acceptance of some degree of deterioration. For each index a different target value may be selected, depending on local conditions. The targeted values of each individual indices is rescaled so as to fall on a circle, "AMOEBA" (Ten Brink et al 1991). Thus one can immediately see which index is falling short of or exceeding the target as demonstrated in Figure 8.

The sector size can also vary according to the weightage of the corresponding index, and may depend on the local regional or national values and views. For the time being the weightage of the indices are kept equal.

Field of Application in Water Pollution Control

Rational formulation of any pollution control program for a water body needs to define water quality objective (target) for that water body in a sound scientific manner. These objectives are used as yardstick to identify the areas in need of restoration, extent of pollution control needed, prioritization of pollution control programme and effectiveness of pollution control efforts.

In case the respective indices are falling short of the index target value, the following actions can be taken:

Using the Yamuna River's 3 years data on the water quality the indices are calculated and presented in the "AMOEBA" form in Figure 9 (on following page). The suggested target values for NPI, OPI, IPI, PPI, BSI, BDI, and PRI are 90, 80, 60, 80, 80, 70, 70, and 80 respectively. These targets are suggested based on various water quality objectives identified by the CPCB under its various pollution control programmes. An example of how the proposed yardstick can be applied in the field of pollution control is given in Table 2 (on page 93).

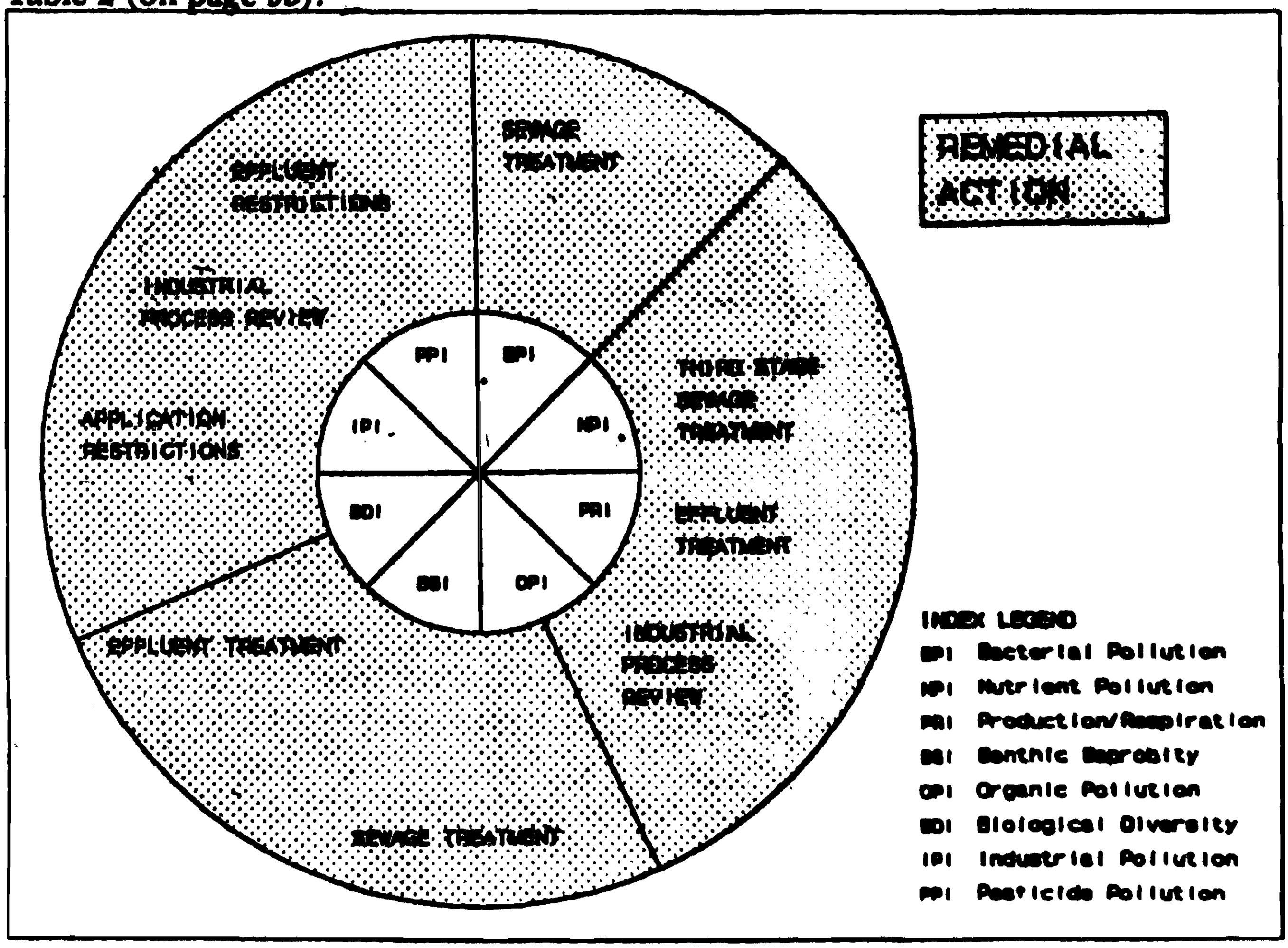

Fig. 8. Remedial measures for various types of pollution.

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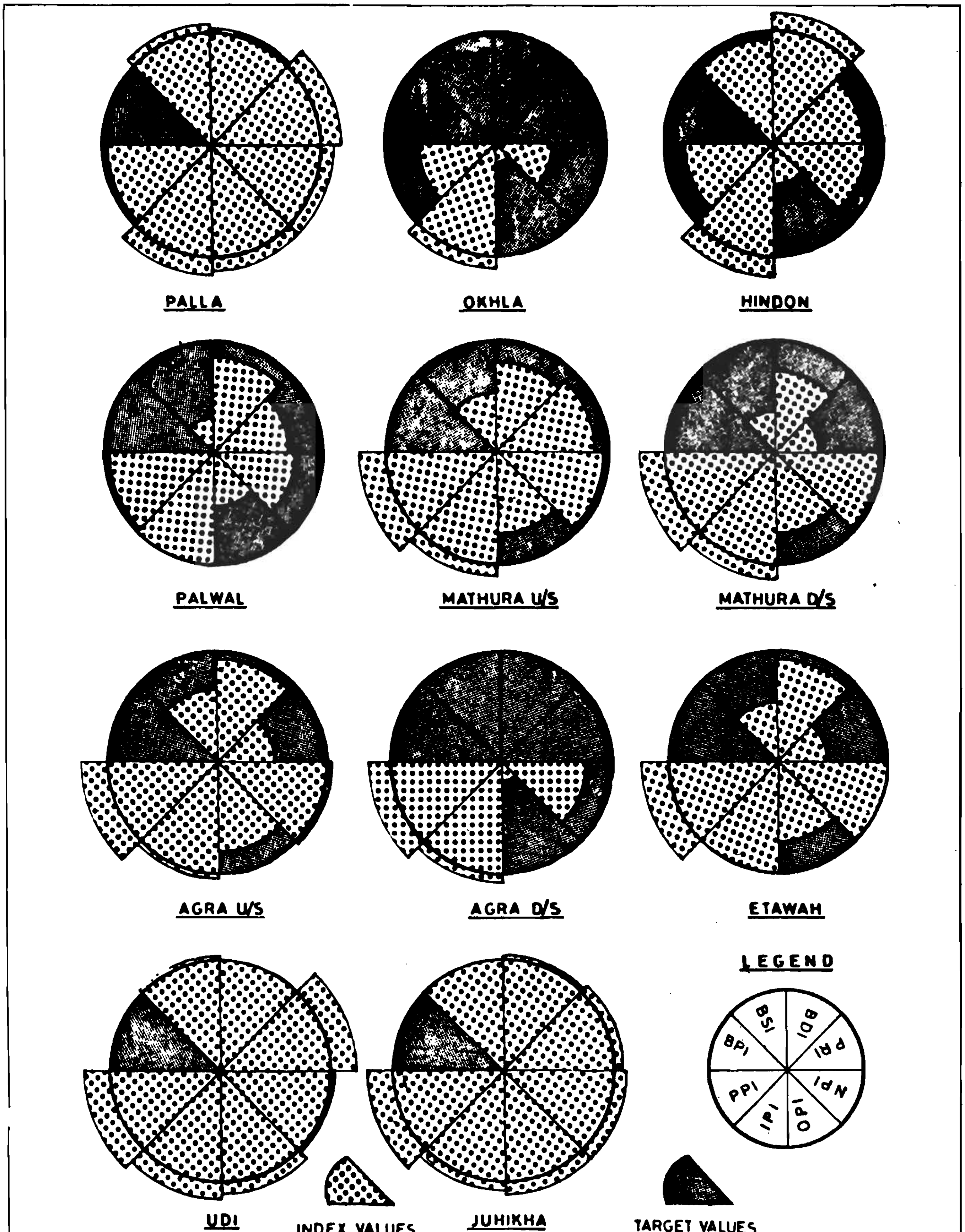

Fig. 9. Amoeba presentation of Water Quality of River Yamuna

Table 2

Example of Application of Yardstick in Pollution Control			
Stretch	**Value not fulfilling the target**	**Major cause for degradation**	**Action Required**
Palla to Wazirabad	BPI	Faecal coliform	Control of sewage from drain no.8 in Haryana
Hindon from Ghaziabad to confluence with Yamuna	BPI, BSI PRI, NPI, OPI, PPI	Sewage and industrial wastes	Control of sewage and industrial wastes from Ghaziabad
Wazirabad Barrage to Okhla Barrage	BPI, NPI, OPI, PRI, BSI, and BDI	Sewage and industrial wastes	Control of sewage and industrial wastes from Delhi
Okhla Barrage to Chambal Confluence	BPI, NPI, OPI, PRI, BSI, and BDI	Sewage and industrial wastes	Control of Shahadara Drain and Mathura-Agra drains
In the city limits of Mathura, Agra and downstream of Delhi (20-30 km stretches)	BPI, NPI, PRI, OPI, BSI, BDI	Sewage and industrial wastes	Control of Shahadara and Mathura-Agra sewage inflows

This yardstick so developed is validated in other river systems of India during the year 1992-93. A detailed manual prescribing the complete methodology for the evaluation of the yardstick is prepared and is being published. Now the yardstick is proposed to be introduced in the legislative framework of pollution control in India.

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FRESHWATER ECO-SYSTEM WITH SPECIAL REFERENCE TO FISHERIES

AJOY KUMAR GHOSH[1] AND KUMUDRANJAN NASKAR[2]

Introduction

Ecosystem is a vast term, which signifies the intimate relationship and coexistence between the living and non-living components along with the natural consequence (Ashby, 1973). No individual organism can survive without interfering the surrounding biotic and abiotic factors. A balance ecosystem is a functional one, self-sufficient and self-regulated (Ambasht, 1970). The primary consumers only depend on this primarily produced organisms on the one hand and simultaneously, provide food and shelter for the secondary, tertiary, quaternary and top consumers (Naskar, 1990). This is the normal route of ecological chain or rather food-chain.

Depending on the nature and surrounding natural consequence, these overall eco-systems can be grouped in several minor ecosystems like grass-land ecosystem crop-land ecosystem forest ecosystem, desert ecosystem freshwater ecosystem, brackish water eco-system mangrove ecosystem and marine ecosystem etc. (Naskar, 1993).

In a freshwater pond the first life initiated as microscopic algae. These algal forms may be unicellular or multi-cellular and would convert the solar energy in the form of chemical energy through photosynthesis or chemosynthesis (Naskar, 1990). By trapping these solar energy, this micro flora provides food and energy to zooplankters and other animalcules. Then macro flora and macro fauna came into existence one after another. Fishes, frogs, snakes and other aquatic lives depend solely on each other in this closed aquatic ecosystem and then directly provide foods for the top consumers, like human beings, eagles and other carnivores (Naskar, 1990). All these biological stepping are also dependent or correlated with the availability of both organic and inorganic sources of carbon, nitrogen, sulphur, phosphorus and other minerals. Therefore, the ideal ecosystem only can maintain the productivity of that environment, which is also essential for the human beings as they get benefit from them (Sharma, 1995). The natural tendency of any particular ecosystem is to resist the chains and remain in a state of equilibrium (Oostina, 1956). The science of cybernetics is largely depend on the feed back system and has its application in understanding homeostasis (Oostina, 1956). The control of these ecological factors in any stage by artificial means may damage the equilibrium abruptly and affect the human life (Naskar, 1990).

Fisheries Potentialities

The fisheries potentialities in the different inland ecosystems can be grouped under i) Riverine fisheries, ii) Lake and Reservoir fisheries, iii) Pond culture (human manipulated) and iv) Wetland fisheries etc. (Jhingran, 1986).

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Most of the inland water bodies are captive ecosystems, leaving room for intensive human intervention in the biological production processes and thereby holding enormous potential for manifold increase in fish output. In fact, inland fish production in the country registered a phenomenal increase during the last four decades (Jhingran, 1986). But, due to ever increasing population pressure and indiscriminate pollutant discharge in these open water system *viz.*, over exploitation, pollutant from paper industries, breweries factories, tanneries, oil-refineries, thermal power stations and mining etc. must affect very adversely on the inland fish production. These pollutant also affect fish growth, natural breeding, migration and alarming the environmental condition also threatened the indigenous fish population (Jhingran, 1989).

Fish yield potential of water bodies varies according to the basic productivity of the ecosystems, the efficacy of energy flow in different-tropic levels and the degree of human intervention in monitoring the biotic communities (Ambasht & Ram, 1976). All these above factors are closely associated with the environmental variables. The major inland fisheries resources comprise (a) the capture fisheries of river, canals, lakes and the estuaries and (b) the capture fisheries in ponds, tanks, hills and small reservoirs where the management strategy comprises a combination of both capture and culture fisheries (Jhingran, 1982).

Riverine Capture Fisheries

The different river systems of the country having a combine length of 29,000 km provided the means of livelihood to the fisheries communities (Jhingran, 1989). Since time immemorial these rivers still contribute lion's share of the total inland fish production in the country. They bear one of the rich fish genetic resources in the world, comprising Indian major carps, minor carps, catfishes, prawns and an array of anadromous fishes and prawns (Jhingran, 1983).

The Ganga river system with its main tributaries like Yamuna, Ganga, Ramganga, Ghagra, Gomati, Kosi, Gandak, Chambal, Sone, etc. have a combined length of 12,000 km and the Brahmaputra 4023 km (Jhingran, 1989). The peninsular rivers like Mahanadi, Godavari, Krishna and Cauvery have length of 6437 km. River Narmada and Tapti and the West-flowing drainage of Western Ghats have a combined length of 3380 km. The Ganga river system is the original habitat of the three major fish species of the sub-continent viz., Catla, Rohu and Mrigal, better known as the Indian major carps. Major part of the river Ganga and its tributaries pass through the plains and this river system continues to be the most important from the point of view of the fisheries (Table 1).

The Ganga is also the major source for riverine spawn which still meets requirements of fish seed to the extent of 30% (Jhingran, 1983).

Data presented in following table compares the water quality of the Ganga during the Sixties to that of 87-88.

Table 1

Water Quality in the River Ganga Over The Years (According to Jhingran, 1989)

Year	DO mgl^{-1}	pH mgl^{-1}	CO_2 mgl^{-1}	TA mgl^{-1}	SC µmhos	TDSm gl^{-1}	CHLmg l^{-1}	PHOmgl^{-1}	NITmg l^{-1}	SILmg l^{-1}
Kanpur										
1960	7.8	7.9	2.2	148.5	328	170	10.0	0.14	0.14	11.3
87-88	2.7	7.2	8.2	195.9	565	278	15.0	0.15	0.16	21.8
Allahabad										
1960	8.4	8.1	1.5	142.0	285	148	12.1	0.15	0:17	11.9
1974	7.6	8.0	2.4	167.5	375	188	7.43	0.13	0.18	14.8
87-88	8.0	8.12	0.68	171.0	398	198	19.0	0.18	0.22	18.1
Varanasi										
1960	7.0	8.0	3.1	127.5	257	130	21.0	0.04	0.10	8.3
87-88	7.6	8.1	0.6	178.6	436	216	25.0	0.22	0.17	12.8
Patna										
1960	7.0	7.9	5.0	141.7	300	148	10.7	0.10	0.14	10.2
87-88	7.8	7.9	2.0	139.6	283	138	20.2	0.21	0.20	25.2
Bhagalpur										
1960	6.9	8.2	2.3	131.4	268	134	11.2	0.09	0.14	9.3
87-88	7.2	8.1	2.5	142.2	310	158	28.3	0.12	0.18	13.5
Estuary Zone-I										
75-77	7.4	8.2		124.1	286	151	14.1 (.03)	0.10	0.07	10.0
1987	7.7	8.3		113.3	339	175	12.9 (0.02)	0.196	0.04	12.1
Estuary Zone-II										
53-54	5.6	8.2		166.0			60 (0.11)		0.09	9.8
75-78	6.8	8.2		123.0	939	390	138.7 (0.25)	0.11	0.05	12.1
82-87	6.4	8.3		115.0	947	500	162.2 (0.29)	0.28		
Estuary Zone-III										
53-54	3 .4-5.1	7.9-8.4		102-357			0.2-12	0.07-0.140.1	0.03-0.1	2.7-9.1
75-78	7.8	8.4		105.3	25301	10545	8270 (14.9)	2	10.09	2.8
82-87	6.8	8.3		101.6	21596	10830	8986 (16.2)	0.13	0.02	6.2

DO: dissolved oxygen — TA: total alkalinity
SC: specific conductivity — TDS: total dissolved solids
CHL: chlorides — PHO: phosphates
NIT: nitrates — SIL: silicates

(values in parentheses indicate salinity in ppt)

Reservoir Fisheries

A large number of artificial impoundents have been created in different river basin of the country for irrigation, power generation, flood control and other water resource development projects. According to one estimate, 3 million hectares areas were man-made lakes in the early seventies and these areas were estimated to double by the turn of the century. Recently, the IIM has identified 975 major reservoirs in the country in a size ranges between 1,000 to 10,000 ha, under a total water speed of 1.7 million ha (Jhingran, 1989).

The fish yield from the reservoir is very poor. At the present level of management, they yield 14.5 kg/ha, whereas a production of 50 kg/ha can easily be realized from large and medium reservoir. The small reservoirs have the potential to yield more than 100 kg/ha (Jhingran, 1986).

Reservoirs being a unique man made ecosystem, its fisheries management is of a complex nature. In many cases, the poor yield is a result of inadequate understanding of the ecosystem. Each class of the reservoir depends a well evolved package of practices, depending on the morphometric, hydrographic and biological characteristics of the reservoir.

CIFRI has evolved separate packages for small, as well as medium and large reservoirs. Small reservoirs management is very much akin to culture fisheries. Proper stocking and harvesting schedules, selection of right species for stocking and employing the appropriate gears are the keys to the successful management of such water bodies. A production level up to 100 kg/ha/yr. has been demonstrated in small reservoirs (Jhingran, 1986).

The medium and large reservoirs are predominantly capture systems and the management norms centre round the principal of stock manipulation. This is done by adjusting the fishing efforts, observance of closed sessions and gear selectivity. Selective stocking is resorted to for correcting the imbalances in species spectrum and to fulfill the ecological gaps created due to unshared food niches. CIFRI has demonstrated that a three-pronged strategy comprising enlargement of mesh size, increased fishing effort and stocking support, paid rich dividends in Bhavanisagar and Gobindasagar reservoirs, where the fish production increased from 90t to 300t and 200t to 1000t respectively (Jhingran, 1986).

Development of infrastructure facilities for raising adequate stocking material, ice plants, quick transport facilities by road and water, tenurial security and remunerative prices to fishermen are *sin qua non* for reservoir fisheries development (Jhingran, 1986). Since ownership of reservoirs vests in the state, it is the duty of the Government to develop these facilities. The cooperative societies should be encouraged in order to eliminate the middlemen and private money lenders, who exploit the fishermen.

By adopting the available package of practices, developing the necessary infrastructure facilities and providing a conductive socio-economic environment, it is possible to achieve a production level of at least 1.61 lakh t from the reservoirs during the 8th plan period, *i.e.*, 1.4 lakh to more than the present yield. Taking the increase in reservoir area into consideration, a production of 3.22 lakh t is possible by the turn of the century (Jhingran, 1986).

Pond Culture

The country has 7.53 lakh ha of ponds and tanks that can be used for freshwater aqua culture, though only 1.50 lakh ha are being utilized at present (Jhingran, 1989). The remaining 6 lakh hectares either remain fallow or produce fish at the subsistence level. The yield from the pond culture is at a miserably low level of 50-500 kg/ha though the present level of technology assures a higher production level ranging from 3-10 t of fish from one ha pond area. Constraints like non-availability of crucial inputs such as fish seed, feed material and chemical fertilizers often retard the productivity. Further, inadequate infrastructural and policy support in respect of market regulation, liberalized fundings and suitable tenancy legislation have slowed the rate of progress (Jhingran, 1989).

CIFRI has evolved a carp culture technology as early as in sixties, employing a six species combination based on the principle of optimum utilization of trophic niches in the pond (Jhingran, 1983). The technology has since been tested successfully in different geoclimatic regions of the country. The technology comprises, pond preparation, stocking with three Indian and three exotic species of carps, pond fertilization, intensive feeding and proper fish health protection. A production of 10 t/ha has been demonstrated in different regions of the country. However, the technology gives room for modifications depending upon the local emergent situations faced by the farmers (Jhingran, 1983).

The technology is not uniformly rigid with regard to application rates of material inputs. It may give corresponding results at different level of input. Even under the low input package, wherein only organic fertilizers are used, a minimum production rate of 3 t/ha is ensured. Any technology in its adoption seeks its own level keeping in view the economic resource level of users and availability of monetized and non-monetized inputs at a particular point of time.

There is an urgent need to bring the remaining 6 lakh ha under aquaculture and to extend the scientific culture practices to more and more of the water bodies presently under culture. At present 45,000 ha areas are under the FFDA. It has been proposed to bring an additional 3 lakh ha under new FFDAs proposed during the 8th Five Year Plan. By raising the productivity of the ponds to the tune of 1500 to 3000 kg/ha, an additional 1.2 lakh ton of fish can be raised from the 1.5 lakh ha presently under stocking. It is possible to bring all the 6 lakh ha of ponds under aquaculture by 2000 AD and at a production rate of about 2 t per ha, these ponds can yield 12 lakh t of fish by the turn of the century. Concerted efforts by the development, extension and financing agencies are required to meet this target.

Fish Seed Production

Quality fish seed is the most crucial input in the aquaculture enterprise and its timely availability is an essential prelude to any ambitious aquaculture development project. Though CIFRI had developed induced breeding techniques through hypophysation as early as 1957, it took two decades before the practice made any impact on the country's seed production. The riverine seed still constitutes 30% crore fish seed used in the country during 1984-85. The breeding and seed raising technology developed by CIFRI ensures a survival rate of 60-70% in nursery phase and 80% in rearing phase. Success has also been achieved in recent years to innovate the seed raising technology through the use of synthetic analogs of LHRH and HCG for induced maturation and spawning, by breeding carps during the off season months and by high density rearing. However, the existing technology is sound enough in taking care of the carp seed requirement of the country. The revised 6th Plan target of 1200 crore of fingerlings was achieved through massive developmental and extension programmes by the agencies like FFDA, National Fish Seed Programme and the World Bank Programme. Entry of private entrepreneurs in fish seed production will be a long way in bridging the gap between requirement and availability of fish seed. Banks and other financing agencies have a vital role to play in providing necessary incentives to such entrepreneurs.

Other Aquaculture Practices

Though carps account for most of the freshwater fish produced in the country, there are many other areas where the technologies are readily available for adoption. For example the giant freshwater prawn which attracts a lucrative overseas market can be grown in ponds ensuring a production rate of 700 kg/ha. The availability of seed was the main constraint that retarded the popularization of this culture practices (Ghosh, 1995). This constraint has now been overcome as Central Inland Capture Fisheries Research Institute has developed a technology for hatchery management of the prized freshwater prawn, *M. Rosenburgii* (Ghosh, *et al.* 1986)

Pond fertilizers and fish feed are the main components of input costs in aquaculture. By integrating fish culture with livestock farming, it has been found that a sizable fish crop can be harvested while fertilizing the ponds with the animal wastes, like duck dropping and pig dung. This practice of integrated fish-cum-livestock farming conforms to the maxim of recycling the organic wastes. CIFRI has developed a fish-cum-duck rearing technology with a production potential of 1480 kg fish, 200 kg of duck meat and 6334 eggs from 0.4 ha (1 acre) farm. Similarly, in fish-cum-pig farming, 2400 kg of fish and 1980 kg of pig meat can be produced from a 0.4 ha farm. Under the integrated rice-cum-fish farming system, paddy fields and a crop of fish is harvested along with the kharif crop of paddy. Under this system, 5500 kg of paddy and 700 kg of fish are obtained (Ghosh & Datta,1986).

Technologies are also available for fish culture in water bodies treated with sewage effluents. Sewage acts as a pond fertilizer and substantially brings down the operational coast. Under a six species combination of Indian and exotic carps, a fish production of 7200 kg/ha is possible, ensuring high return on capital costs (Ghosh, *et al.* 1986). At present only 12000 ha are utilized for sewage-fed fish culture, whereas vast tracts of suburban wetlands adjoining the cities and towns of the country can be utilized for the system. Integrated aquaculture is highly location-specific and restricted to certain pockets. For example, the poultry-cum-fish farming has bright prospects in the North Eastern region where piggeries and duck farming are in vogue. Rice-cum-fish farming is limited to low-lying paddy plots where deep water varieties of paddy are cultivated. Similarly, sewage in an urban phenomenon and, naturally, sewage-fed fish culture is restricted to low-lying wetlands adjoining cities and towns.

Stress and Strain of Inland Fisheries

Effect of dams, barrages, weirs and other hydraulic structures on riverine ecosystem can be summarized as:

i) reduced discharge downstream,

ii) habitat destruction due to impoundment and

iii) obstruction of migratory pathways of fishes.

As the impacts of diminutive flow rates have already been dealt with the other two aspects are considered below:

Effect on Migration of Fishes

One of the direct effects of dams on fishes is obstruction of migratory pathways. Hilsa is classical example of anadromous fishes being affected due to obstruction of their migratory path in river Ganga. Freshwater eels and other catadromous fishes are known to undertake long migration into deep sea for breeding and their offspring, at the elver stage, ascend the river to return home. Barrages prevent adult eels to migrate to the sea for breeding and the elvers fail to negotiate the home ward route (Das, *et al.* 1980). Apart from these fishes, the freshwater prawn. *Macrobrachium rosenbergii* lives in the river and migrates down the estuaries for breeding. Dams and barrages threaten to obliterate these freshwater prawn populations due to constant recruitment failures.

Impact of Farakka Barrage

No other hydraulic structures erected by man across a river in India can perhaps be a better example then Farakka barrage to illustrate what a dam can do to the riverine environment and its fisheries. It also brings to sharp focus, the conflicts of interests in multiple use of riverine resources.

Before construction of the Farakka barrage in 1975, the tongue of the estuary used to extend 290 km into the river i.e., up to Nabadwip which has now been pushed down to Kuntighat-Medgachi area about 20 km downstream. The table given below depicts a sharp decline in salinity during the post-Farakka years in zones I and II due to extra discharge of freshwater.

Industrial Effluents

Survey of Central Pollution Control Board in 1981 showed that 317 major industrial units operated all along the banks of Ganga and its tributaries and only 30% of the units followed some control measures or other to contain the pollutional hazards. More often than not, mixed discharge of industrial and domestic effluents expressed in terms of BOD has been estimated at 1,166,240 ppm for Ganga basin with U.P. accounting for more than three fourth of the load, followed by West Bengal and Bihar (Ghosh, *et al.* 1992).

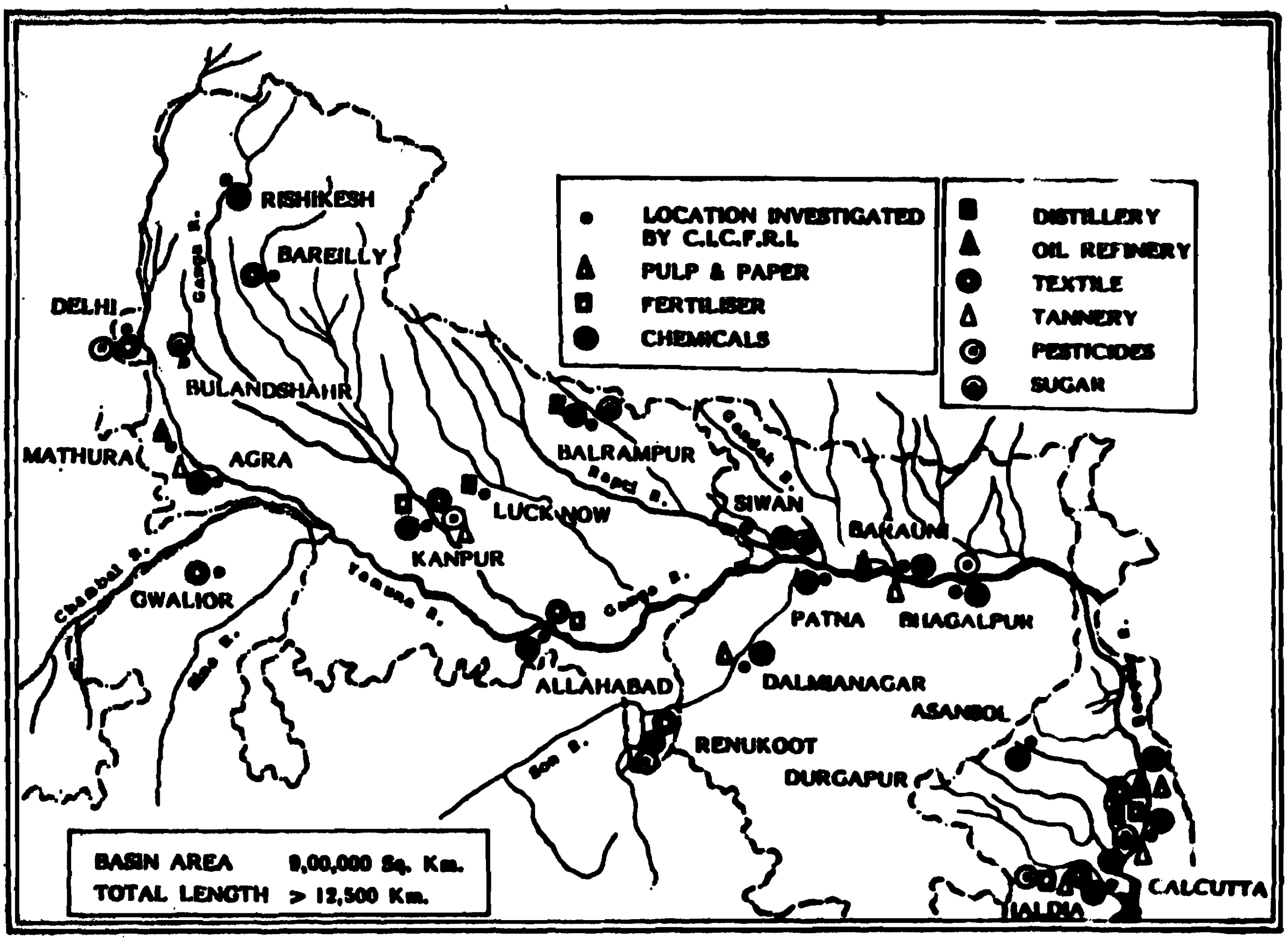

Fig. 1. Location of Industrial Establishments affecting the Fishery Resources of the Ganga River System (Source: Jhingran, 1989)

Location of some of the major industrial units along the river Ganga and its tributaries has been depicted in Fig.1. The mountainous stretch of the river above Rishikesh is almost free from industrial pollution and the upper plain is mildly polluted due to effluents received from antibiotic and heavy electrical factories at Rishikesh, tanneries, woolen units, textiles, jute mills at Kanpur and fertilizer plants at Allahabad. Contribution on industrial effluents to the pollution in main river at the non-tidal deltaic plain stretch is negligible. However, there is a burgeoning growth of industries along the lower estuary between Nabadwip and the bar mouth. The deltaic tidal stretch receives heavy discharge of industrial effluents to the tune of 430 mld from more than 96 factories such as pulp and paper, distillery, yeast, viscose rayon, cotton textiles, tannery, paints and varnishes, rubber and cycle rims, metal and steel, safety matches, chemicals, thermal power plants, pesticide manufacturing plants, hydrogenated vegetable oil and soap, phosphate fertilizer, oil storage, chloralkali plant, antibiotics, etc. The organic compounds of industrial wastes in the tidal stretch make a total BOD of 55.1 day of which pulp and paper mill effluents contribute to 18.8 t d^{-1} of lignocellulose matter equivalent to a BOD demand of 28.6 t day^{-1}.

The main sources of industrial pollution in Yamuna are at Delhi, Mathura and Agra. Chambal, Son, Gomti, Suvaon, Kali and Daha receive heavy loads of industrial effluents. The minor tributaries of the lower Ganga are drained by the Asansol-Durgapur industrial belt in the Damodar region and add to the acute problem of pollution in the stretch. Apart from 70 industrial establishments in the region, the upper stretch of Damodar between Bokaro and Panchet also gets wastes from chemical fertilizer plants and thermal power plants besides pollution from washings of coal mines.

Biological Impact of Industrial Pollution

In addition to the sub-lethal chronic effects on the environment, industrial effluents cause direct fish kills, destruction of habitat for benthic and planktonic communities and toxicity to organisms. Tannery, textiles and other mixed organic wastes cause depletion of dissolved oxygen and high BOD load at Kanpur. Plankton benthic fauna are known to disappear up to a stretch of 300 km downstream due to high pH and ammonia toxicity. The oil bearing wastes at Barauni affect the major and minor carp populations and cause periodic mortalities. Free chlorine washed down to Son at Amla causes total depletion of dissolved oxygen. Industrial effluent load in Gomti detected at Lucknow to the extent of 95.670 m^3 per day contain toxic chemicals causing depletion of dissolved oxygen and high BOD load. Extensive fish kills due to industrial waste washings are common in Gomti.

Pollutants in the Asansol-Durgapur belt include alkalies, chromates, ammonia, cyanide, phenols, naphthalene and fine coal particles. Toxicity tests with industrial effluents revealed that cotton textiles effluent is most toxic to *Macrobrachium* sp. under continuous exposure followed by paints and varnishes wastes; rubber and rayons. Distillery wastes were toxic to *Puntius sophore* and *Mystus vitiatus*. Cycle rim factory wastes were found to be highly toxic to *Catla catla* and *Labeo rohita*.

Municipal Effluents

The sewage generated in the 692 cities and large towns all along the Ganga basin is estimated 1,528.1 million cu metre. The total BOD load in Ganga basin from the urban centres is 2.504 million kg/day^{-1} of which, the share of domestic sewage is 1.338 million. Uttar Pradesh having 256 urban centres contributed 31% of the total BOD load, followed by 152 towns in West Bengal, Delhi and its suburbs generate a BOD load equivalent to 250,500/kg day^{-1} which is 19% of the total BOD.

The magnitude of pollution from domestic sewage is better understood from Figs. 2 and 3 (on following pages). Out of the 692 urban centres in the Ganga basin, at least 100 of them discharge untreated sewage into the river. Sewage effluents received by Ganga at Hardwar, Farukhabad, Mirzapur and Bhagalpur are 16 million liters per day. While Allahabad and Varanasi receive 100 mld, the load increases to 154 mld at Patna and 275 mld at Kanpur. The Calcutta city agglomeration comprising three cities and 44 municipalities is inhabited by about 9 million people and it produces an unprecedented sewage pollution load of 850 mld.

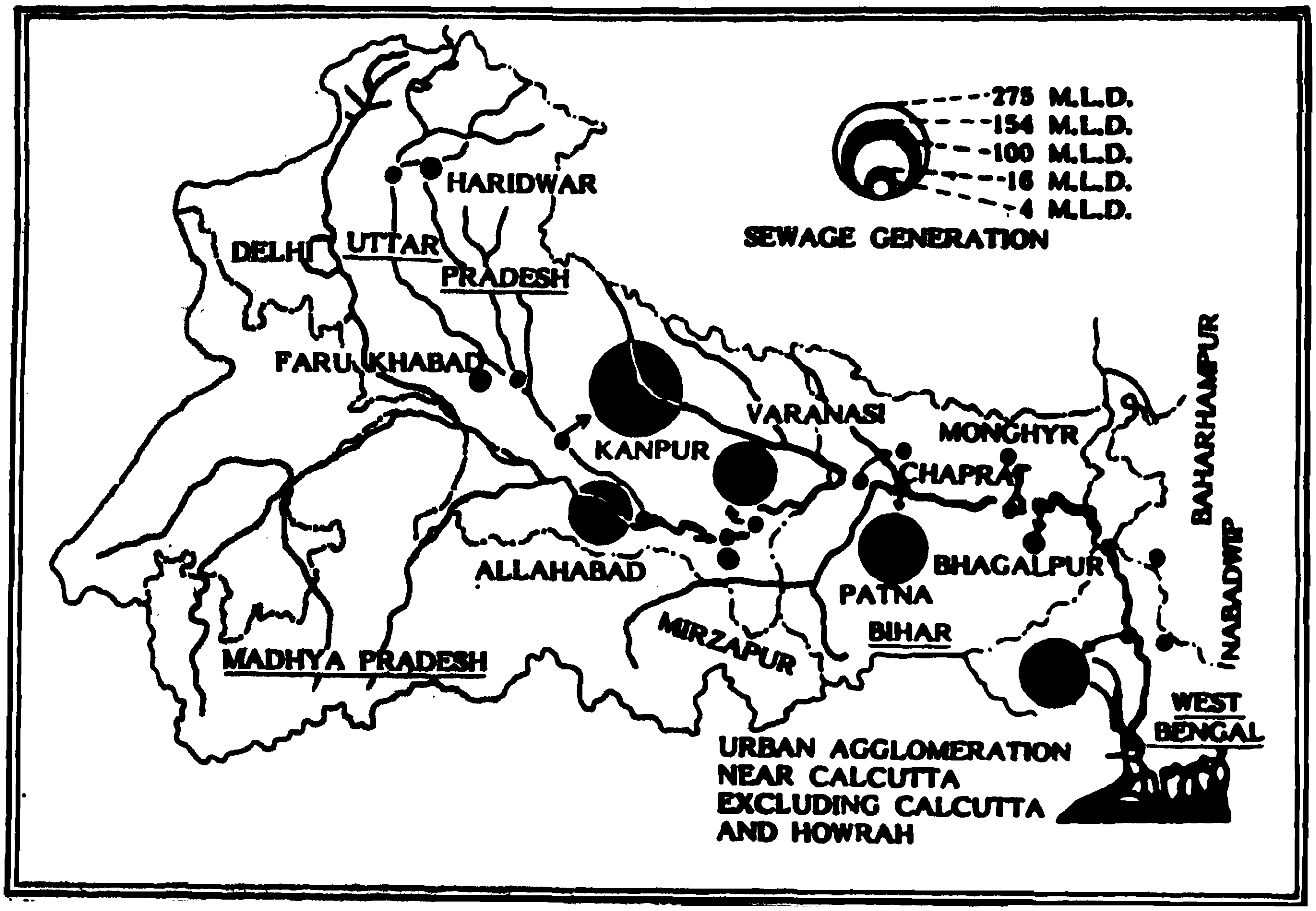

Fig. 2. Estimated Sewage Generation from Class-I Cities on the banks of the River Ganga
(Source: Jhingran, 1989)

Impact of Sewage Pollution

The major adverse impacts of sewage pollution are deoxy-generation, high BOD load, rapid eutrophication and accumulation of heavy metals in the environment. Sharp fall in dissolved oxygen in water puts the biotic communities under severe stress. While some species can tolerate a wide range of dissolved oxygen, many communities are highly sensitive to this parameter. For instance, complete absence of zooplankton during January to August and its reappearance in September represented by *Keratella* sp. have been observed in the downstream if sewage effluent out fall on the Ganga and Yamuna.

Bacterial population in river water and river bed gives a direct indication of the organic waste load. The mean concentration of total coliform organisms in Ganga water shows considerable seasonal and sectoral variations. The count is low in the sectors from Rishikesh to Kanauj (normally less than 2,400 MPN/100 ml) and higher concentrations are noticed at Uluberia, Dakshineswar, Palta, Kalyani and Darbhanga Ghat (Patna). It is estimated that domestic waste water contains 100 ml. Synthetic detergents being absorbed into the body system of fish impair their growth and reproduction capacity. Detergents mixed with oil may be 60 times more toxic than oil alone. Synergistic action of detergent with insecticides has been recorded. Its sub-lethal concentration causes thinning and elongation of respiratory epithelial cells.

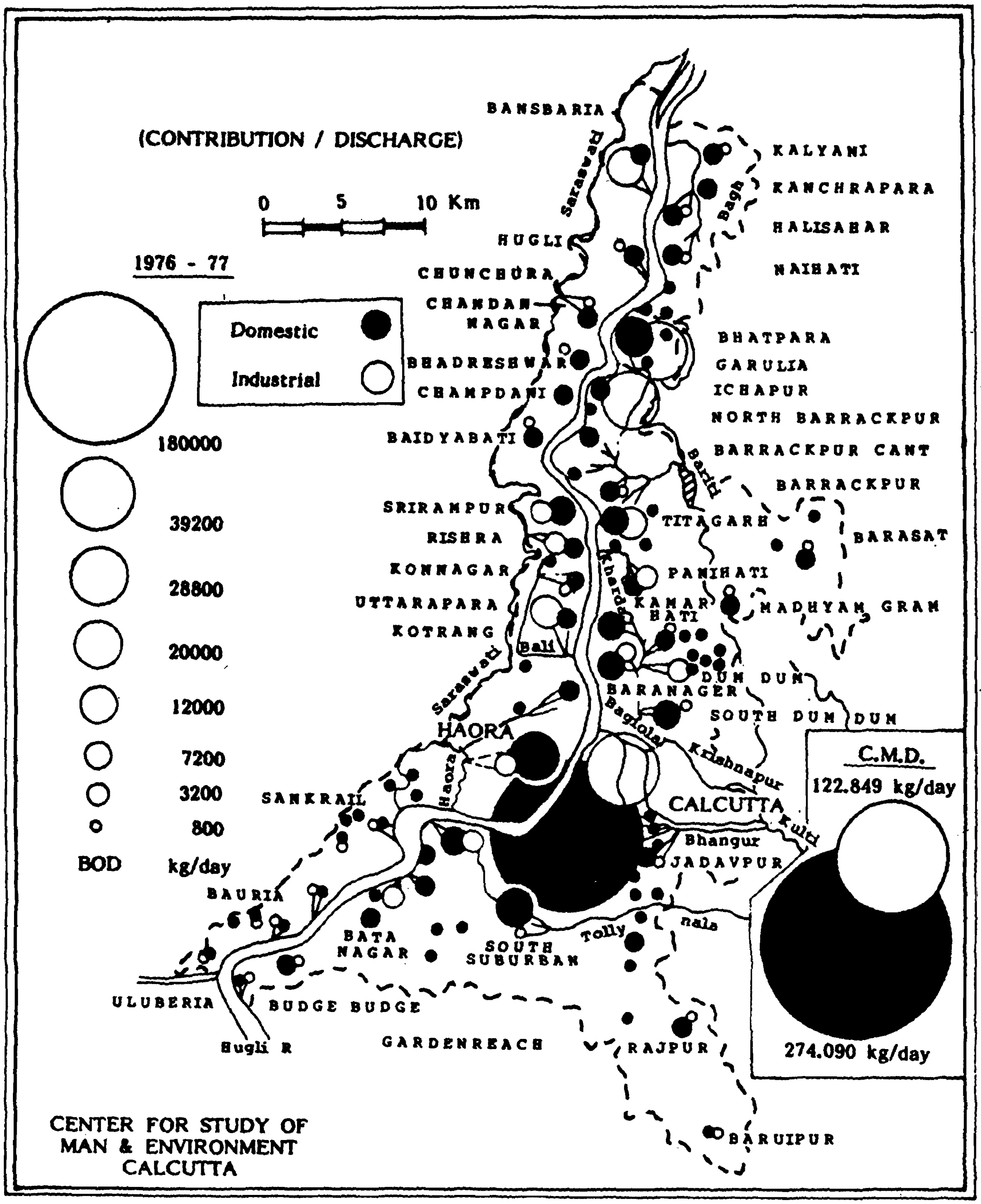

Fig. 3. Generation and Discharge of Waste Water (Source: Jhingran, 1989)

Waste and Chemical Inputs

Agricultural Wastes: The agricultural sector in Ganga basin draws freshwater to the tune of 134,484 million cu. m. and generates waste discharge to the extent of 26, 896 million cu.m. Agricultural runoff affects the riverine environment mainly in four ways, viz., increase in salt and alkali levels in water, increasing the nutrient load due to the residual effects of chemical fertilizers and the accumulation of pesticides in environment.

Salt Load: Excess salt coming from irrigation waters is largely responsible for raising the salinity level in the Yamuna especially near Agra. In the main Ganga too, a similar trend of rising salinity is observed from Hardwar to Kachla bridge. There is also a consistent upward trend in the alkalinity status in Ganga from Hardwar to Kachla bridge.

Impact of Agricultural Wastes: Increased salt load and alkali status of the water coming from the extensively irrigated basin area due to leaching in excess affect the biotic communities affects fish populations tempting them to migrate away from such areas or causing decline due to breeding failure.

Chemical Inputs

Nutrients: Nitrogen content of the fertilizers used in the Ganga basin is estimated at 8,87,133 t followed by phosphorus at 173,445 t and potassium at 91,427 t. It is generally estimated that 10 to 15% of the nutrients added to the soils eventually find their way to the surface flow.

Pesticides: About 2,573 t of pesticides are used in an year in the Ganga basin. Incidence and magnitude of DDT and BHC-Y residues in fishes of the tidal stretch of the Ganga were of higher order in the industrial zone, compared to the riverine and estuarine zones. Greater accumulation of DDT was 65-150 ppm recorded in molluscs, followed by fish 31-460 ppb, plankton (15-150) and sediments (17-80ppb). BHC-Y in fish was 46-210 ppb, in molluscs 40-86 ppb and in sediments 21-70 ppb (Fig. 4). On the basis of ambient water, the biomagnification values were 2,500 in plankton, 3,600 in gastropod molluscs, 7,500 in fish and 15,800 in bivalve molluscs. (Fig. 5).

Among the pollutional hazards from the agricultural sector, the damage caused by the pesticides is the most lethal and interminable to the environment. The organochlorine pesticides are lipophilic, extremely toxic and non-biodegradable. Like heavy metals, they assume alarming proportions as they are prone to be biologically magnified and accumulated in fish, posing serious threat to the fish eating public. Most of the commonly used pesticides in India like DDT, BHC, endosulfun, ethyl parathion, methyl parathion, dimethorate, phosphamidon, carbaryl and 2.4-D have been screened to evaluate their toxicity. All of these have been found to be toxic to fish food organisms and fish population (Ghosh, & Naskar 1985).

Sub-lethal concentrations of DDT and BHC adversely affect growth RBC count. Hb and PVC level has been noticed in Oreochromis mossambicus. Similar effects have been noticed in L. rohita and C. mrigala.

Heavy Metals: Instances of heavy metal accumulation have been reported from more and more stretches of the river Ganga and its tributaries. The main sources of heavy metal

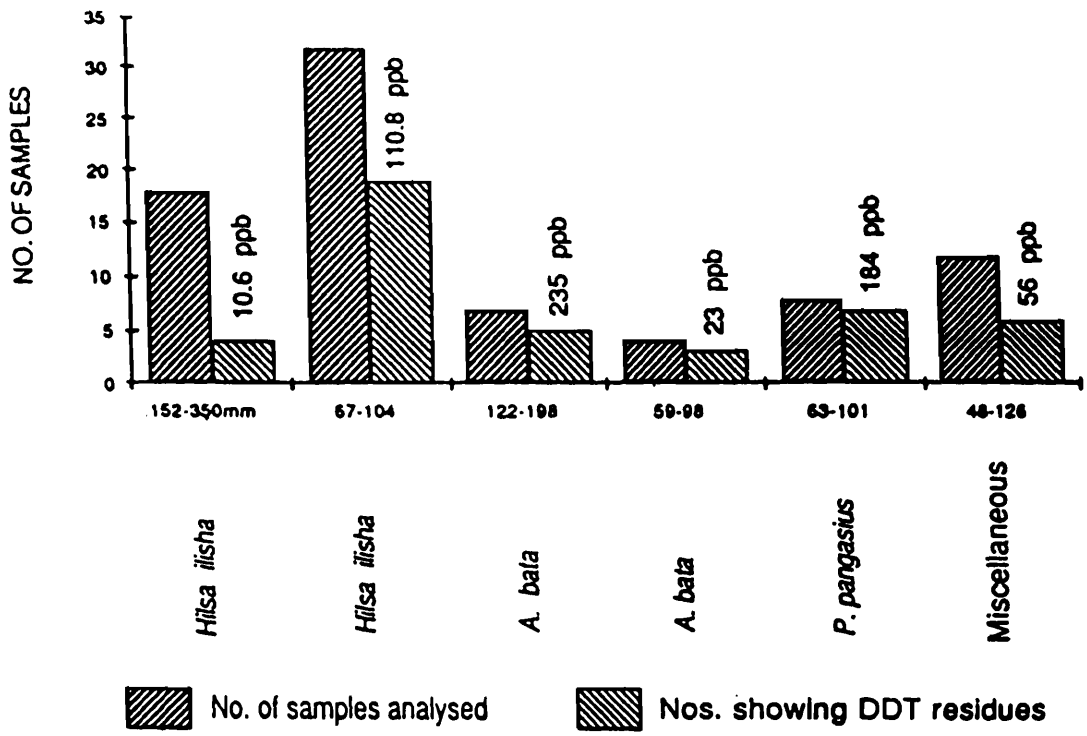

Fig. 4: DDT Residues in Fish in the Hooghly Estuary (Source: Jhingran, 1989)

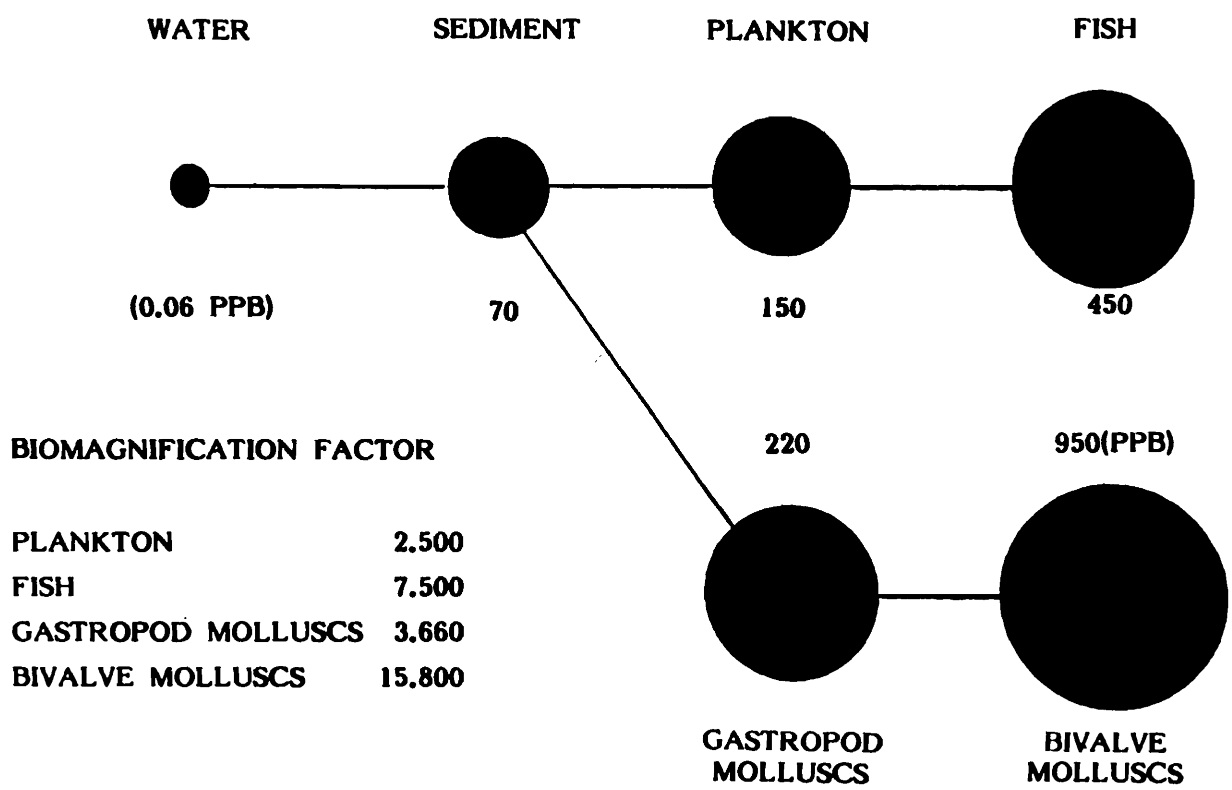

Fig. 5. Biomagnification of DDT in Aquatic Food Chain in Hooghly District (Source: Jhingran, 1989)

is the industrial effluents. However, municipal sewage is very often accompanied by trade wastes containing heavy metals. The tidal waters in the lower Ganga have registered metal contamination (Zn, Cu, Cr, Cd, and Pb) in the upper non-industrial zone around Nabadwip, industrial zone between Kuntighat and Batanagar and the lower non-industrial zone at Nurpur and Kakdwip. The tidal stretch of the Ganga recorded heavy metals in sediments, too.

Bio-accumulation of heavy metals is rampant in the Hooghly estuary. Heavy metal residues have been detected in the tissues of fishes, molluscs and the crabs. Highest bioaccumulation detected in Hooghly estuary is that of Zn in the kidney of fish (295.1 ppm) followed by gonad (146.8 ppm). Biomagnification of heavy metals have been reported from the Hooghly.

Ambient water in the main Ganga around Kanpur has shown higher metal contamination (Fig.6). Yamuna registered the presence of Zn, Cu, Cr, Cd, and Pb in water phase at Agra and downstream of Delhi. Heavy metal in sediment phase in Yamuna is depicted in Fig. 7.

Fig. 8 shows the bioaccumulation of Zn, Cu, Cr, Cd, Pb and Hg in fish tissues in Yamuna. Zn had the maximum bioaccumulation of 36 Hg^{g-2} dry weight in Delhi. Incidence of the Cr was high in Agra, heavy metals were found in molluscs tissues in river Ganga as well (Fig. 9).

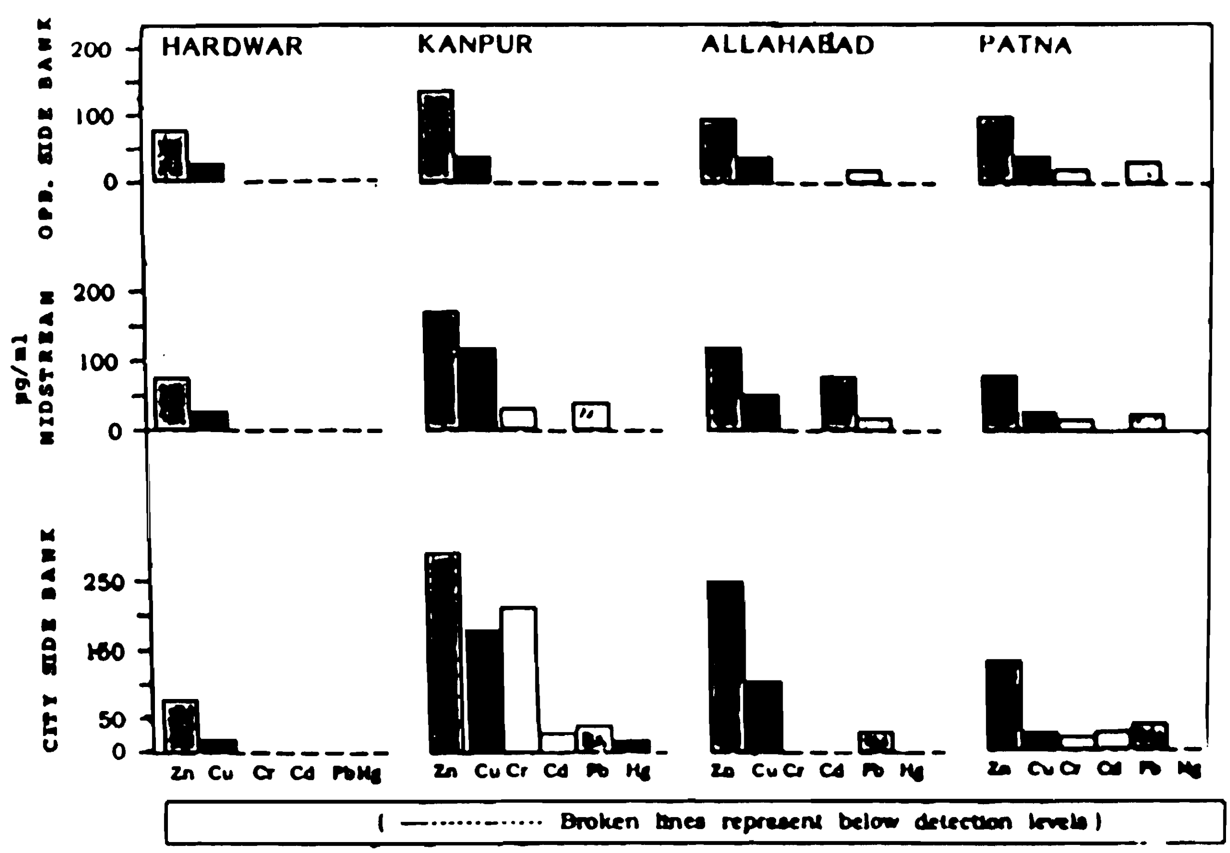

Fig. 6. Heavy Metals in the River Ganga (Source: Jhingran, 1989)

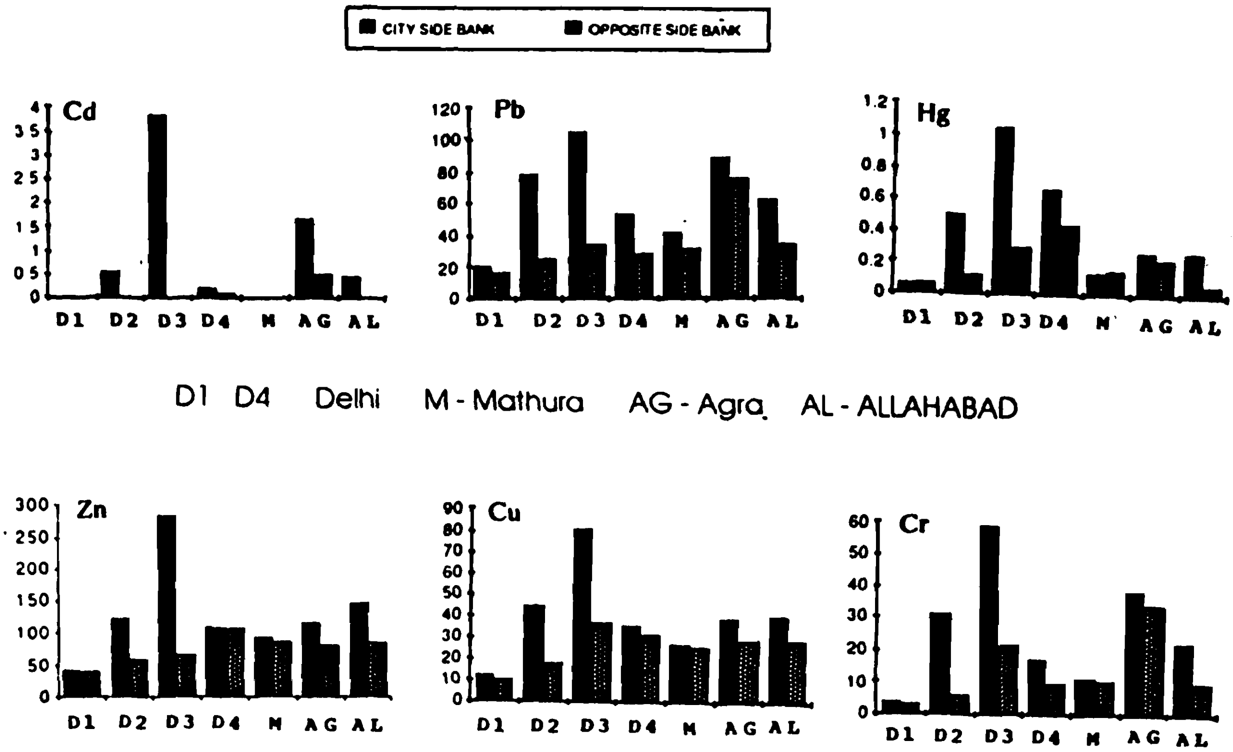

Fig. 7. Heavy Metals in sediments in the River Yamuna (μg g^{-1} dry wt.) (Source: Jhingran, 1989)

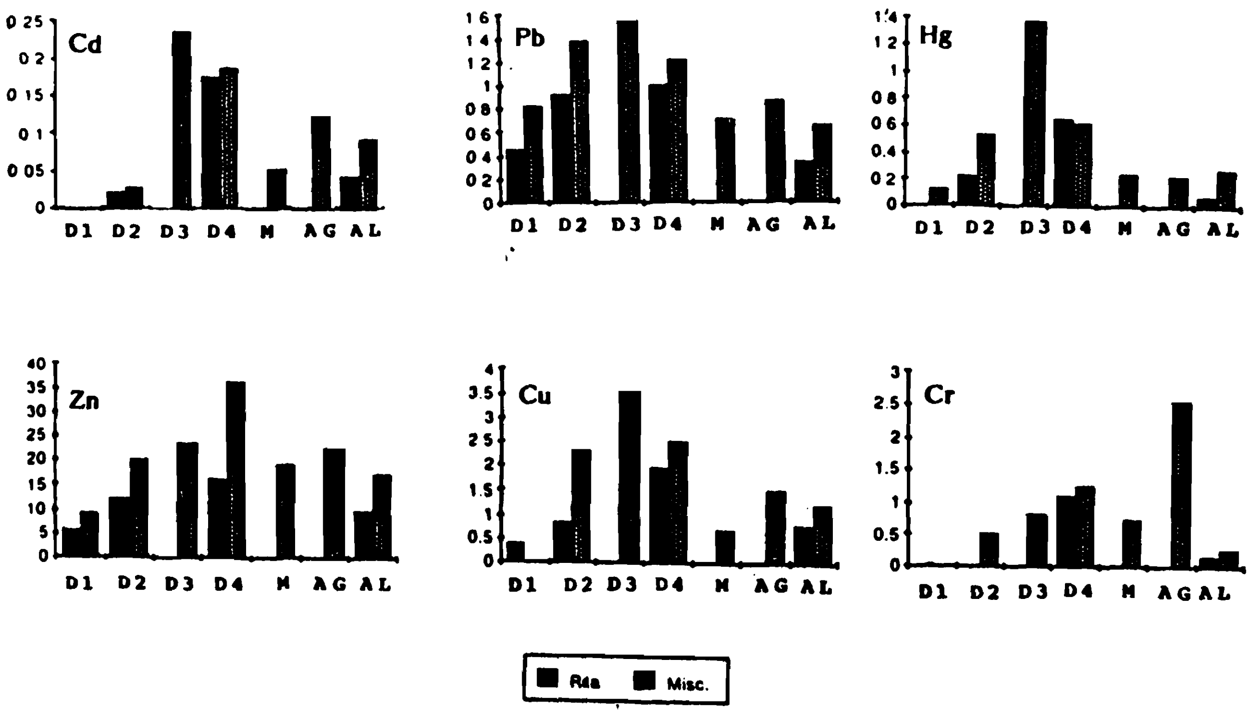

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Fig. 8. Heavy Metals in fish in the River Yamuna (μg g^{-1} wet wt.) (Source: Jhingran, 1989)

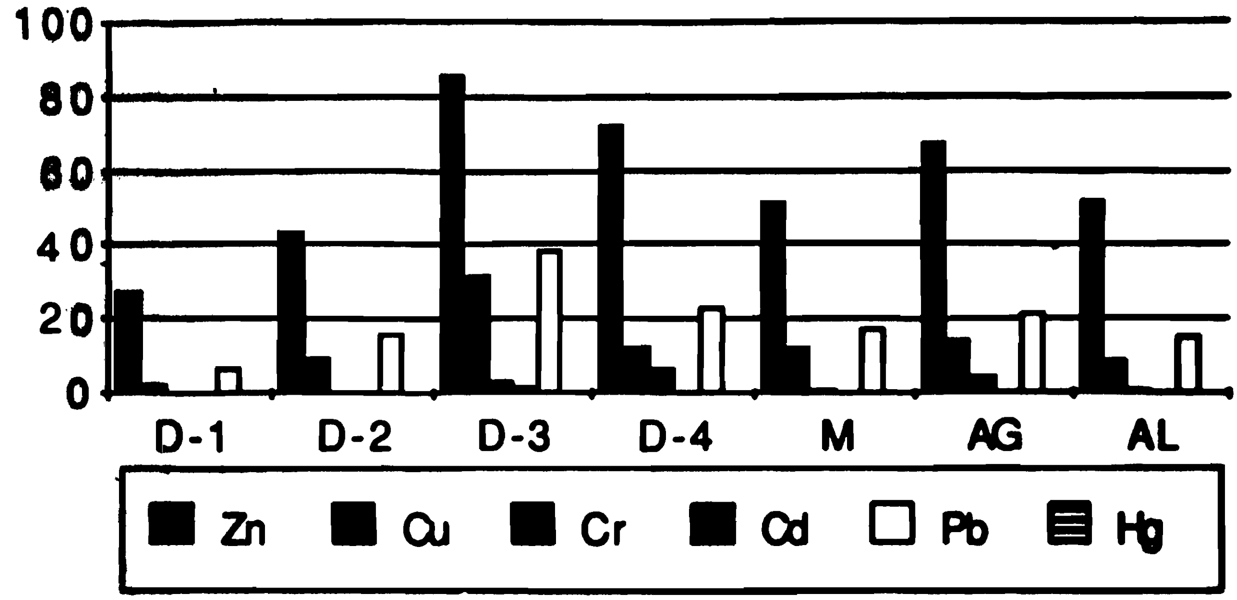

Fig. 9. Heavy Metal concentrations in molluscs at selected centres of the River Yamuna ($\mu g\ g^{-1}$ wet wt.) (Source: Jhingran, 1989)

Biological Impact of Heavy Metals Pollution: Accumulation of Zn in gonad at a high level (148.8 ppm) was found to be detrimental to fish health affecting its reproductive potential in the long run. Fish food organisms such as *Cyclops* and *Daphnia* are more sensitive to metals like Z. Presence of such persistent pollutants in the water course not only creates unfavourable environment for fish, but also cause paucity of fish food organisms.

Thermal Pollution: Since Ganga basin provides ideal conditions like large coal reserves and waterfront, a large number of thermal plants sprang up along the river course and its tributaries. Rihand reservoir is a man made lake of 46, 500 ha, into which converge wastes from four super thermal power stations in the public sector and one in the private sector. All these power plants are located within a small area of 30 km^2. Two more thermal power stations have been set up viz., Barauni and Farakka in the lower Ganga basin besides numerous others on the small tributaries.

Recommendations With regard to the programmes aimed at restoring the quality of river water and abating pollution, urgent action needs to be taken to evolve viable standards for various parameters, stretch-wise, and to ensure that standards are strictly adhered to by the agencies concerned, viz., industries, municipalities, etc. There is also a need for direct monitoring of the ecosystem by the enforcing agency.

At present, diverse agencies are empowered to take action against agencies violating water quality standards. It is highly necessary to remove such overlapping and to entrust clear-cut responsibilities to specific agencies.

It should be mandatory on the part of municipalities concerned to treat the domestic sewage invariably before it is discharged into the river. The water so treated can also be used for sewage-fed aquaculture based on the technology developed by CIFRI. power plants with effective cooling towers or similar cooling systems should only be permitted to avoid adverse effects on the river ecology. The future power plants must reduce their heat waste at critical times. The non-point pollution from agriculture fields and storm water pollution need be minimized. This requires retention basins or grids and treatment facilities to handle urban rainwater.

The systematic charting of the deep pools and the fish shelters in the river Ganga and prohibition of fish exploitation from the area during summer is to be strictly implemented.

To prevent juvenile mortality, there should be a total ban on the juvenile exploitation from the whole river system. Juveniles trapped in the water bodies like creeks, and gullies which become severed off from the main river with the recession of flood level may be salvaged and restocked in the river.

Rehabilitation of the Hilsa fisheries in the upstream areas of Farakka barrage through artificial propagation and restocking is an urgent need. Attempts to raise the Hilsa progeny in fish hatchery are being made of CIFRI. Similarly, for fostering recovery of dwindling mahseer fisheries in upland waters of the country, setting up of hatcheries for subsequent restocking of depleted river/lake stretches needs priority attention.

A proper pre-impoundment survey of the river emphasizing the fish fauna and their biological requirements is to be made mandatory before any future river valley project is taken up in the system.

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RESERVOIR FISHERIES

N.C. DATTA *

Introduction

The Biosphere comprises four major habitats: marine, estuarine, freshwater and terrestrial. Marine, estuarine and freshwater habitats are the components of hydrosphere which from ecological view point constitute the aquatic ecosystem.

Although ecology and ecosystem have recently become a kind of customary vocabulary for the politicians, planners and administrators perhaps it is necessary to explicitly define the terms as a background information. Ecology has been defined as the study of any and all kinds of relationships between organisms and their environment, physical and biological. This classical definition of ecology does not necessarily recognized the role of man as if man is apart from nature and obviously therefore does not fulfill the demand of present day ecology. The present author (Datta, 1990) defined ecology as a branch of science or rather a discipline of human knowledge dealing with the strategies of survival of man biosphere in space and time. This definition integrates ecology with economics, sociology and development and incorporates the part played by man as an ecological component. Ecosystem is a compound word formed by the two basic vocables "eco = ecological" and "system". The term "ecology" has already been defined and therefore, the term "system" needs an expressive definition. "System" may be defined as a set of different interacting elements or compartments or units. The connectedness of the compartments constituting a system exhibits an 'orderly working totality' and this conceptual outlook is philosophically known as holism. One of the principal objectives of environmental impact assessment is to identify the structural and functional links of the various compartments of the system so that precise appraisal of any impact on environment could gainfully be made.

What are reservoirs? Geographically reservoirs are receptacles for holding water at the dam sites. Ecologically reservoir is a kind of unique aquatic ecosystem which possesses the combined attributes of lotic and lentic environment. Reservoirs and lakes are very similar aquatic bodies but the former as a rule are man made whereas the latter are natural. However, reservoirs and dams are constructed simultaneously and therefore, environmental impact assessment studies of both the components are to be tackled concurrently. Although most of the reservoirs of the world were built in the present century but the evidence of construction of reservoirs in Egypt dates back to 3200 B.C.

Purpose of construction of reservoirs: Reservoirs are multipurpose units of ecosystem. The main uses are irrigation, flood control, power generation, fisheries production, water supply for drinking and industrial purposes, water transport and sport and tourist attraction. Reservoirs play an important role in landscape beautification and in conservation of aquatic resources.

Reservoirs in India: In pre-Independence India reservoirs were very few in number. But after Independence quite a large number of reservoirs are being built, in keeping

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with the India's stride for industrial, agricultural and power development. Multipurpose river valley projects are planned and installed to boost up the level of quality of life.

According to one estimate there are about 60 large, 152 medium and 2,155 small size reservoirs making a total of 2357. Indian reservoirs cover more than 3 million hectares of land surface. Recently there is a combative controversy over Tehri and Narmada valley projects. Developers are in favour and environmentalists are against the large scale modification of our ever-flowing river systems. Major reservoirs are Govindsagar, Bhabanisagar, Nagarjunasagar, Gandhisagar, Stanley reservoir, Shivajisagar, Hirakud, Rana Pratapsagar, etc.

Pre-Impoundment Survey

Before construction of dams and reservoirs necessary survey (Pre-impoundment survey) should be done to consider the following aspects.

Physical

1. Suitable site selection is the first step.
2. Nature of landscape with special reference to geomorphology of the area.
3. Water holding capacity of the soil.
4. River drainage system.
5. Mapping of the area.

Biological

1. Flora, fauna, forests, wildlife of the reservoir site should be explored. Inventory of all kinds of biota should also be made.

Socio-cultural

Human settlements with special reference to their economic dependence on the area of reservoir construction should be studied. If the required information could be procured before construction of dams and reservoirs, real impact assessment could be possible. After the construction of reservoirs the biotic communities are to be studied qualitatively as well as quantitatively. Limnologically the organisms are grouped as follows:

1.	Plankton	These are floating organisms, mostly microscopic which are drifted by currents. Although these have feeble mobility, some plankton serve as good bioindicators.
2.	Periphyton	Organisms remaining attached to submerged substrata.
3.	Nekton	Organisms of larger size having potential power of locomotion which enable them to move against current. Fish are typical nekton.
4.	Neuston	Organisms resting or swimming on surface layer of water bodies.
5.	Pleuston	Large size floating plants drifted by wind or water current.
6.	Benthos	Organisms living on or in the bottom sediments.

Besides the above, there are submerged and emergent vegetation. Reservoirs like those of the lakes have three district zones.

1. Littoral; 2. Limnetic and 3. Profundal zones.

Each of the zones is characterized by its own biotic communities.

On the basis of light penetration the zones of the reservoirs are euphotic and aphotic. According to nutrient status the reservoirs may be classified as eutrophic, mesotrophic and oligotrophic. In deep reservoirs, thermal and chemical stratification may occur.

Reservoirs and Fisheries

Since reservoirs are large water bodies and give shelter to a good number of commercially important fish, therefore fishery constitutes a very valuable component which deserves special attention. But unfortunately fishery occupies the fourth position in the priority list (irrigation, power generation, flood control and then fishery).

The fish yield from Indian reservoirs is indeed very poor. It is about 14 kg/ha/yr. Whereas China produces 60 kg to 1,000 kg/ha/yr from big to small reservoirs. With proper management fish production can be increased to a great extent.

Impact assessment studies on reservoirs: As a result of large scale ecodegradation caused by industrialization, urbanization and agricultural development (specially indiscriminate use of fertilizers and pesticides) the question of environmental impact assessment has come in a big way. We need to know:

1. What is meant by environmental impact? and
2. Impact of what or whom? The meaning of the term impact is very comprehensive. It may be ecological, economical, social as well as cultural. Keeping these view points in mind it has now become obligatory to make a precise prognosis of the possible adverse impacts which might incur in case any large scale developmental plan like the construction of dams and reservoirs is mooted. Environmental impact assessment studies will immensely help in promulgating proper precautionary measures in order to circumvent large scale disastrous changes in the environment. It is likely to provide a judicious outlook to the planners and environmental managers about all round impact of the proposed plan on the status of environment taking into account the aspects of cost benefit analysis.

Problems of reservoirs and Recommendations for Reservoir fisheries

Reservoirs like lakes are not permanent features of the landscape because eutrophication may bring death to them.Allochthonous and autochthonous eutrophication may reduce the carrying capacity of the reservoirs. Cultural eutrophication is a matter of serious concern. Incoming pollutants to the reservoirs from the catchment receiving industrial effluents and agricultural wastes lower the quality of soil and water adversely affect the aquatic biota including fish. The life of the reservoirs depends on the rate of silt loading.

In order to augment fish production following steps may be taken:

1. Abatement of pollution,
2. Replenishment of depleted stock,
3. Construction of suitable fish passes,
4. Proper management of watersheds,
5. Prohibition on juvenile fishing,

6. Establishment of balance between harvest and stock renewal,
7. Introduction of surveillance programme to examine the water quality and stock position,
8. Development of proper craft and gear for fishing,
9. Suitable steps for cage and pen culture,
10. Betterment of socio-economic condition of the fisherman community.

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WATER QUALITY MODELLING

SUTANU GHOSH *

Concept of Modelling

Environmental system are often delicately balanced, and perturbations imposed on them may produce either positive or negative effects. An understanding of the reaction of these system under stress is fundamental to sound planning. Quantitative models can provide valuable insights to systems performance and, if used in the proper context, can be effective tools in the hands of water resources planners.

The use of models to guide the decision-making process is not new but is of a different, more sophisticated and more encompassing form than in the past. Models are representations of actual or proposed systems and their use permits manipulation over real times of seconds which would take years for the prototype. This is the feature which makes use of these tools so attractive and which holds such potential for the analysis of even the largest, most complex systems. It is also the feature that makes this approach so well suited to water resources planning.

Models can be used to determine end results of various courses of action and translate questions being asked into predictive answers. Questions such as – What will be the net effect of a given level of treatment on the water quality of a stream? or, How will a particular watershed management practice affect water quality? – can be answered Quantitative predictions of short-and long-term effects of conceived plans can be made with a higher level certainty than before and this enables decisions maker to chart more rational courses of action.

Water Quality Models

A water quality models is a mathematical statement or set of statements that equate water quality at a point of interest to causative factors. Mathematical modelling is an effective way to approach quantitative problem solving. Models may be simple or complex, the degree of sophistication depending on the complexity of the problem, the nature of objectives, and the ability to describe the system in mathematical terms.

Water quality models should provide for (1) the determination of constituent concentration versus time at points of entry to the system, (2) the determination of the mixing and reaction kinetics of the system, and (3) the synthesis of the time-distributed output at the system outlet.

Either stochastic (containing probabilistic elements) or deterministic approaches may be taken in developing methods for predicting pollution loads. The former technique is based upon determining the likelihood (frequency) of a particular output quality resource by statistical means. This is similar to frequency analysis of floods or low flows. Water-quality records should be available for at least 5 years (preferably much longer) for this approach to have great fidelity.

The deterministic approach (output explicitly determined for a given input) requires

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that a model be developed to relate the water quality loading to a known or assumed hydrologic input. Such a model may vary from and empirical concentration – discharge relationship to a soundly based physical equation representing the hydrochemical cycle. The ultimate modelling technique is that which best defines the actual mechanism triggering the water quality resource. The cause of a given state of pollution can then be specifically identified.

Water Quality Constituents

Water quality constituents may be classified as conservative or non-conservative; somewhat more narrowly as organic, inorganic, radiological, thermal, and biological; and finally further subdivided into specific forms, such as BOD, nitrogen, phosphorous and so on. Pollutants of interest include fecal organism, salt, pesticides, fertilizers, solid waste, nitrates and phosphates.

Hydrologic data necessary to compute pollution loadings of various constituent must be obtained concurrently with water quality data to ensure proper calibration and verification of models. A knowledge of the frequency and time distribution of loading. This is particularly true in case where the objective is to determine the impact of a waste flow on a receiving stream. For example, a short, high-peaked surface runoff hydrograph of suspended matter could be expected to more seriously affect a stream that a hydrograph which released the same volume of suspended matter over an extended period of time. On the other hand, when waste flows enter a lake, the annual volume of contaminants takes on special importance. In general, it is desirable that water quality data be recorded in a continuous manner so that the time rate of delivery of the constituent loading can be determined. If this is not done, only very gross estimates of the impact of water quality inputs on receiving water can be obtained.

Organic Loads on Streams

The discharge of wastes into a body of water presents a problem of primary importance in the field of water-pollution control. The reduction of this organic matter by bacteria results in the utilization of dissolved oxygen. The primary replacement of this dissolved oxygen occurs through the water surface exposed to the atmosphere. An increase in the pollution load stimulates the growth of bacteria, and oxidation proceeds at an accelerated rate. The concentration of the organic load can be so great that all the dissolved oxygen in a receiving water is utilized by the bacteria. This lack of oxygen inhabits the higher forms of biological life, and conditions develop that are detrimental to man. The concentration of dissolved oxygen is one of the most significant criteria in stream sanitation.

Every stream is limited in its capacity to assimilate organic wastes. As long as this limit is not exceeded, the disposal of organic wastes in stream represents the most economical methods of waste disposal. The evaluation of the natural purification capacity of a stream is of fundamental engineering values. Streams are used as natural treatment plants, and it is necessary to determine their capacity in order not to destroy their usage for other purposes.

The simultaneous action of deoxygenation and reaeration produces a pattern in the dissolved-oxygen concentration of river water. This pattern, known as "the dissolved-oxygen sag", was first described by Streeter and Phelps in 1925. The equation describing the simultaneous action of deoxygenation and reaeration is :

$$\frac{dD}{dt} = K_1' L - K_2' D \qquad (1.1)$$

Where D = Dissolved Oxygen deficit
L = Concentration of the Organic Matter
K_1' = Coefficient of deoxygenation
K_2 = Coefficient of reaeration

The rate of change in the dissolved oxygen deficit D is the result of oxygen utilization in the oxidation of organic matter and the reaeration which replenishes oxygen from the atmosphere. The concentration of the organic matter L must be expressed in terms of the initial concentration L_o at the point of waste discharge before integrating (Fig. 1).

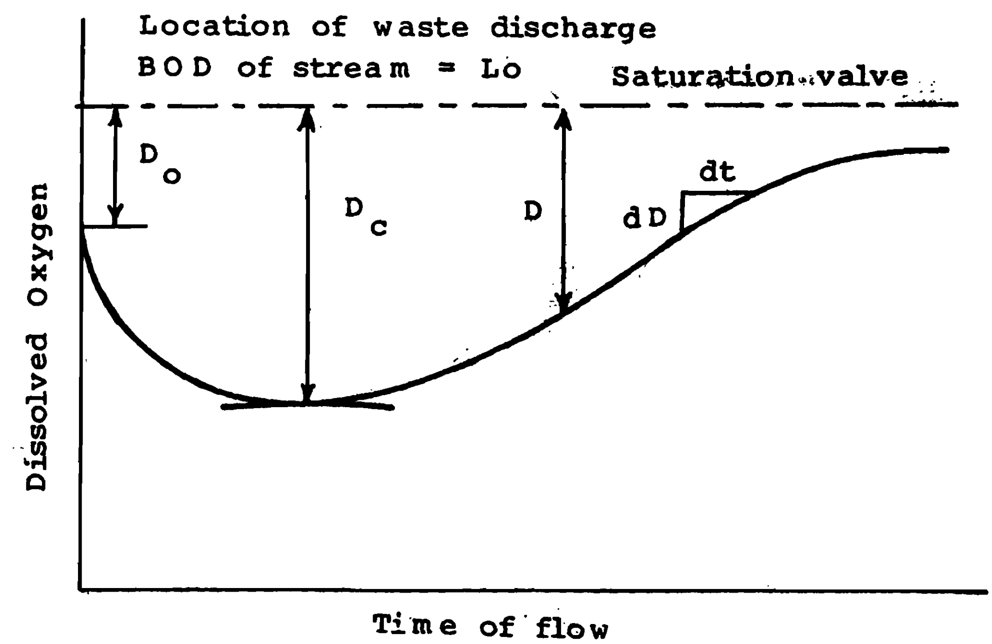

Fig. 1 Dissolved oxygen – sag curve

$$L = L_o e^{-k_1' t} \qquad (1.2)$$

where L is the initial concentration of the organic matter in the stream (BOD in mg/1). The substitution of Eq. 1.2 for the value L in Eq. 1.1 and integration gives

$$D = \frac{K_1' L_o}{K_2' - K_1'}\left(e^{-k_1' t} - e^{-k_2' t}\right) D_o e^{-k_2' t} \qquad (1.3)$$

Where D = oxygen deficit in time, t mg/l
D_o = initial oxygen deficit at the point of waste discharge, mg/l.

Equation 1.3 is normally used with common logarithms.

Since $e^{-k't} = 10^{-kt}$, where $k = 0.434k$

$$D = \frac{k_1 L_0}{k_2 - k_1}\left(10^{-k_1 t}\ 10^{-k_2 t}\right) D_o\, 10^{-k_2 t} \tag{1.4}$$

The proportionality factor k_1 is a temperature function. The proportionality factor k_2 is also a temperature function but, more important, it is function of the turbulence of the stream.

A general approximate formula for the reaeration coefficient of natural rivers is given by O'Connor and Dobbins,

$$k_2 = \frac{(D_L U)^{1/2}}{H^{3/2}} \tag{1.5}$$

Where k_2 = reaeration coefficient (base e) per hour
D_L = diffusivity of oxygen in water
= 0.000081 ft^2/hrs at 20°C.
U = Velocity of flow, ft/hr
H = depth of flow, ft.

The effect of temperature on the reaeration coefficient k_2 is as follows:

$$k_{2T} = k_{2-20} \times 1.047^{T-20} \tag{1.6}$$

where k_{2T} = reaeration coefficient at temperature T and
$k_{2\text{-}20}$ = reaeration coefficient at 20°C

The value of k_2 ranges from 0.20 to 10.0 per day, the lower values representing deep slow-moving rivers, and the higher values, shallow streams with steep slopes.

From an engineering design viewpoint, the dissolved -oxygen sag curve indicates the point of minimum D_o. This critical point is the place in the stream where the rate of change of the deficit is zero and the demand rate equals the reaeration rate.

$$k_2' D_c = k_1' L = k_1' L_o e^{-k_1' t_c} \tag{1.7}$$

Solving for the critical time t_c,

$$t_c = \frac{1}{k_2' - k_1'} \ln\left[\frac{k_2'}{k_1'}\left(1 - D_o \frac{k_2' k_1'}{k_1' L_o}\right)\right] \tag{1.8}$$

These equations have constants which must be carefully evaluated. The k_1 term reflects the rate at which bacteria demand oxygen and is calculated from the BOD test by running BOD determinations. The k_2 term is the reaeration characteristic of the stream and varies from reach to reach in most stream. Constant k_1 can be evaluated in the laboratory while k_2 must be determined from field studies. In the development of these equations, it is assumed that k_1 and k_2 are constant and that only one source of pollution exists and that the only oxygen demand is the BOD. Variations from these assumptions may be taken into account in any practical case. Some of the following processes, in addition, may be taking place to significant effect in any given river stretch:

1. Removal of BOD by absorption or sedimentation.
2. The addition of BOD along the river stretch by tributary inflow.
3. The addition of BOD or the removal of oxygen from the water by the Benthal layer.
4. The addition of oxygen by the photosynthetic action of plankton.
5. The removal of oxygen by plankton respiration.

Temperature Dispersion Modelling in Streams

A very simple from of a temperature dispersion model applicable for rivers or streams assumes that the dispersion is one -dimensional in nature, ignoring the vertical effects. It assumes that the temperature decreases exponentially with time or distance along the length of the stream, from the mixing temperature attained at the point of discharge of the thermal effluent. The phenomena is mathematically expressed as

$$T = T_n + (T_o - T_n)\, e^{-k\rho ch\,(t - t_o)} \qquad (1.9)$$

Where, T = temperature at time of travel t
T_n = ambient temperature of the stream
T_o = initial temperature after mixing
k = coefficient dependent on wind speed
ρ = density of water
c = mechanical equivalent of heat and
h = mean depth of the stream.

The model can be adequately used to describe the affected stretch of the river, due to receipt of thermal discharge.

Complex Water Quality Models for Rivers

The more complex water quality models are used to simulate the dissolved oxygen balance as well as other interrelated and interdependent parameters as phytoplankton biomass represented by the chlorophyll – a content, nutrients (nitrogen and phosphorus) and first stage BOD.

The models are generally one-dimensional; it assumes that the water quality calculated at one point represents the average over the corresponding transversal section. Longitudinal dispersion is neglected. The water columns thus move upstream to downstream by advection associated with the rate of flow of the river.

The models which are fundamentally unsteady take account of the rate of flow and very importantly, the meteorological parameters. The computations are made adopting a 3-hour or 1-hour time-step, depending on the availability of data as well as its variability.

One of the disadvantages of these simulation models is that it requires a considerable length of time for a given ecosystem; it would be appreciated that validation forms one of the most important exercise in modeling applications.

Water Quality Modelling For Lakes And Reservoirs

Lakes and Reservoir models assume further complex forms than the river models. In order to render them applicable, they are normally one-dimensional vertical models. Such models are perfectly adaptable to deep and small reservoirs, where the assumption of horizontal homogeneity is reasonable. The models are useful for predictive and cognitive purposes and also enables the simulation of a perturbation of a system. For more complex situations, they fail to represent adequately the advective process and two or three dimensional models are therefore developed. Understandably, these models are computationally heavy.

In the one-dimensional models, the energy transfer at the air-water interface is assumed to be constant at a given time, over the entire surface area of the waterbody, but is allowed to vary in time. Thus, the model is time-dependent and akin to the river models, a 3-hour or 1-hour computational time-step is generally adopted, depending on the suitability.

The lake or reservoir is assumed to be composed of a certain number (N) of horizontal layers. Each layer has a thickness ΔZ and a horizontal cross-section area A(i), and is assumed to be homogenous and isothermal. The model is run for each individual layer over the corresponding time steps to generate information over the entire volume of the water body.

It would be recognized that temperature is the primary controlling parameter in case of a lake and thus the model consists of a thermal sub-model coupled with a water quality parameter submodel as dissolved oxygen, BOD, nutrients or phytoplankton biomass. The thermal model deals with all the heat transfer and mechanical mixing process in the water body due to local meteorological conditions. Heat transfer by advection is considered in the model. Most of the heat transfer mechanisms occur at the surface of the waterbody.

Correspondingly, each water quality parameter is represented by a forcing function, describing the inter-relationship between each other and other affecting variables.

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AIR POLLUTION

A. K. SAHA*

Introduction

Any constituent of the air which is present in excess so as to cause injury to human beings or to animals and plants constitutes air pollution.

Air is something which is essential for the survival of man and most plants and animals. Pure "healthy" air should contain 20-21% volume oxygen, 0.9% argon, 0.03-0.04% carbon dioxide and traces of ozone, water vapour, apart from nitrogen (about 78%). It is not often realized that air is a most important resource for mankind. The gases of the atmosphere provide the four principal elements of all living matter, *viz.*, oxygen, carbon, hydrogen and nitrogen. The importance of air for the support of life on the earth is undisputed. The atmosphere shields, intercepts, reflects, diffuses and absorbs particular wavelengths of solar radiation, prevents excessive loss of heat energy transmitted from the earth, provides pathways for energy and nutrient cycling. Also, existence and distribution of atmospheric water vapour is of fundamental importance to weather and climate.

In practice, the composition of air deviates from its ideal composition mainly in two ways: (a) presence of excessive carbon dioxide and relatively low oxygen contents, and (b) presence of pollutants in varying proportions; these are of three kinds: (i) particulate pollution, which includes suspended matter (SPM), *i.e.*, fine dust and smoke which float about in the air, and dustfall *i.e.*, the relatively smaller particles (<10 microns) which settle down; (ii) gaseous pollutants which are given off principally by industrial plants and motor vehicles – sulphur dioxide, nitrogen oxides, carbon monoxide, hydro-carbons, photochemical oxidants, vapours of lead compounds, chlorine, methane, etc. (iii) In addition, we have some natural pollutants, *e.g.*, pollens of trees which cause allergies, methane which is generated in marshy lands and rice fields.

There are two other parameters of air, which, though not strictly considered as pollutants, nevertheless constitute important environmental hazards, *viz.*, (a) increasing level of CO_2 in the atmosphere, and (b) the problem of acid rain.

Before going into some details of the different parameters of air pollution, it will be useful to have an idea about prescribed upper limits of the major pollutants in ambient air. The World Health Organization (WHO), United Nations Environment Programme (UNEP) and statutory bodies of many countries have prescribed upper limits for many of the pollutants for ambient air. Such ceilings have been decided on two considerations – (a) maximum limits of such pollutants as would not cause health problems, and (b) most industries and vehicles would generate pollutants in variable quantities which might cause some health problems but would not cause *incurable and deadly diseases* – the point is that industrialization is essential for maintaining a certain standard of living; the people will have to pay a price for this even by agreeing to certain lowering of health standards; but such lowering must not be such as to cause incurable and deadly diseases. The

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permissible limits of Annual Mean and 24-hour measurements of the major pollutants in ambient air as prescribed by WHO, USEPA and the Central Pollution Control Board, India are as follows:

Table 1

Permissible limits of Annual Mean and 24-hour Measurement of major pollutants in Ambient Air (values in micrograms per cubic metre)

	WHO		USEPA		Central Pollution Control Board, India 95-percentile limits of 24-hour Measurement	
	Annual Mean	98th-percentile (daily average)	Annual Mean	24-hour Measurements	Residential	Industrial
Suspended matter	90	230	75	260	200	500
SO_2	60	150	80	365	80	120
NOx	—	—	100	—	80	120

In addition, different countries have permissible limits of emissions from different types of industries, such as cement, iron and steel, thermal power plants, etc.

The Salient Air-Quality Parameters

As already stated, the air-quality parameters fall into two physical groups, *viz.*, particulate pollutants and gaseous pollutants. The particulates in turn are classified into (a) suspended particulate matter, usually finer than 10 microns in size, which float about in the ambient air; parts of such matter are inhaled by human beings, and (b) Dustfall, *i.e.*, the free-falling dust particles which settle down by gravity. Source-wise, a part of the particulates represents ground-blown dust, another major part represents emissions from industries, which travel far and wide (over hundreds of kilometres downwind), still another part is derived from emissions from motor vehicles, railway engines, etc., still another part is derived from the burning of firewood/coal for cooking purposes. A natural source of air pollution is provided by volcanic eruptions, enormous quantities of fine dust and gas (including SO_2) so generated might cover the entire globe for several years, as was the case with the famous Krakatoa eruption in 1883. Cigarette smoking constitutes another source of air pollution because the air whose quality is important to your health is the air you breathe and not the entire global atmosphere (Turk, 1985). Smokers inhale several times more particulates than the average non-smoking city-dwellers. US scientists have found that smokers are six times more likely to die from pulmonary diseases than non-smokers.

The gaseous pollutants again are partly of natural origin but predominantly anthropogenic. Emission of methane produced by bacterial decomposition of organic matter, particularly in rice fields and also from natural gas leakage has been considered within recent years to be an important contributor to the "greenhouse effect" Methane is also produced naturally in marshy wetlands. We shall discuss the greenhouse effect in more detail later. The main sources of anthropogenic gaseous pollutants are industries – primarily the chemical plants and thermal power plants, followed closely by emissions from automobile exhausts, while burning of firewood and coal for cooking purposes also contributes considerably to gaseous pollution. Excessive use of nitrogenous fertilisers and their oxidation, particularly when there are no crops in the fields, produce N_2O and NO.

Carbon compounds: These include a large number of chemicals, most of which are toxic even in minute concentrations. These compounds are classified as:

(a) Hydrocarbons in gaseous form; usually compounds ranging from C_1 - C_5 are present in ambient air. The ranges of values for several hydrocarbons in urban ambient atmosphere (in ppm by volume) are as follows:

	Min	Max
Methane	1.2	15
Ethane	.005	.5
Propane	.003	.3
Isobutane	.001	.1
Ethylene	.004	.3

Concentration of various hydrocarbons can be measured accurately by gas chromatography, with lower limit of 0.01 ppm by volume; using special techniques, the detection limit can be lowered to ppb level.

(b) Benzo(a)pyrene (Ba P) present in airborne particulates of urban and industrial areas, is highly carcinogenic; it is generated mostly in auto-exhausts and it has been detected in Calcutta's air.

(c) Polynuclear aromatic hydrocarbons (PAH) constitute a group of about 20 compounds (present both in particulates and in gas) of which the prominent ones are anthracene, phenanthrene, fluoranthrene, pyrene, benzo(a)pyrene, benzanthracene. These are found in auto-exhaust, exhausts of industrial and domestic heating plants, coal tar pitch, etc. These compounds are measured by column chromatography or by UV – Visible absorption spectrography.

(d) Aliphatic hydrocarbons include alkenes, naphthalenes, squalin, olefins, etc., and are highly toxic, though they are usually not as abundant as the PAH.

(e) Other carbon compounds include several hazardous chemicals, such as Mercaptans, phenolic compounds, PAN (peroxyacetyl nitrate), benzene and lastly (but not the least) carbon monoxide. PAN is particularly injurious to leaves of plants. Carbon monoxide is generated in the exhausts of incompletely burning petrol engines, but its incidence is less in diesel exhausts. In this respect, auto-exhausts of petrol vehicles are more toxic than diesel vehicles.

Halogen and Halogen compounds: These include free chlorine, chlorides and fluorides, which are emitted by chemical plants. Also chloride vapour, which is highly corrosive is a natural hazard in coastal areas, such as at Digha.

Metals: These include elemental mercury, arsenic and lead compounds in a gaseous state and they are toxic even in minute proportions. Arsenic in ambient air lies between <0.1 - 1.0 $\mu g/m^3$. Lead compounds occur in appreciable quantities in the ambient air within 30 metres of the highways and busy roads, being primarily generated from the automobile exhausts; grass and foliage in that zone also carry Pb.

In addition, fine dusts of the compounds of iron, manganese, cadmium, chromium, copper, nickel and vanadium are common in ambient air close to the respective metallurgical industries, as well as in the mining areas. Fine dusts of iron ore occur around the iron ore mines and some of the dusts settle in agricultural land several kilometres away from the mines, causing loss of soil fertility and land degradation; however, iron ore dust is not particularly toxic, but dusts with Mn, Cd, Cr, Ni and V are highly toxic. Trace metals in the atmosphere can be detected up to ppb level using ICP and AAS techniques.

Enormous quantities of toxic metals are being emitted into the atmosphere through anthropogenic sources. Some of these are as follows (Nriagu, 1988): Arsenic 18.8, Cadmium 7.6, Chromium 30, Copper 35, Nickel 56, Lead 332, Selenium 3.8, Tin 6.4, Vanadium 86, Zinc 132. *(Metal emission in 1000 tonnes/year)*

Nitrogen compounds: These include ammonia, nitrites, NO, N_2O and NO_2. The main sources of these pollutants are auto-exhausts and industrial emissions, but oxidation of fertilisers and bio-mass burning also contribute considerably to NO_x pollution. There is a general global trend of increasing NO_x pollution.

Sulphur compounds: These include H_2S, SO_2 and SO_3. These parameters, particularly SO_2, are monitored individually, but an indication of the general level of sulphur compounds in ambient air is given by month-wise measurements of sulphation rate, where sulphur compounds in the air are made to oxidise and combine with PbO_2 to form lead sulphate.

Oxidants: These include ozone and organic peroxides. Apart from being toxic, these compounds are responsible for photochemical smog, the greyish-brownish haze which develops when sunlight (particularly ultra-violet component) falls on air-carrying oxidants. Though the ozone content in the upper atmosphere is decreasing (ozone hole) largely due to the effects of the CFC's, the tropospheric ozone (i.e., ozone up to 1 km above ground surface) is on the increase, thanks to industrial emissions. At all places, ozone content is minimum at night and increases to a maximum in mid-afternoon (2 to 3 p.m.) owing to oxidation of oxygen in air to ozone in the presence of sunlight. In non-polluted mid-latitude areas, the mid-afternoon O_3 is c. 72 ppb but less than 20 ppb at night. In polluted areas, however, mid-afternoon ozone concentration may rise to 300 ppb (Krupa & Manning, 1988).

In general, there is a steady-state relationship between NO, NO_2 and ozone in the atmosphere –

$$NO_2 + h_v(\lambda \leq 430\text{ nm}) \rightarrow NO + O$$
$$O + O_2 \rightarrow O_3$$
$$NO + O_3 \rightarrow + O_2$$

Human activity contributes to formation of O_3 and photochemical oxidants through introduction of VOC (Volatile Organic Carbon) compounds and NO_x.

A Review of the Status of Air Pollution

It has been noticed that at many places in the world, particularly in urban and industrial areas, the levels of SPM, SO_2 and NO_X in ambient air exceed the permissible limits. Thus, in the city of Calcutta, the annual mean SPM exceeds the WHO-prescribed annual mean by about 600%, the SO_2 95-percentile values too exceed the CPCB-prescribed limits (Table 2). An alarming aspect of the SPM is that 15-30% of the SPM consists of benzene-soluble organic matter (BSOM) while 25-30% of the BSOM, or 7-12% of the total SPM is made up of polynuclear aromatic hydrocarbons (PAH), which are known to be carcinogenic. It has been found that the levels of air pollution at Durgapur, Kalyani, and Haldia are also alarming (Table 3); in particular, the level of SPM far exceeds the norm for residential areas at all these towns, and at Durgapur and Kalyani, the SPM level exceeds even the norm for industrial areas, though marginally; at these places, too, the proportions of BSOM and PAH are substantial. Even in the rural/near-rural places in Gangetic West Bengal, viz., Debagram (Nadia), Jhalda (Purulia), Debagram (Midnapur) and Digha (Midnapur), the annual mean level of SPM exceeds the prescribed annual mean and the major part of the SPM consists of organic matter (Table 4), and the PAH content varies from 2 to 30% of the total SPM.

Table 2

Annual Mean and Monthly Maximum Values for SPM, SO_2, NO_X and Sulphation Rate for six Ambient Air Quality Monitoring Stations in Calcutta Industrial Area during 1978 and 1979
(unit for SPM, SO_2, NO_X is in *micrograms/m³*; *unit for Sulphation Rate is in mg SO_3/100 cm²/day*)

	SPM		SO_2		NO_X		Sulphation Rate	
Year 1978	**Annual Mean**	**Monthly Max**	**Annual Mean**	**Monthly Max**	**Annual Mean**	**Monthly Max**	**Annual Mean**	**Monthly Max**
Bhowanipur	292	546	20	51	17	32	0.37	0.93
Dalhousie	393	692	23	75	21	45	0.43	0.91
Cossipore	353	591	54	136	20	37	0.70	1.10
Maniktala	405	741	42	134	17	31	0.60	1.06
Howrah	415	722	48	127	20	30	0.45	0.07
Tollyganj	506	981	36	194	15	33	0.65	1.18
Year 1979								
Bhowanipur	440	1111	28	79		78	0.44	0.73
Dalhousie	483	917	50	112		55	0.54	1.16
Cossipore	413	897	48	146		43	0.60	1.04
Maniktala	519	1525	42	122		58	0.52	1.02
Howrah	578	1090	85	310		62	0.67	1.10
Tollyganj	558	1484	53	124		58	0.56	0.99
1980	404		36					
1989 – [illegible] Calcutta	554		87.5					
1992 – Mar-Dec (10 months)	225		19.5		99		0.28	

Table 3

Annual Mean and Monthly Maximum Values for SPM, SO_2, NO_x and Sulphation Rate for Durgapur (1978, 1979), and Haldia (1985-86), mean of four 4-hourly measurements at Kalyani in Sept. 1984 for comparison
(all values in micrograms/m^3; Sulphation Rate in mg SO_3/100 cm^2/day)

Year 1978	SPM		SO_2		NO_x		Sulphation Rate	
	Annual Mean	Monthly Max	Annual Mean	Monthly Max	Annual Mean	Monthly Max	Annual Mean	Monthly Max
Durgapur (1978)	147.2	606.4	16.9	104.6	22.6	139.7	-	-
Durgapur (1979)	196.1	384.5	14.9	63.5	27.3	136.8	-	-
Haldia (1985-86)	189.3	611.8	4.3	17.6	16.4	137.5	0.116	0.27
	Monthly		Monthly		Monthly			
	(mean)	(max)	(mean)	(max)	(mean)	max)		
Kalyani (Sept. '84)	101.7	171.9	65.6	97.8	46.0	62.1	-	-

Table 4

Seasonal means of suspended matter and some gaseous pollutants (in micrograms/m^3) at four rural and non-industrial places in Gangetic West Bengal (Saha *et al*, 1985)

Stations	Season	Suspended matter (SPM)	Sulphur di-oxide	Nitrogen Oxide	Mean organic matter concentration (as % of SPM)
Debagram	Winter	123.5			
	Summer	190.1	5.4	10.1	54.7
	Rainy season	43.9	6.3	9.3	52.6
Jhalda	Winter	191.0	10.8	17.4	40.9
	Summer	190.5	3.7	7.1	46.8
	Rainy season	94.7	6.6	10.7	47.9
Jhargram	Winter	105.8	5.0	10.3	55.1
	Summer	95.6	4.1	5.9	46.8
	Rainy season	43.5	4.8	4.4	67.2
Digha	Winter	109.7	9.5	23.2	24.8
	Summer	88.3	5.1	4.7	38.7
	Rainy season	62.2	8.0	9.6	57.0

The fact that a substantial portion of the SPM consists of benzene-soluble organic matter indicates that a major part of it is of industrial and vehicular origin. Now in Gangetic West Bengal the industries and vehicles are clustered in two zones only – the Calcutta Metropolitan area and the Durgapur-Asansol region, where the industries are coal-burning. Thus the entire emissions from these two regions are spreading over the entire Gangetic West Bengal, even to the sea-coast health resort of Digha. This is not surprising, because it is known from the experience of other countries that the emissions from industries, particularly the gaseous pollutants travel far and wide and pollute the rural atmosphere far away from the industrial areas. For example. SO_2 emitted from the factories in the UK is known to have travelled to Norway, where the pH of the water of some lakes has been lowered appreciably owing to the SO_2 being dissolved with rain.

An analysis of the 11-year annual data (1978-87) on SPM, SO_2 and NO_x for 10 large Indian cities was carried out by Sundaresan (1991). Annual mean values indicated positive trends in Bombay, Cochin and Jaipur; SO_2 levels also showed a positive trend in Cochin, Delhi and Nagpur, while NO_x levels showed a positive trend in as many as seven cities – Bombay, Calcutta, Cochin, Delhi, Hyderabad, Kanpur and Nagpur; increased trends in NO_x levels indicate higher levels of automobile pollution (Table 5). Studies carried out by CSME over the 10-month period March-December 1992 (Table 2) suggest that the trends indicated for Calcutta by Sundaresan, of decreasing SPM and SO_2 and increasing NO_x appear to be continuing, but the sharp increase of NO_x during 1992 is alarming – the most probable cause of such an upward trend of NO_x appears to be the sharp increase in the number of vehicles on the road with no worthwhile emission control measures.

Table 5

Long-term trends of ambient air: SPM, SO_2 and NO_x values (1978-87)

	Annual Mean Trends		
City	SPM	SO_2	NO_x
Ahmedabad	–	–	–
Bombay	+	–	+
Calcutta	–	–	+
Cochin	+	+	+
Delhi	–	+	+
Hyderabad	–	+	+
Jaipur		–	–
Kanpur	–	–	+
Madras	–	–	–
Nagpur	–	+	+

The problem of Acid Rain: Precipitation (rainfall and snowfall) is naturally acidic because of its equilibrium with atmospheric carbon dioxide as well as natural emissions of NO_x and SO_2. In the absence of human activity, natural long-term mean acidity in remote regions is of the order of pH 5.0, with range between pH 4.0 to 6.0. Hence a strict definition of acid rain is difficult. However, in recent years, industrial and vehicular emissions of SO_2 and NO_x have gone up sharply and these are causing increased precipitation acidity in certain parts of the globe, to pH 2.0 to 3.0. In areas of acid rain the soil gets severely degraded and the drainage in such areas is highly disturbed ecologically.

Global natural emissions of sulphur have been estimated to be in the range of 50-100 Tg Sy-1 (1 Tg - 10^{12}g) while man-made emissions are calculated to have been 80 Tg Sy-1 in 1979 (Twin & Williams, 1988); 90% of man-made emissions originate in the developed countries of North America and W. Europe. Emission of NO and NO_2 also play an important role in acid rain deposition, both directly and through photochemical production of ozone and OH radicals. A probable estimate of global NO_x emission is 60Tg N y^{1}. While SO_2 emissions in many countries began to decrease slightly since the 1970s, NO_x emissions have continued to increase. It is possible that over the next 5-10 years NO_x emissions may become proportionately more important than SO_2 emissions.

Air Pollution and the Greenhouse Effect

In recent years, one important aspect of air pollution has assumed global significance. Because of the increasing emission of carbon dioxide from industries and vehicles and cutting down of trees (which inhale a part of carbon dioxide), the level of CO_2 in the atmosphere has been going up sharply. From an estimated CO_2 content of 250 ppm about three hundred years ago, the present level of CO_2 (global average) has come up to 350 ppm. Along with some other gases as nitrous oxide, methane and chloro-fluoro-carbons (CFC's), CO_2 has the property of absorbing heat which normally radiates out of the earth; as a result the global air temperature is slowly going up (greenhouse effect). If such global warming continues, parts of glaciers and ice on high mountains and the polar regions will melt; also sea water will undergo thermal expansion, leading to rise in the sea level. It has been estimated that if emissions of CO_2 and other greenhouse gases go on increasing, by 2050 AD, the sea level might rise by 1 metre, causing flooding of densely populated coastal areas of many countries and various other hazards. The CFC's contribute another serious hazard – they destroy ozone in the upper atmosphere which serves as a shield against ultraviolet radiation – already large holes have formed in the ozone layer over Antarctica and over the Arctic. Excessive ultraviolet radiation is deadly for man; also excess ultraviolet radiation may kill the plankton in the oceans (which absorb CO_2 from the atmosphere), then the CO_2 content of the atmosphere will go up further. Therefore there is a move to ban manufacture of CFC's all over the world. But unless consumption of coal and petroleum is drastically reduced, CO_2 concentration will go up (Leggett, 1990). Therefore, economic alternative sources of energy (such as solar energy) must be developed within the next few years in the interest of human survival.

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AIR QUALITY MODELLING

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Introduction

Air pollutants emitted from anthropogenic sources must first be transported and diluted in the atmosphere before these undergo various physical and photochemical transformations and ultimately reach their receptors. Otherwise, the pollutant concentrations reach dangerous levels near the source of emission. Hence, it is important that we understand the natural processes that are responsible for their dispersion. Effective dispersion of pollutants in the atmosphere depends primarily on the degree of stability of the atmosphere and on its turbulent structure. In the broadest sense, dispersion is controlled by meteorological conditions prevailing in the atmosphere.

Meteorological Aspects of Air Pollutant Dispersion

Temperature lapse rates and Stability: The degree of stability in the atmosphere, in turn, depends on the rate of change of ambient temperature with altitude. The relationship between temperature and altitude can be obtained by considering air to be an ideal gas. The change of pressure in the vertical direction may be represented as:

$$\frac{dp}{dz} = -\rho g \tag{1.1}$$

where p is the atmospheric pressure, z is the altitude and ρ is the atmospheric density. Also, the perfect gas relation,

$$p = \rho RT \tag{1.2}$$

holds at any point in the atmosphere where R is the gas constant for air, and T is the absolute temperature. Substitution of Eq. (1.2) into (1.1) gives the general expression for the variation of pressure with altitude:

$$\frac{dp}{dz} = -\frac{pg}{RT} \tag{1.3}$$

If we consider the simple case of isothermal atmosphere, Eq. (1.3) could be integrated directly to give

$$p = p_0 \exp\left(-\frac{g}{RT} z\right) \tag{1.4}$$

where p is the pressure at ground level (1.013 bars).

The above equation gives an exponentially decreasing pressure with altitude which is a typical characteristic of compressible fluids such as air. Comparison of this exponential behaviour with observed profiles shows a slight quantitative discrepancy and this discrepancy may be attributed to the fact that in the troposphere, the temperature decreases with altitude and is not a constant as was assumed in the model. However, this model of the atmosphere may still be used by assuming a series of air layers, each layer having a uniform but different temperature.

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A better model for the atmospheric dependence of p and T is the polytropic atmosphere which obeys the relation

$$T = T_0 \left(\frac{p^{n-1/n}}{p_0} \right) \tag{1.5}$$

Substituting Eq. (1.5) for p in Eq. (1.3) and differentiating, we get

$$\frac{dT}{dz} = -\frac{n-1}{n}\frac{g}{R} \tag{1.6}$$

Thus, Eq. (1.6) represents the variation of temperature with altitude for a polytropic model where the temperature decreases with altitude linearly with a slope of − (n−1) g/nR. The decrease in temperature (Fig. 1) with altitude is known as the lapse rate. Based on meteorological data in the troposphere up to about 10 km, where the temperature decreases linearly with altitude, the environmental lapse rate is found to be about

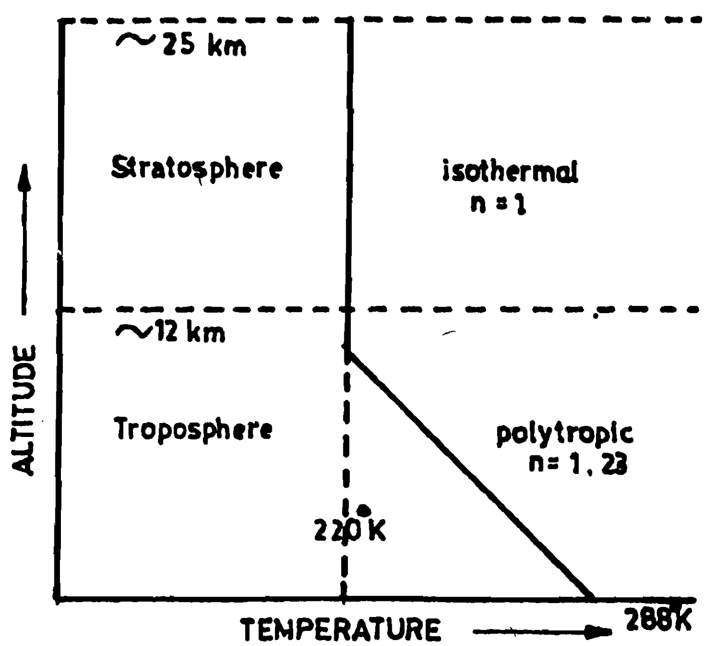

Fig. 1. Temperature-Altitude Profile.

6.5°C/1000 metres. Putting this value for dT/dz in the equation for polytropic model, we have

$$\left(\frac{dT}{dz_{env}} \right) = -\frac{6.5°C}{1000 \text{ metres}} = -\frac{n-1}{n}\frac{g}{R} \tag{1.7}$$

From the above equation, the value of n works out to 1.23. The lower atmosphere ends at the tropopause which is at an altitude of about 12 km. Above the tropopause is the stratosphere. In the stratosphere there are two distinct regions of temperature variation. The lower region, extending up to 25 km, has a temperature which is essentially constant, and in the upper region the temperature increases with altitude as a result of ozone formation. In the lower region of the stratosphere, the isothermal model based on n=1 is applicable. The temperature profiles based on these models are represented in Fig. 3.

The environmental lapse rate, however, is not always constant particularly in the lower troposphere, a zone from ground level up to an altitude of about 2 km where there is a considerable variation from the normal rate of 6.5°C/1000 metres. This is due to the character of the underlying surface and the rate or radiation emanating from it. On sunny days, because of strong solar heating from the ground, the environmental lapse rate often exceeds 10°C/1000 metres, although this is usually confined to the lowest 200 metres of the atmosphere. Extreme cases of atmosphere are characterized by a negative lapse rate, where the temperature increases with altitude.

Adiabatic Lapse Rate: The adiabatic decrease in temperature with altitude is especially important in the vertical movement of air pollutants and can be explained by utilizing the concept of an air parcel, which is pictured as a little sphere of air. As the air parcel rises in the atmosphere, it goes through a region of decreasing pressure and expands to accommodate the decreasing pressure. As it expands, it does work on the surroundings. Since the process is usually rapid, there is no heat transfer between the air parcel and the surrounding air. Hence, for the case of an adiabatic process, the first law of thermodynamics yields –

$$-dW = dU \tag{1.8}$$

This means that the internal energy decreases, thereby decreasing the temperature. The decrease in temperature of a rising, expanding air parcel is an important feature of vertical air motion. Now, the work done on the surroundings is equal to CVdT, where CV is the specific heat at constant volume. Substituting these terms in Eq. (1.8), we get

$$pdV + C_V dT = 0 \tag{1.9}$$

Eq. (1.9) may be written for unit mass of the air parcel as,

$$pdv + C_v dt = 0 \tag{1.10}$$

where V is the specific volume and CV is the specific heat per unit mass. For a perfect gas, Eq. (1.10) becomes,

$$\left(C_v + R\right)dT = vdp \tag{1.11}$$

The variation of temperature with altitude can be written as a product of two terms:

$$\frac{dT}{dz} = \frac{dT}{dp} \bullet \frac{dp}{dz} \tag{1.12}$$

Rearranging Eq. (1.11), we obtain

$$\frac{dT}{dp} = \frac{v}{C_v + R} \tag{1.13}$$

Substituting Eqs. (1.13) and (1.3) into Eq. (1.12), we get

$$\frac{dT}{dz} = \frac{g}{C_v + R} \tag{1.14}$$

Noting that CV + R = Cp, the specific heat at constant pressure per unit mass of air parcel, we can write Eq. (1.14) as

$$\frac{dT}{dz} = -\frac{g}{C_p} \qquad (1.15)$$

The above expression gives the temperature lapse rate For a dry parcel of air moving upwards adiabatically and is known as the 'dry adiabatic rate' When Eq. (1.15) is evaluated for dry air, the lapse rate is found to be

$$\frac{dT}{dz\ adia} = -9.86°C/1000 \text{ metres}$$

Thus, the dry adiabatic lapse rate, which is denoted by Γ, is given by

$$\Gamma = \left(-\frac{dT}{dz\,adia}\right) - 10°C/1km \qquad (1.16)$$

Comparing Eqs. (1.15) and (1.16), we see that for the adiabatic case n = γ = Cp/Cv, and is equal to 1.4 for dry air.

In the presence of moisture in the atmosphere, the lapse rate applicable is termed 'wet adiabatic lapse rate', which for warm tropical air is approximately equal to one-third of the dry adiabatic lapse rate.

Atmospheric Stability: The ability of the atmosphere to disperse the pollutants emitted into it depends to a large extent on the degree of its stability. A comparison of the adiabatic lapse rate with the environmental lapse rate gives an idea of the stability of the atmosphere. Fig. 2 (on following page) illustrates the temperature profiles for various cases of stability. When the environmental lapse rate and the dry adiabatic lapse rate are exactly the same, a rising parcel of air will have the same pressure, temperature and density as the surroundings and would experience no buoyant force. Such an atmosphere is said to be neutrally stable, where a displaced mass of air neither tends to return to its original position nor tends to continue its displacement.

When the environmental lapse rate (–dT/dz)env is greater than the dry adiabatic lapse rate, Γ, the atmosphere is said to be super-adiabatic. Hence a rising parcel of air, cooling at the adiabatic rate, will be warmer and less dense than the surrounding environment. As a result it becomes more buoyant and tends to continue its upward motion. Since vertical motion is enhanced by buoyancy, such an atmosphere is called unstable. In the unstable atmosphere the air from different altitudes mixes thoroughly.

On the other hand, when the environmental lapse rate is less than the dry adiabatic lapse rate, Γ, a rising air parcel becomes cooler and more dense than its surroundings and tends to fall back to its original position. Such an atmospheric condition is called stable and the lapse rate is said to be sub-adiabatic. Under stable conditions there is very little vertical mixing and pollutants can only disperse very slowly (Fig. 2).

A similar reasoning may be applied to the case of a saturated atmosphere. Thus, instability and stability may be defined with reference to a neutrally stable atmosphere where the environmental lapse rate is equal to the dry adiabatic lapse rate for dry or unsaturated air, and wet adiabatic lapse rate for saturated air. Strictly speaking, however,

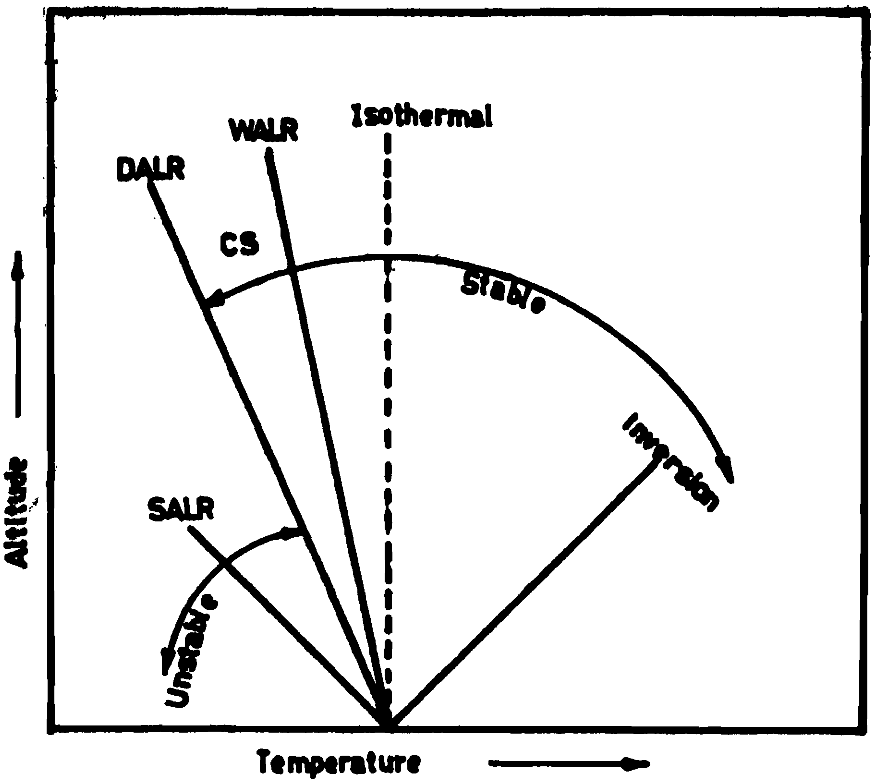

Fig. 2 Atmosphere stability region
(SALR: Super-adiabatic lapse rate; DALR: Dry adiabatic lapse rate;
WALR: Wet adiabatic lapse rate; CS: Conditional stability)

an absolute instability exists if the environmental lapse rate is greater than the dry adiabatic lapse rate, and an absolute stability exists if the environmental lapse rate is less than the wet adiabatic lapse rate. Conditional stability occurs if the environmental lapse rate is between these two values.

The extreme case of a stable atmosphere, called an 'inversion', occurs when temperature increases with altitude. Such a lapse rate is known as the 'negative lapse rate' Under these conditions, the atmosphere is very stable and practically no mixing of pollutants takes place.

Inversions: Atmospheric inversions influence the dispersion of pollutants by restricting vertical mixing. There are several ways by which inversion layers can be formed. One of the most common types is the 'elevated subsidence inversion' This is usually associated with subtropical anticyclones where the air is warmed by compression as it descends in a high pressure system and achieves temperatures higher than that of the air underneath. If the temperature increase is sufficient, an inversion will result. Fig. 3 illustrates this condition and temperature profile for the subsidence inversion. The subsidence is caused by air flowing down to replace air which has flowed out of the high pressure region.

The second common form of inversion is the 'radiation inversion' This results from the normal diurnal cooling cycle. After sunset, the ground cools quickly by radiation heat transfer and the lowest layer of air in contact with the surface loses sensible heat through conduction and small-scale mixing. Consequently, a temperature inversion is set up between the cool low-level air and the warmer air above, in the first hundred metres above the surface. Valleys and low-lying areas are particularly affected by this type of nocturnal inversion because denser, colder air tends to sink beneath the warmer air. The next day sunlight destroys the inversion and the air previously stratified by inversion is overturned by convective currents. The temperature profile for a combined radiation inversion and subsidence inversion is illustrated in Fig. 4 (on the following page). The subsidence inversion is potentially more serious than radiation inversion because the

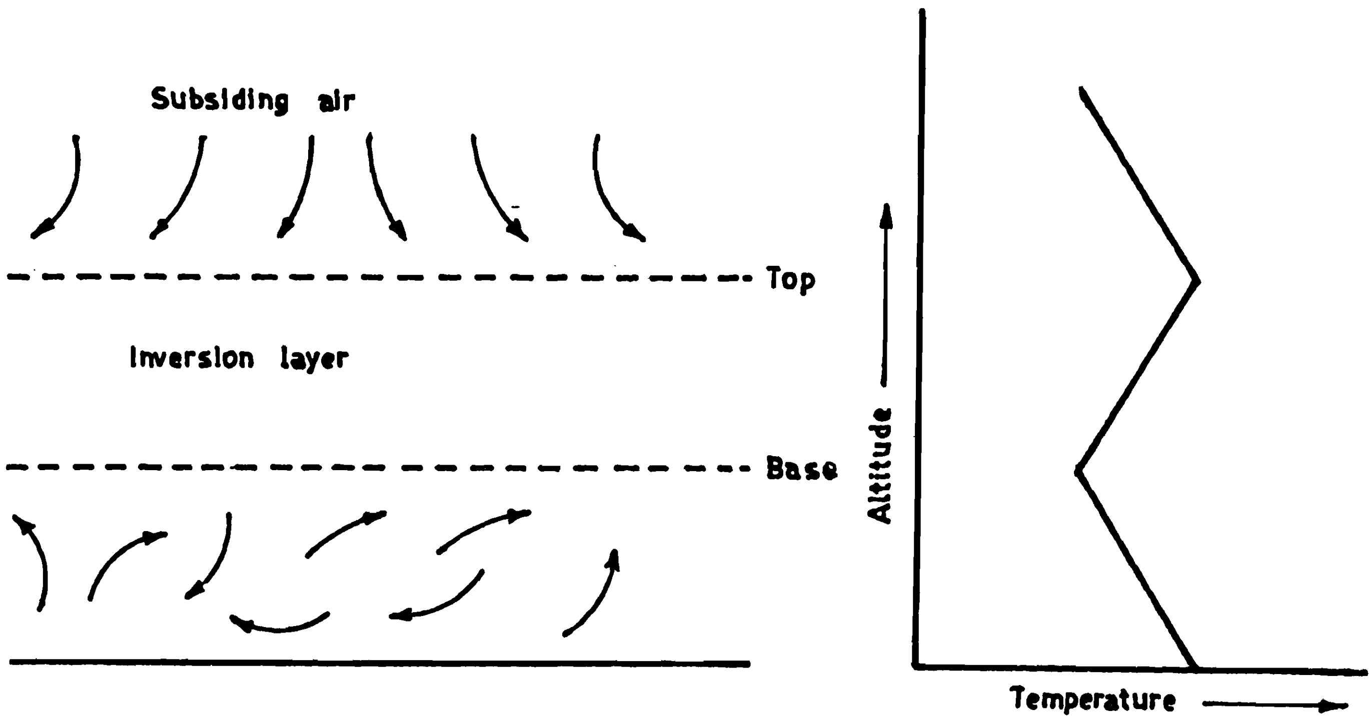

Fig. 3: Formation of subsidence inversion and the temperature profile

latter usually dissipates quite rapidly after sunrise.

The third type of inversion, known as 'advective inversion', is formed when warm air moves over a cold surface or cold air. The inversion can be ground-based in the former case, or elevated in the latter case. An example of an elevated advective inversion occurs when a hill range forces a warm land breeze to flow at high levels and a cool sea breeze flows at low levels in the opposite direction. This is shown in Fig. 5.

As mentioned earlier, during an inversion, the vertical mixing of air is practically absent as the atmosphere is very stable, but this condition does not preclude horizontal motion of air currents. It is quite possible that strong winds may be encountered within an inversion.

Wind Velocity and Turbulence: Differential solar heating of the earth's surface produces pressure and temperature gradients. As a result, the atmosphere is practically in continuous motion with air movements being always turbulent. The motion of air near the surface of the earth is retarded by friction, which varies with surface roughness. The

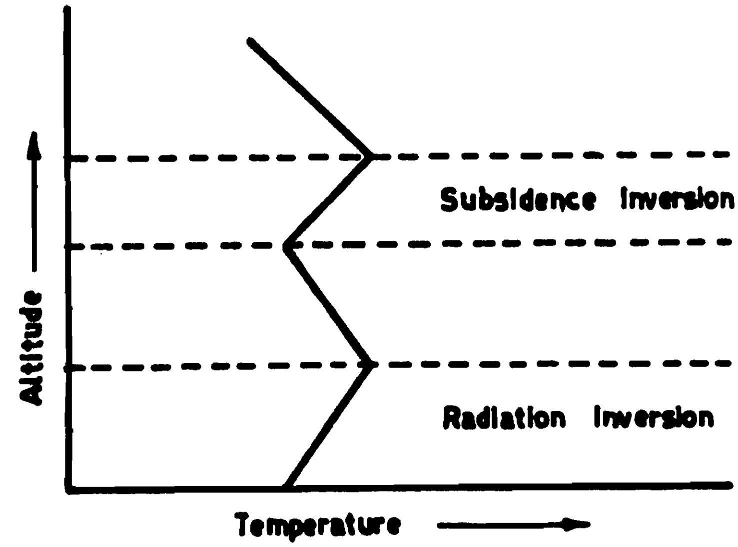

Fig. 4: Temperature profile with subsidence and radiation inversions

planetary boundary layer, in which friction is significant, extends to about 1 km above the earth's surface. The wind velocity profile within the layer is not only influenced by the surface roughness but also by the time of the day. During the day, solar heating causes thermal turbulence or eddies and these eddies set up convective currents, so that turbulent mixing is increased. This results in a more flat velocity profile in the day than at night. Typical profiles during the day and night are shown in Fig. 6. Thermal

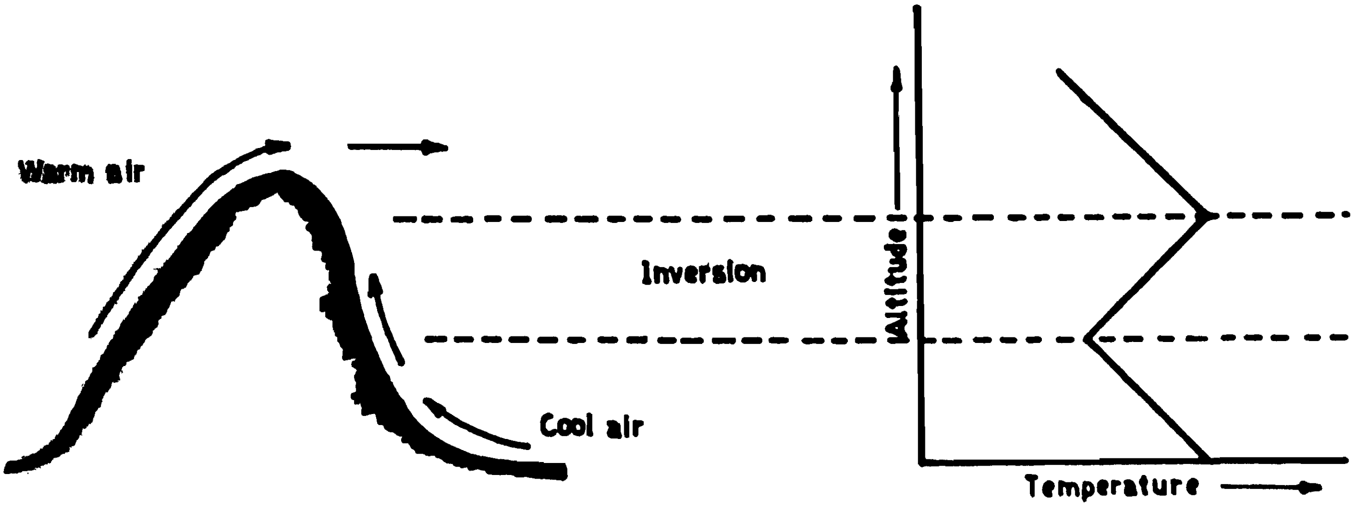

Fig. 5: Elevated advective inversion

turbulence also depends on the thermal stability of the atmosphere. It is maximum on a clear sunny day in the afternoon and minimum at night or in the early morning.

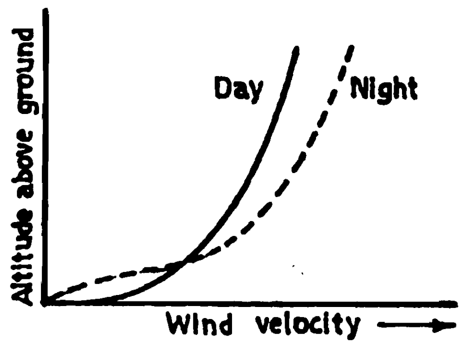

Fig. 6: Wind velocity profiles during the day and night

The second type of turbulence is the 'mechanical turbulence' which is produced by the shearing stress generated by air movements over the earth's surface – the greater the surface roughness, the greater the turbulence. The effect of terrain on the wind velocity profiles is shown in Fig. 7. For smooth surfaces, the air velocity profile becomes very steep near the ground. For rougher surfaces, such as those in urban areas, more mechanical turbulence is generated and the velocity profile becomes less steep and reaches deeper into the atmosphere.

The mean wind speed variation with altitude in the planetary boundary layer can be represented by a simple empirical power law such as:

$$\frac{u}{u_1} = \left(\frac{z}{z_1}\right)^{\alpha} \qquad (1.17)$$

where u is the wind speed at altitude z, u_1 is the wind speed at altitude z_1 and exponent α varies between 0.14 and 0.40, depending on the roughness of the ground surface, as well as on the temperature stability of the atmosphere. If the environmental lapse rate is dry adiabatic and the terrain is fairly smooth, α is approximately 1/7. The exponent is observed to increase with increasing stability or with increasing surface roughness. The recommended values of α for a range of conditions are given in Table 1. In practice, because of the appreciable change in wind speed with altitude, a wind speed value must be quoted with respect to the elevation at which it is measured. This reference height for surface wind measurement is usually 10 metres.

Plume behaviour: The behaviour of a plume emitted from an elevated source such as a tall stack depends on the degree of instability of the atmosphere and the prevailing wind turbulence. Typical situations, as generally encountered, are shown in Fig. 7.

A common type of plume behaviour is 'looping' It occurs under super-adiabatic conditions with light to moderate wind speed on a hot summer afternoon, when large-scale thermal eddies are present. These eddies carry portions of the plume to the ground level for short time-periods, causing momentary high surface concentration of pollutants near the stacks.

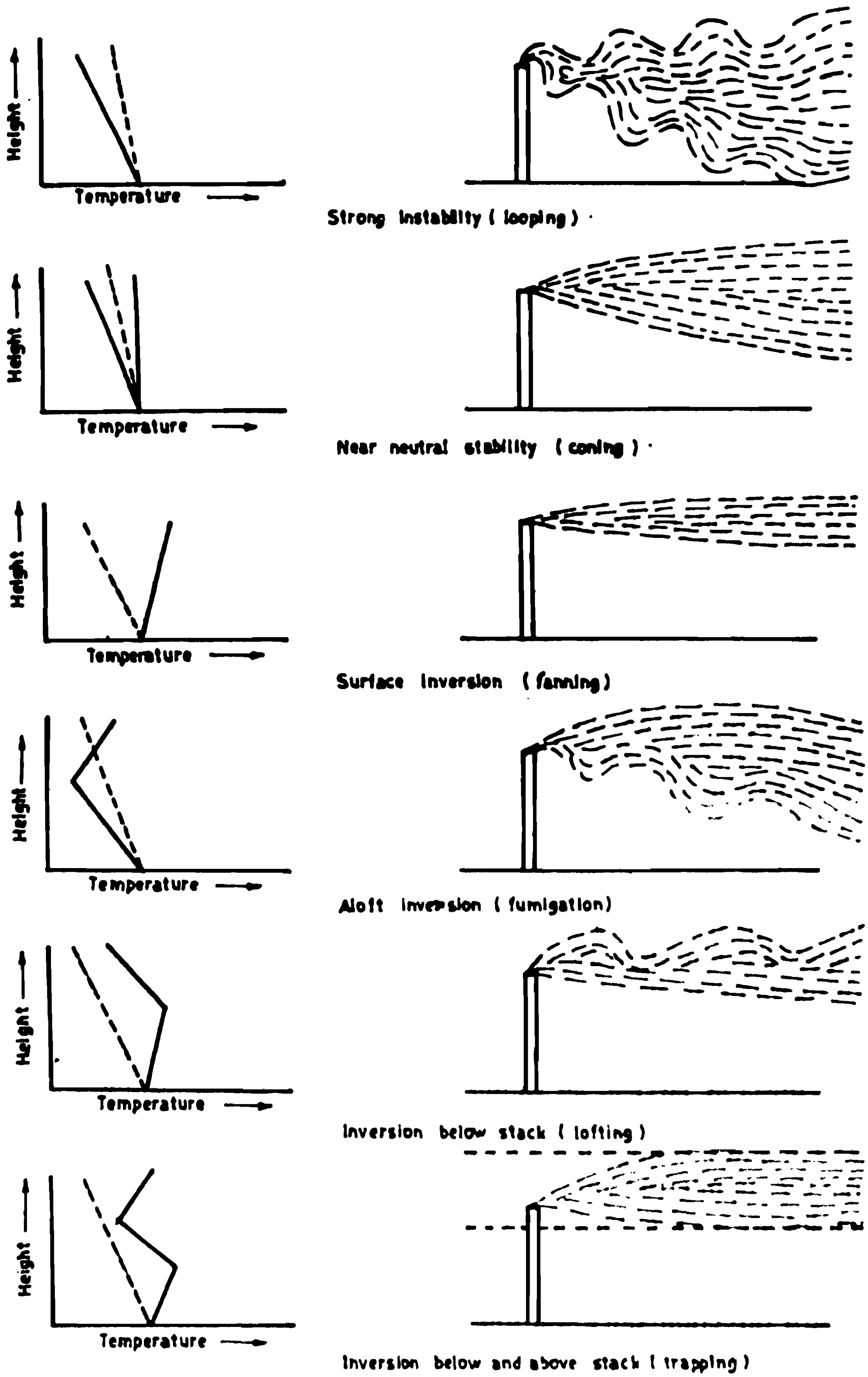

Fig. 7. Plume behaviour under various conditions of stability

Table 1

Values of Exponent in Eq. (1.17)*

Surface configuration	Stability		Ref
Smooth Open country	Unstable	0.11	(1)
	Neutral	0.14	
	Moderate stability	0.20	
	Large stability	0.33	
Flat Open country	Neutral	0.16	(2)
Suburbs	Neutral	0.28	
Urban Areas	Neutral	0.40	

**From G.H. Strom,* Air Pollution, *edited by A.C. Stern, Vol. 1, 3rd Edition (Academic Press, New York) 1976*

'Coning plume' can occur under cloudy skies both during day and night, when the lapse rate is essentially neutral. The plume shape is vertically symmetrical about the plume line and a major part of the pollutant concentration is carried fairly downwind before reaching the ground level. Coning is often associated with moderate to high wind speeds.

'Fanning' occurs when the plume is dispersed in the presence of very light winds as a result of strong atmospheric inversions. The stable lapse rate suppresses the vertical mixing, but not entirely the horizontal mixing. If the density of the plume is not significantly different from that of the surrounding atmosphere, the plume travels parallel to the ground in a flat, straight ribbon downwind and, on occasions, plumes in a stable layer may be observed for 10 to 20 km downwind. For high stacks, fanning is considered a favourable meteorological condition because the plume does not contribute to ground pollution. A fanning plume is often observed at a certain height and in the early mornings.

The preceding three types of plume behaviour are observed under conditions of uniform lapse rate, but when the lapse rate changes from stable to unstable – a situation usually arising when an inversion is breaking up in the early morning when the sun comes up – a condition known as 'fumigation' takes place. Here a stable layer of air lies a short distance above the release point of the plume and an unstable air layer lies below the plume. This unstable layer of air causes the pollutants to mix downwards towards the ground in large lumps, but fortunately this condition is usually of short duration, lasting for about 30 minutes. Fumigation is favoured by clean skies and light winds, and is more common in the summer season.

The conditions for the 'lofting plume' are the inverse of those for fumigation; the lapse rate in the upper portion of the plume is unstable and in the lower portion, stable. When the pollutants are emitted above the inversion layer, they are dispersed vigorously in the upward direction since the top of the inversion layer acts as a barrier to the movement of pollutants towards the ground. Lofting is the most favourable plume type are far as ground level concentrations are concerned and is one of the major goals of tall-stack operation.

The 'trapped plume' occurs when the plume is caught between two inversion layers. The diffusion is severely restricted to the unstable layer between the two stable regions. Trapping may also be associated with subsidence inversions lasting for several days, where almost all emissions are trapped below the inversion layer, thus creating one of the worst pollution situations.

Terrain Effects: Deflection and disturbance of the wind field by a structure has a major influence on the distribution of pollutants from a stack on or close to the structure. The flow around an isolated building is characterized by the formation of a cavity behind the building and a wake further downstream. A simplified and idealized representation for a sharp-edged building is shown in Fig. 8. When the chimney stack is situated on or adjacent to the building, the plume may be entrained in the characteristic flow pattern. An empirical rule-of-thumb for such stacks is that the height of the stack should be at least two-and-a-half times the height of the surrounding building(Fig. 9). If the stack

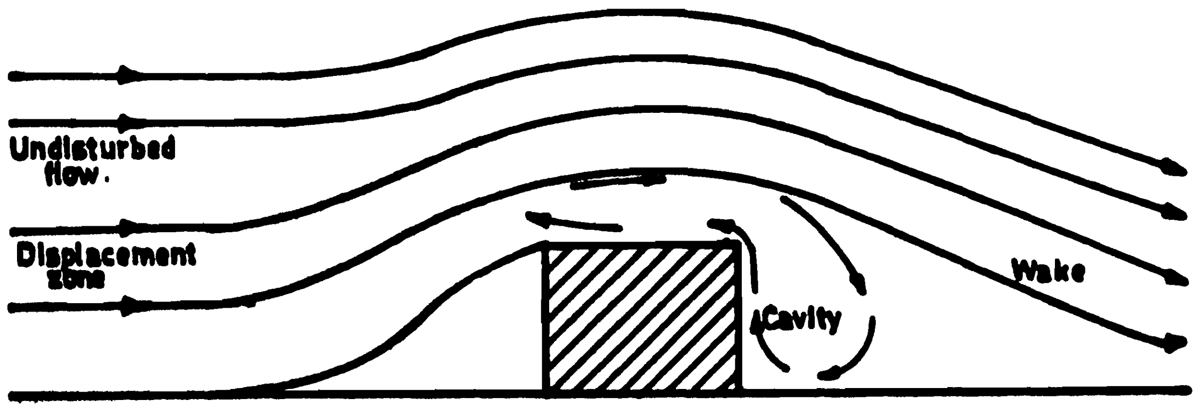

Fig. 8. Wind flow field around a sharp-edged building.

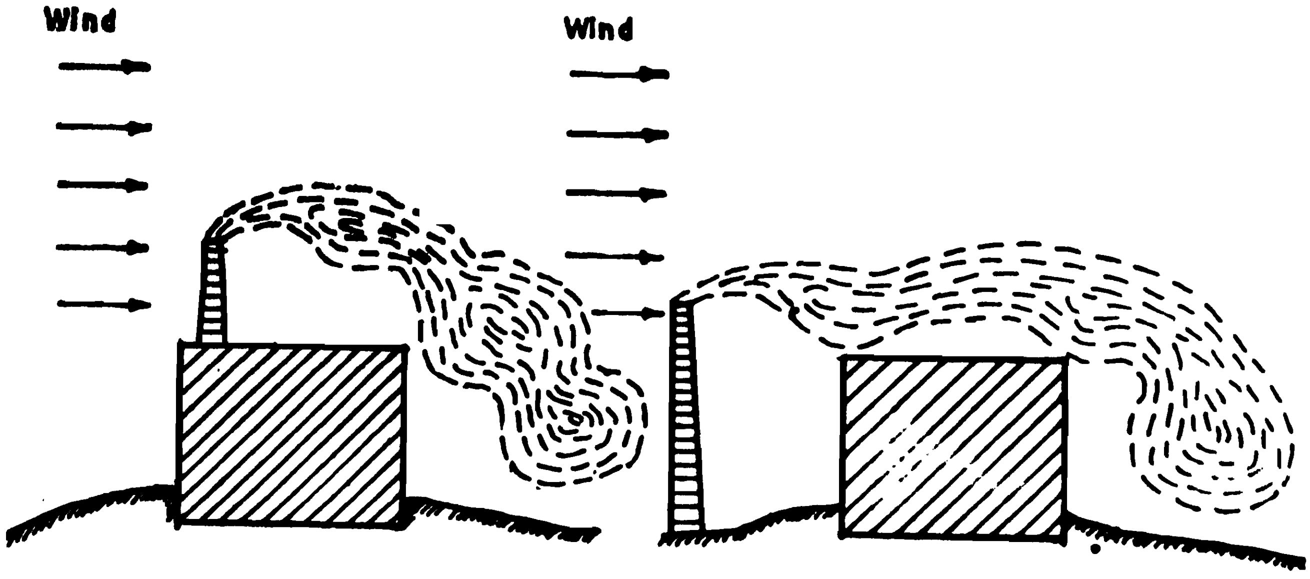

Fig. 9. Effect of buildings on plume behaviour.

height is much below this value, the plume is trapped in the wake zone of the building. Pollutants remain in the wake because of very poor mixing between the cavity and the mainstream.

Similarly, an irregular terrain surrounding a stack can have a marked influence upon the behaviour of a plume. A plume emitting from a stack located in a deep valley can be carried to the ground when the wind blows over a cliff, as shown in Fig. 10. This condition, known as 'downwash' occurs unless the stack extends well above the rim of the valley.

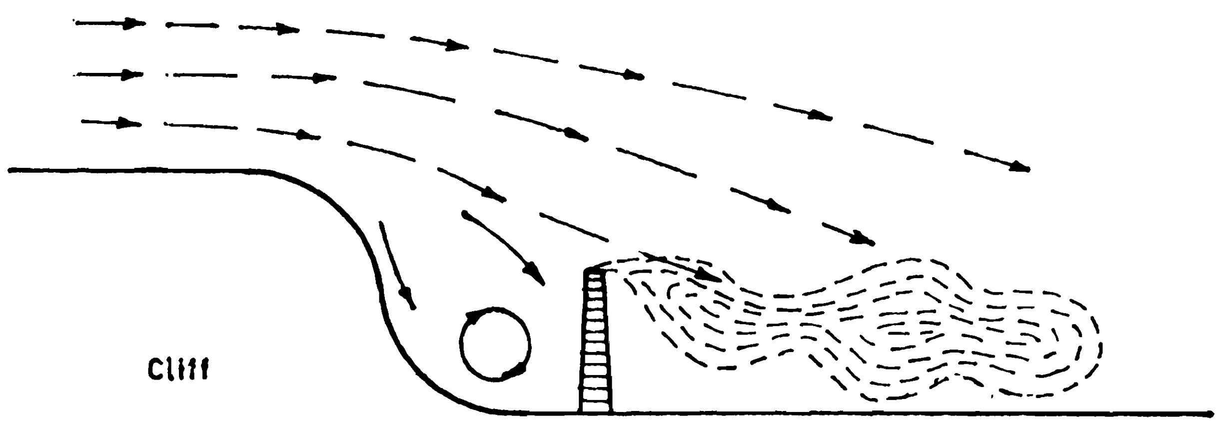

Fig. 10. Behaviour of the plume in a valley.

Separation behind a cylinder or a chimney will also result in downwash of the pollutants trapped in the separated regions of flow. If the velocity of the plume through the stack is about equal to or less than the wind velocity, the plume may not rise above the stack level and may even be carried downward on the backside of the stack (Fig. 11). The behaviour of the plume in the presence of aerodynamic disturbances is difficult to estimate and most of the design information is obtained through wind tunnel testing.

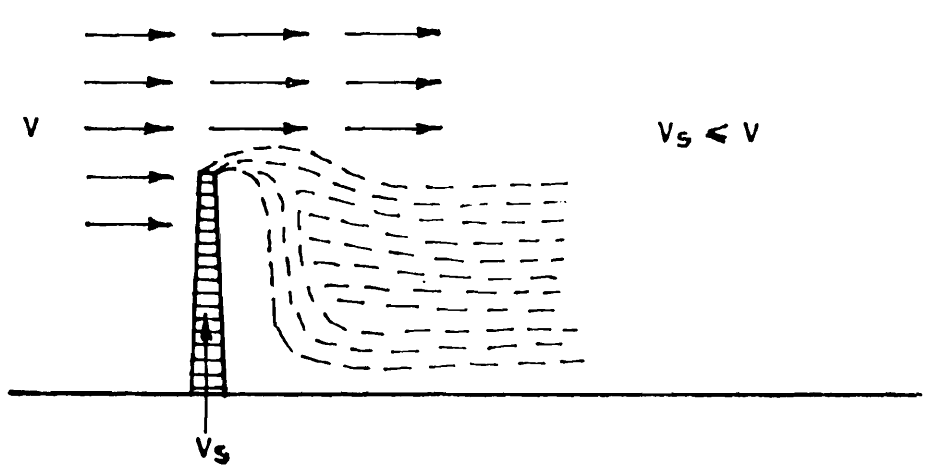

Fig. 11. Downwash of pollutants in the separated region

Gaussian Plume Model: Many types of air quality dispersion models are in existence, *e.g.*, statistical models, diagnostic models, eulerian dispersion models, etc., of both simple and complex forms. However, the Gaussian plume model remains the most commonly used air pollution dispersion model due to its easy applicability.

The dispersion estimates are made following the assumption that the plume spread has a Gaussian distribution in both horizontal and vertical planes with standard deviations of plume concentration distribution in the horizontal and vertical planes of σy and σz respectively. The model is represented by equation 1.18:

$$C = \frac{Q}{\pi_{\sigma_y}\sigma_z u}\exp\left\{-\frac{1}{2}\left(\frac{y^2}{\sigma_y}\right)^2\right\}\exp\left\{-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right\} \qquad (1.18)$$

where	C	=	the ground level concentration of the pollutant
	Q	=	the emission concentration of the pollutant
	σy, σz	=	the standard deviations of plume concentration distribution in the horizontal and vertical planes
	u	=	the wind speed at stack height
	H	=	the effective stack height.

The concentration C is normally expressed in micrograms/cubic metre of air.

The algorithm provides values for 10-minute concentrations, from which the 1-hour, 8-hour or 24-hour values may be deduced, as required. Long-term seasonal concentrations may also be determined using the Gaussian version, after accounting for wind frequencies in the different cardinal directions.

The stability classes are determined from Pasquill's dispersion classes, based on surface wind speed and incoming solar radiation in accordance with Table 2.

Table 2

UNSTABLE CONDITION EITHER A OR B OR AB					
	DAY			NIGHT	
	Incoming Solar Radiation			Thinly overcast or > 4/8 low cloud	< 3/8 cloud
surface wind speed (at 10m) metres/sec	Strong	Moderate	Slight		
< 2	A	A	B		
2 - 3	A	B	C	E	F
3 - 5	B	B	C	D	E
5 - 6	C	C	C	D	D
> 6	C	D	D	D	D

Class A: Most unstable; Class B: Most stable; Class D: Neutral

The power law function is used to compute σy and σz. The variation of σy and σz with downwind distance and stability class is presented in the homographs (Figs. 12 and 13),

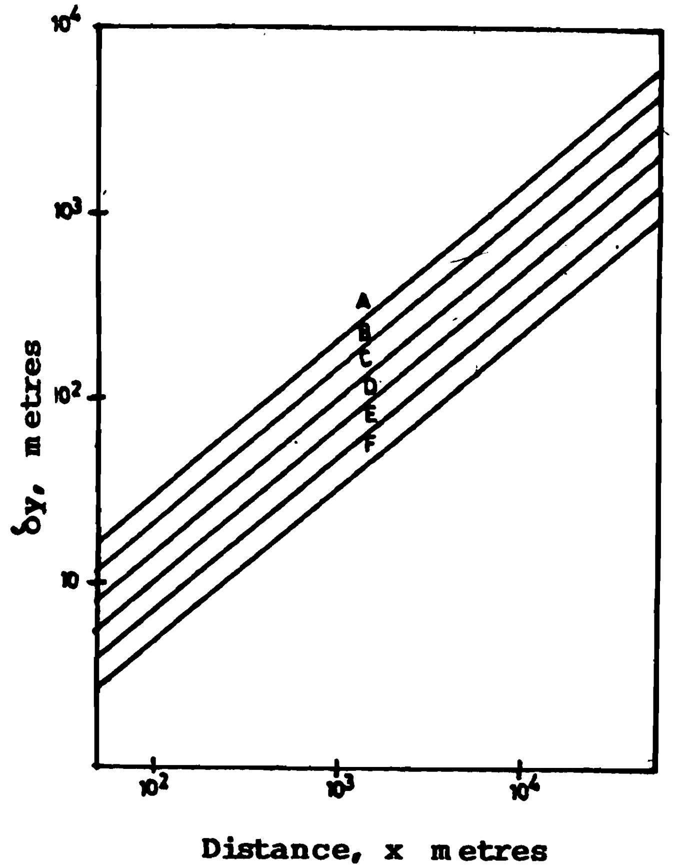

Fig. 12: σ_y as a function of down wind distance

The model is widely used to predict incremental increase of pollutants from future projects, as well as to determine the contribution of exiting ones in operation, to the baseline ambient air quality, thus leading to a validation of the monitoring data.

Plume rise: An important consideration in the methodology is that the dispersion starts from the topmost point in the vertical line of the plume, thus rendering the plume rise computation, a very important aspect of the model. The effective stack height, represented in algorithm 1.19, is thus the sum of the stack height and the plume rise, viz.,

$$H = H' + \Delta h \qquad (1.19)$$

where,

H' = the physical stack height

Δh = the plume rise.

Likewise, there are many versions for computing plume rise presented by Holland's,

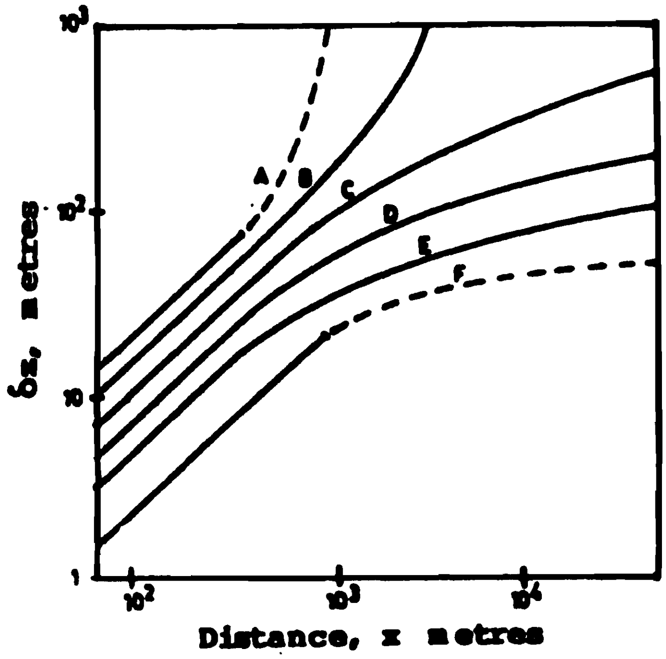

Fig. 13: σ_z as a function of down wind distance

Lucas' or Briggs', etc.; the latter is however, accepted to be most apt for hot plumes. The plume rise in Briggs' equation is a function of the buoyancy flux parameter.

Suggested Readings

1. GIFFORD, F.A. 1960. Atmospheric Dispersion Calculations using the generalised Gaussian plume model, Nuclear Safety, 2, 2, 56-59, 67-68.

2. U.S. Department of Health, Education and Welfare, PHS. 1965. Workbook of Atmospheric Dispersion Estimates: 1-59.

3. DICKSON, K.L, BUKI, A.W., and CAIRNS, J. Jr. 1982. Modeling the fate of Chemicals in the Aquatic Environment, Ann Arbor Science, p. 407.

VEGETATION AND FLORA

L. K. BANERJEE *

Introduction

At the very beginning it is important to provide an idea regarding the Ecology and Ecosystem for understanding various natural processes of Environment. The term Ecology may be defined as a study comprising the inter-relationship between the living organisms and the surrounding environmental factors and the term Ecosystem, the structural and functional unit of ecology may be defined as reciprocal interaction of organism and their environmental factors involving flow of energy and cycling of minerals in an uniform topographic situation and vegetation pattern. The limitation on the rate and amounts of the mineral and energy circulation depend on the environmental factors, such as climate, edaphic biotic and energy economy processes and impact of this limitation react upon the structure of the ecosystem. It is established that Structure, Function, and Factors of an environment form a Triangular interaction in the study of Ecology and Ecosystem.

Vegetation

Vegetation is the total plant cover of a region, area or place with various aspects of plant community zonation, their structure, function, environmental factors and classification. The efficiency with which each plant community tolerates environmental condition largely determines its position in a phytogeographical division and nature of their morphological adaptation. Vegetation is the renewable natural resource and primary producer of both food and energy. It stands in the top place not only as the most precious ones but also as it is in the forefront among the most endangered resources and are constantly under pressure due to ever increasing demand put on them from the rapidly expanding human population. The vegetation cannot simply assume as an unit assemblage of some tree, shrubs and herbs but it should be looked as a socio-biological unit which form a common platform for innumerable other living organism in a harmonized relationship with the nature in its biodiversity. There is a continuous action and reaction among the living and non living environmental factors like soil, water, air, temperature etc. involving cooperation and conflict for natural balance or Ecological balance. Besides, the primary producer its utility is largely dependent on the preservation and protection of wild germplasm and genetic resource pool. It prevent soil erosion and can reduce particulate matter of 120 micron gram per square meter of leaf surface over a distance of 200m. It is the primary source by which we can reduce the noise and dust pollution and successfully preserve the fertility of the surface soil.

India has a very rich plant diversity and due to its very significant altitudinal variations from the sea level to the highest mountain ranges, hot and cold desertic conditions in the west and in the north and humid-tropical conditions in some parts of the country, the vegetation and flora shows great diversity. Each plant species is unique in its size,

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shape, growth, chemical constituents, productivity and potential source of genes for a variety of characters. These plant resources are responsible for economic products such as food, fodder, timbers, fuel, minor forest products, medicines, dyes, tannins, fibres, gums and many others.

Our country is now passing through an acute phase of quick development projects like big dams, Hydro-electricity, Thermal-power plant, Mining activities, High sounding irrigation projects, rapid urbanization and various technological extension or expansion of Industrial projects. These are responsible for causing environmental hazards like, soil erosion, water logging, high salinity, loss of top soils, destruction of valuable plant resource etc. injuring our nature and other biotic neighbours. Besides these, it may be pointed out that in an average of 100 billion tonnes of various ores are extracted annually from the earth, more than 50 million tonnes of non-biodegradable synthetic products are dumped on the earth, more than 600 million tonnes of mineral fertilizer and pesticides, more than 200 million tonnes of carbon- monoxide, 146 million tonnes of Sulphur dioxide, 53 million tonnes of Nitrogen oxides, 250 million tonnes of dust particles, 70 million tonnes of other poisonous gasses and 30 billion cubic meters of untreated wastes are discharged on earth's surface and atmosphere resulting a serious pollution of land, water and vegetation. It is found that out of 305 million hectors, as much as 175 million hectors, of land areas in India are now exposed to environmental hazards. These results are becoming very prominent in the form of Acid rain, Green house effect, Ozone layer depletion and others. The relentless pressure of an ever increasing population and un-planned developmental projects have caused a serious loss of habitat for the biotic species and many of our natural biodiversities along with valuable genetic resources have become rare, threatening, endangered and even extinct.

It is a fundamental question how to check these hazards in order to bring a balance development or Ecologically stable development. it is well known that mis-utilization and lack of scientific knowledge and responsible for threatening the natural biodiversity and un-planned developmental activities. Therefore, a balance planning keeping in view of the physical biotic resource, people's need, feasible developmental alternatives and impacts of such development on the people, environment and other valuable biodiversities has to be taken into consideration within the frame work of nationally accepted policies and priorities for developmental work. Department of environment, Govt. of India has been entrusted with this task of environmental protection and conservation policies.

Study of vegetation, correlation between the ecological factors and plant zonation, vegetation types and distribution have been made by various naturalists and Botanists in India and some of them may be briefly mentioned as most important work, such as, Hooker & Thomson (1855), Hooker (1907), Calder (1937), Chatterjee (1939), Meher Homjee (1991), Blasco (1979), Champion & Seth (1968), M.S. Mani (1974), Armen Takhtajan (1988), G.S. Puri *et al.* (1983), Rao & Sastry (1972), L.K. Banerjee (1984, 1985, 1989, 1990) and others. Recently Banerjee & Sastry (1993, in press) have divided Ecozones in India into 4 macro geographical regions depending on the climatic, edaphic and vegetation patterns as: 1. Himalayan regions, 2. Greater plains, 3. Peninsular uplands and 4. Coastal plains and Islands.

According to the micro-ecological variations of these 4 macro zones, Indian vegetation regions have been further divided into 28 meso-vegetation zones. Of these only 13 zones have been discussed here in the text.

Classification of Vegetation

It is required mainly for recording information in an orderly manner of the status of habitat, structure and function of the plant covers, conservation strategy and prompt recovery. In India zonation of plant community varies due to different climatic edaphic and geological settings of the country. The voluminous work in this line by Champion & Seth (1968) will be so far the best classification of Indian forest types and that has been briefly summarized here:

1. **Wet evergreen types:** Tall evergreen trees with dense canopy and many stories are found mostly in highly leached acidic soils consisting of granites, sandstones and alluvial soils, (West Bengal, Assam, Karnataka, and Andaman Islands) with widely distributed genera are : *Dipterocarpus, Hopea, Mesua, Artocarpus, Eugenia,* and *Elaeocarpus.*

2. **Semi-evergreen type:** Tall trees with closed canopy of both evergreen and deciduous types are found exclusively in red soils (upper Assam, West Bengal, Orissa and Western Ghats). Dominant genera are *Xylia, Terminalia, Dipterocarpus, Schleichera, Litsea and Bamboos.*

3. **Moist deciduous type:** Trees (40-60m tall) mostly deciduous during February to April. The understorey is covered with evergreen shrubs. It is restricted to the Indo-Gangetic alluvium mixed with laterite and ferruginous soils (Karnataka, part of Madhya Pradesh and Gujarat, Uttar Pradesh, Bihar, Orissa, West Bengal and Assam). Along the southern part *Tectona grandis* and along the northern part the *Shorea robusta* are the most important elements. *Terminalia, Lagerstromia, Pterocarpus, Careya* and *Mallotus* are the common associates in this type.

4. **Littoral and Tidal swamp type:** Medium size trees, evergreen in nature, are found along coastal beach forests, estuaries and deltas on the Indian coast. Most of the genera are adapted morphologically to withstand diverse ecological conditions of the habitat, found on sand beaches, sand dunes, new alluvium of salty and muddy soils. The dominant genera in littoral beach forests are *Malinkara, Calophylum, Thespesia, Heritiera, Ipomoea, Spinifex* and in tidal forests *Rhizophora, Sonneralia, Buguiera, Avicennia, Ceriops, Heritiera, Phoenix* and others.

5. **Dry deciduous type:** Trees (10-20m tall) will uneven canopy remain deciduous for several months during dry season. Due to more light the undergrowth comprises grasses and shrubs, but canes and palms are absent. Dry deciduous vegetation is found on dry soils of sandy laterite and shallow clay (Peninsular India, Uttar Pradesh, Gujarat, Madhya Pradesh, Rajasthan, Punjab, Bihar, Orissa and West Bengal). *Anogeissus, Tarminalia, Boswellia Sterculia* and *Tactona* are the dominant genera.

6. **Thorn Type:** Trees (5-8m tall) with hard woods and thorns predominate. Undergrowth of herbs and shrubs are spiny with development of xerophytic characters. The thorn forests are found on shallow dry alkaline soils of sandy, black cotton and lateritic

nature (Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Tamil Nadu). Characteristic genera are *Acacia Euphorbia, Capparis, Zyzyphys,* and *Opuntia.*

7. Dry evergreen type: This type is restricted to the dry Karnataka coast with characteristic genera like *Malinkara, Strychnos, Drypetes, Euginia* and others on lateritic and sandy soils.

8. Southern sub-tropical broad-leaved hill type: According to high or low range of rainfall this type is mixed with evergreen and deciduous trees on different ranges of hills between 1,000m and 1,700m. Soil is intermediate between red and brown with lateritic cap on the top (Mt. Abu, Parasnath hill, Valley and higher hills of central India). Most dominant genera are *Syzygium, Melastoma, Memecylon, Hypericum, Litsea* and others.

9. Northern sub-tropical broad-leaved hill type: Trees (20-30m) are mostly evergreen with a prominent storey of evergreen shrubs and herbs, but grasses are absent. Soils are mostly brown earth (lower slopes of the Himalayas, West Bengal, Arunachal Pradesh, and Meghalaya). Dominant genera are *Alnus, Prunus, Betula, Quercus, Castanopsis, Schima* and others.

10. Sub-tropical pine type: Pure association of *Pinus roxburghi* occurs throughout the western and central Himalayas to Sikkim and West Bengal between 1,000 and 1,800m. This type is nothing but a secondary formation after the broad-leaved type.

11. Southern wet temperate type: Trees (4-5m) evergreen with many branches, short boled and dense crowned (Tamil Nadu, Kerala, Nilgiri, Palni, and Tirunelveli hills) are found on reddish-yellow black soils with peat formation, mostly dominated by *Eugenoa, Michelia, Meliosma, Eurya, Symplocos, Lies* and other genera.

12. Northern wet temperate type: Trees (over 25m tall) are evergreen with large branching crowns and girth, festooned with mosses, ferns and aroids. Some deciduous components are also found on higher elevations (Eastern Himalayas, Sikkim, and higher hills of West Bengal and Arunachal Pradesh, from 1,800m to 3,000m). These are found on steep hill soils with sandy loam and rich humus. Dominant genera are *Engethardtia, Schima, Acer, Prunus, Ulmus, Aralia,* and *Bucklandia.*

13. Alpine type: Above 300m there are tree forests associated with some shrubs and grasses. This type is mostly confined to the Western Himalaya and Ladakh regions, along the snow melting belt. These areas are mainly dominated by *Betula, Quercus, Rhododendron, Salix, Abis* and other genera.

Vegetation Analysis Method

A group of plants growing together with a natural relationship among themselves and with the environmental factors is known as a *Stand* and similar stands form a *Community.* The components of community vary in quantity and quality and the total assessment of these parameters may express a composite structure of the vegetation type. There are three main sampling units such as 1. Area Quadrat, 2. Line Transect and 3. Point Framework, of which Quadrat and Line Transect methods are used for analysis of vegetation structure (Misra, 1968.) In the Quadrat method, area should be of definite size, and shape may be different. In Line Transect method, which is a sampling strip across a stand or several stands, where the area is passing through a gradient of some environmental factors, size and number may vary with the extent of area. It is the same as belt transect. The near complete representation of species in a community may be the criteria for determining the size of the huadrat or the line. Experimental data can be expressed as Frequency = F; Density ± D; Relative frequency = RF; Relative density = RD; Relative dominance = RA; and Importance Value Index = IVI. The class value of IVI will be the maximum importance value index of a stand.

Vegetation Response of Pollution

The plants have unique machinery which mitigates pollution stress. The response of plant to sulphur dioxide generally depends upon the amount of SO_2 absorbed and plant's tolerance. The uptake of SO_2 by plants and subsequent response depends on the nature of plant species and environmental factors (Singh & Rao, 1992). Plants act as a sink for various other particulates and filter out dust, smoke and soot. The evergreen, large-leaved species and tomentose surface are more efficient than deciduous, narrow, smooth surfaced leaves. Plants can abate pollution if they are themselves tolerant to pollution and remain within the limit of pollution concentration. The tolerance of SO_2 in plants vary with the change in environmental conditions and leaf age in different seasons. The sensitive plants can serve as indicator of pollution. It is found (Singh, 1992) that there is no direct relation between SO_2 absorption and plants with high rate of transpiration and more stomatal openings.

Plants' response to Ozone can be attributed to genetic behaviour of species along with varying environmental factors. It is found (Pandey *et al.*, 1992) that long-lived woody plants inherently minimize O_3 uptake than herbaceous plants. It is proportional to the age of plants.

Flora

A flora is a work by which we can study various aspects of flowering plant species of a particular region, their taxonomic identification, nomenclature, distribution and systematic classification in accordance with the similarities and differences of floral and vegetative characters. It must include list of plant species, geographical area covered, materials on which the list prepared, and topographic, climatic, edaphic and ecological conditions of the area and list of herbarium on which specimens are deposited.

We are aware of the facts that trees in the forests, crops in the farm land, grasses and ornamental plants in our lawns and gardens, the aquatic plants in our lakes, ponds and rivers, and so on, algae, fungi, lichens, mosses, and ferns which exist in a countless variety and forms over the earth's surface. Botanists and naturalists of different ages starting from Aristotle, Theophrastus (255 B.C.) have formulated a classification on the basis of similar and dissimilar characters from lower to the higher group. It is also found that enormous diversity exists even within a single group and based on the taxonomic characters the similar species are placed in the same genus, similar genera are placed in a family and families into order, etc.

To study the flora it is most important to have a brief idea about the species. A species is the natural representative unit for taxonomic classification and morphologically independent in a population, reproductively isolated from similar other groups and potential for interbreeding in natural system.

Due to very significant altitudinal and climatic variations India has a very rich diversified flora spreading from the sea level to the highest mountain ranges, from the hot desertic condition to the cold desert and from the sub-tropical, humid tropical to the tropical rain forests in some parts of the country. This has been further aggravated due to immigration and colonization of plant species from relatively similar environmental conditions of different bordering countries like China, Malaysia, Europe, Africa and Tibetan-Siberia.

A knowledge of the Indian flora began with efforts of many European Botanists and naturalists who visited India during 17th, 18th and 19th centuries for trade and then political supremacy. The first publication of Indian plants in European language seems to be Garcia de Orta's *Os Coloquios* (1565) systematic collection, study and description of Indian flora were undertaken by many Botanists and naturalists and among them, H.V. Rheede, J.G. Koenig, R. Kyd, W. Roxburgh, N. Wallich, Buchanan-Hamilton, J.F. Royle, R. Wight and J.D. Hooker were the famous contributors in this line. Very comprehensive flora of India including Pakistan, Burma and Sri Lanka was published in the name of "Flora of British India" by J.D. Hooker (1872-1896). This has formed the groundwork for all the later regional floras of the country mainly flora of Madras, upper Gangetic Plain, Bengal, Assam, Bombay, Bihar and Orissa and many others. Recently Botanical Survey of India has published several floras in the district and state level and is engaged in a comprehensive revisionary work for publication of Flora of India. It is estimated that India has about 45,000 species of plants and among them are: Vascular Plants, 15,000; Pteridophytes, 600; Bryophytes, 2,700; Algae, 5,000; Fungi, 20,000; and Lichens, 1,600 species (Jain, 1982).

Plant Responses to Air Pollution

With increasing demands for transportation and industrialisation, air pollution becomes a serious threat to agriculture and forest productivity and stability. Many of the pollutants released into the urban-industrial areas are gaseous in nature. These are either primary pollutants like So_2 or secondary phytotoxic pollutant ozone. Vegetation acts as a significant sink for air pollution. Different species of trees have different architecture and leaf shape as products of genetically fixed growth programme for the purpose of space occupancy and sunlight. While animal species adopt different strategies for obtaining food and orient their relationship with other predators, plants adopt growth habits, leaf shapes, orientation of branching so that each plant species occupying a particular ecological niche can use sunlight to its maximum advantage. The development of trees with particular canopy, growth habit are genetically fixed and it is suggested that growth of plants can be judiciously used with advantage for buffering the deleterious effects of atmospheric pollutants. Uptake of So_2 by plants takes place through absorption processes. Uptake or sorption of So_2 by plants is generally through surface and internal absorption. Plants differ in their capability to remove So_2 from the surrounding air. The uptake properties are basically dependent on their genetic constitution as expressed through morphological and physiological processes. 50 to 90 per cent flux of So_2 is absorbed by plants into their leaves and rest on the leaf surface. The So_2 absorbed by the plant undergoes various chemical reactions during metabolization and get translocated to other plant parts. The absorbed So_2 on the leaf surface is neutralised by cations of K^+, Ca^{+2} and Mg^{+2} Therefore, total So_2 uptake by leaves eventually gets incorporated into the soil system either by rain-wash or leaf fall.

It is found that trees with higher photosynthetic rate and lower CO_2 compensation concentration are more sensitive to So_2. Thus, deciduous trees are more sensitive than evergreen ones. It is also observed that sensitivity of deciduous trees are more during winter and the evergreen during summer. These differences are found also related to different environmental conditions and leaf age of the trees in the two types.

Plants' response to ozone, the photochemical pollutants in various ways and the variability is related to the genetic behaviour of plants in varying environmental factors. Stomata play a major route for gaseous exchange and thus stomatal resistance can contribute significant role in determining plant sensitivity to ozone. Perennial woody plants which are well adopted for withstanding various fluctuation environmental conditions are inherently possessing higher stomatal resistance that minimise ozone uptake. Herbaceous annuals which are less adapted and with less stomatal resistance are more sensitive to ozone.

Potential of leaf surface acts as a dust, pollutant sink. Some of the morphological features of leaf such as pubescence nature, surface water, cuticular formations may provide effective sites for impingement and removal of pollutant molecules from the air. Some of the factors with the role of plants in mitigating dust, So_2 and pollution tolerance indices are shown in the following tables:

Table 1

Dust collecting efficiency of trees	
Name	**Dust-gm/m² of leaf surface**
Tectona grandis	5.35
Shorea robusta	4.50
Terminalia arjuna	4.49
Mangifera indica	4.05
Lagerstroemia parviflora	3.90
Azadirachta indica	2.92
Emblica officinalis	2.70
Tamarindus indica	2.08

Table 2

Trees serve as tolerant to pollutant = T, and highest sorption of SO_2 = HS; Singh (1989) and Farooq et al (1988)

Name	Indicator
Leucaena leucocephala	T + HS
Dalbergia sissoo	H.S.
Terminalis arjuna	T + HS
Cassia fistula	T + HS
Eucalyptus citriodora	HS
Ficus racemosa	T + HS
F. religiosa	T + HS
F. bengalensis	HS
Azadirachta indica	T + HS
Bombax ceiba	HS
Psidium guajava	T + HS
Syzygium cumini	T + HS
Tamarindus indica	HS
Mangifera indica	HS
Adina cordifolia	HS
Buchanania latifolia	HS

Table 3

Trees susceptible and resistant to Ozone (R = Resistant, S = Susceptible)

Name	Ozone response
Quercus alba	S
Acer saccharum	R
Acer rubrum	R
Fraxinus americana	S

Table 4

Air Pollution tolerance indices of plant species	
Name	**Index No.**
Albizia procera	62
Azadirachta indica	38
Emblica officinalis	37
Tamarindus indica	21
Madhuca longifolia	18
Aegle marmelos	11
Mangifera indica	10
Syzygium cumini	10
Alstonea scholaris	9
Dalbergia sissoo	6

Endangered species concept

The numbers of endangered species of vascular flora in India have taken an alarming shape today. It is found that it has risen from a few hundred to a few thousand species and is feared that 15 to 20 percent of the total vascular flora i.e. about 2,500 species may now become rare, threatened and endangered category. India has about 5,000 plant species as native or endemic in the country and BSI has published Red Data Book (Jain & Sastry, 1984) volumes I, II, and III, from these endemic species to evaluate the present and past status of the plant species and the cause and recovery of the threats.

Threats to species can be both natural and man-made. The man-made threats are more prominent nowadays due to quick economic development for upgrading social structure. The problem of Endangered species, 'concept and solution' has been clearly pointed out (Jain, 1992). Some common names of rare and threatened species are mentioned below for awareness:

Rauvolfia serpentina	Rare in Eastern and Western India.
Coptis teeta	Endangered in remote hills of N.E. Region.
Rotala macrandra	Rare in wetlands of South India.
Cryptocoryne retrospiralis	Rare in wetlands of South India.
Podophyllum Sp	Endangered in W. Himalayas.
Platycerium alcicorne	Rare stag horn fern in Manipur and Nagaland.
Musa velutina	Rare wild banana of North East India.
Nepenthus khasiana	Pitcher Plants, rare in Mikir hills and Meghalaya
Bentinkia condapanna	Rare and endangered Palm.
Cyathea sp	Rare tree fern, in North East India.
Arisaema griffithii	Rare species in Sikkim.

Gingko biloba	A living fossil, rare and re-established in Missouri Botanical Gardens, USA.
Rhododendron dalhousiae	Rare in Sikkim.
R. parryae	Rare in Arunachal.
R. arizelum	Rare in Arunachal.
R. tanenium	Rare in Arunachal.
Phaphiopedilum	Rare orchid, Lady's slipper.
P. insigne	Rare orchid, Lady's slipper.
P. hirsutissimum	Rare orchid, Lady's slipper.
Dendrobium sulcatum	Rare orchid, in North East India.
D. densiflorum	Rare orchid, in North East India.

Measures of Conservation

Conservation of wild Flora and Fauna had been a part of Indian culture by creating traditional forest reserves, 'Ashrams' and 'Sacred groves'. Governmental, semi-governmental bodies and some public organisations are created general awareness for conservation activities of threatened plant and animal species by establishing National Parks, Sanctuaries, Project Tigers and Biosphere Reserves.

The various methods for conservation of threatened species and reserve of genetic resources may be described here briefly as follows:

1. Control on over exploitation, 2. Creation of nature reserves, 3. Cultivation of rare species and captive breeding of animals, 4. Collection and preservation of germ Plasma materials i.e. seeds, Pollen, tissue, semen bank and 5. Legislation for conservation.

Recently Government of India has become a signatory of CITES for controlling the trade of the threatened species of flora and fauna and have taken measure for species loss due to over-exploitation.

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FOREST AND FOREST LANDS

U. BANERJEE*

Introduction

One of the major challenges facing mankind for the remainder of the 20th century is meeting the basic human needs while sustaining the natural resource–base upon which satisfaction of these needs depend. The demand for natural resources is increasing dramatically over the years due to population and economic growth and introduction of more capital and technology–intensive production system. If the adverse environmental impacts associated with these developments are not avoided or at least controlled within tolerable limits, the capability to maintain the productivity of the natural resource–base, to imitate wastes and to combat disease and privation will greatly decline. Much of the present environmental crisis is a failure to recognize the physical limits imposed by ecological system on economic activities.

Nevertheless, it is increasingly realized that sustainable economic development depends on the rational use of environmental resource and on minimizing to the extent possible, adverse environment impacts through improved project selection and more responsive project planning and design. Under this concept, development must be environmentally sound in the broadest sense. Indeed as a concept, 'sustainable development' assumes that environmentally unsound projects, those failing to safeguard adverse environmental side-effects or which fail to recognize the need to protect the natural resources or their users will not be economically let alone socially acceptable. Fortunately there is now a general consensus that the planning perspective must shift its focus from 'scientific determinism' and 'economic determinism' to 'ecological determinism'

Hopefully, many governmental and non-governmental agencies (mainly major international donor agencies) now accept the need to protect and conserve the natural resources and environment, while formulating and implementing economic development policies and programmes. In many countries the concept of environmental management through Environmental Impact Assessment (EIA) and legislation is now well established. Advocated by various national and international agencies the concept of achieving 'sustainable development' through sound environmental management is gaining ground in most developing countries.

Environmental Problems and Trends

Environmental problems vary in nature, from, scale and extend. A study of environmental trends in Asia–Pacific region during 1960–80 with projections for 1980–2000 was undertaken recently. The study revealed: deforestation, soil erosion, desertification, land degradation, vector control, water supply sanitation, domestic and industrial pollution control, pesticide buildup, domestic and industrial pollution and solid and toxic waste disposal will continue to be major environmental concerns for sometime to come (Table 1).

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The environmental problems mentioned above can largely be divided into two broad categories – those related to inadequate disposal of waste or overuse of toxic substances and those related to the degradation of the natural resources base. While India has both the sets of problems, the first set is neither as extensive nor as severe when compared to the second set. These problems are largely concentrated in and around urban and industrialized areas or areas of highly Commercialized Agriculture and related more to the question of quality of life. The second set related to the steady degradation of the land, water and forest resources of the country, has already affected survival of millions of people across the country with potential to affect many more in years to come. In fact, these problems are such that they can make or break the country, on their successful resolution depends the food, fuel, fibre and water needs and employment of not only the 800 million odd rural people but also the need of 200 million odd urban Indians as well. From a careful examination of this somewhat macabre limits of environmental problems it is clear that much of these are connected directly or indirectly with land resources and forest degradation. Forests have historically constituted on of man's most important natural source of renewable wealth. Over the centuries he drew sustenance from the natural ecological system of which forests were a vital component. A concept of stewardship for this priceless possession formed part of the human experience. As direct beneficiary and nearest neighbour man was expected to judiciously administer this resource, but he has done so what we have on hands a record of man's profligacy. Unfortunately, the profligacy is not sealed in vacuum. 'When one tugs at a single thing in nature, he finds it attached to the rest of the world' The chain of event following deforestation with significant environmental implications may be seen in Fig. 1.

Yet forest lands till very recently and even today are looked upon as an inexhaustible land bank to meet a large range of development needs. In developing countries environmental control often carries a negative connotation of locking up of usable resources conflicting with urgent need to use them for economic development. This is due to a wrong notion held in India and many developing countries that environmental control is an inappropriate luxury. The conflict is between those who view resource exploitation as serving the basic human needs and those who regard wasteful use of such resource as a sure guarantee for lower productivity of the environment for the future.

The Indian Forestry Scenario

The present areas under forests (State and local authorities ownership) is estimated at 64 million has. against the legal defined area of 75 million ha. Geographical distribution of these forest is uneven, with concentration in the north-eastern, western and the central parts of the country. 36 million ha, only can be categorized as good forests (crown density 40% and over), the balance consisting mostly of open or degraded forests. Currently annual consumption requirements of forest products, mainly fuel-wood and timber far exceed annual yield from the forest. Present consumption levels for such commodities are also expected to grow substantially in the future. For these and other reasons forests are progressively being denuded, the annual rate of depletion is estimated at 1.5 million ha, (due to lack of standard methodology and data other than the above, differing estimates are also advocated.

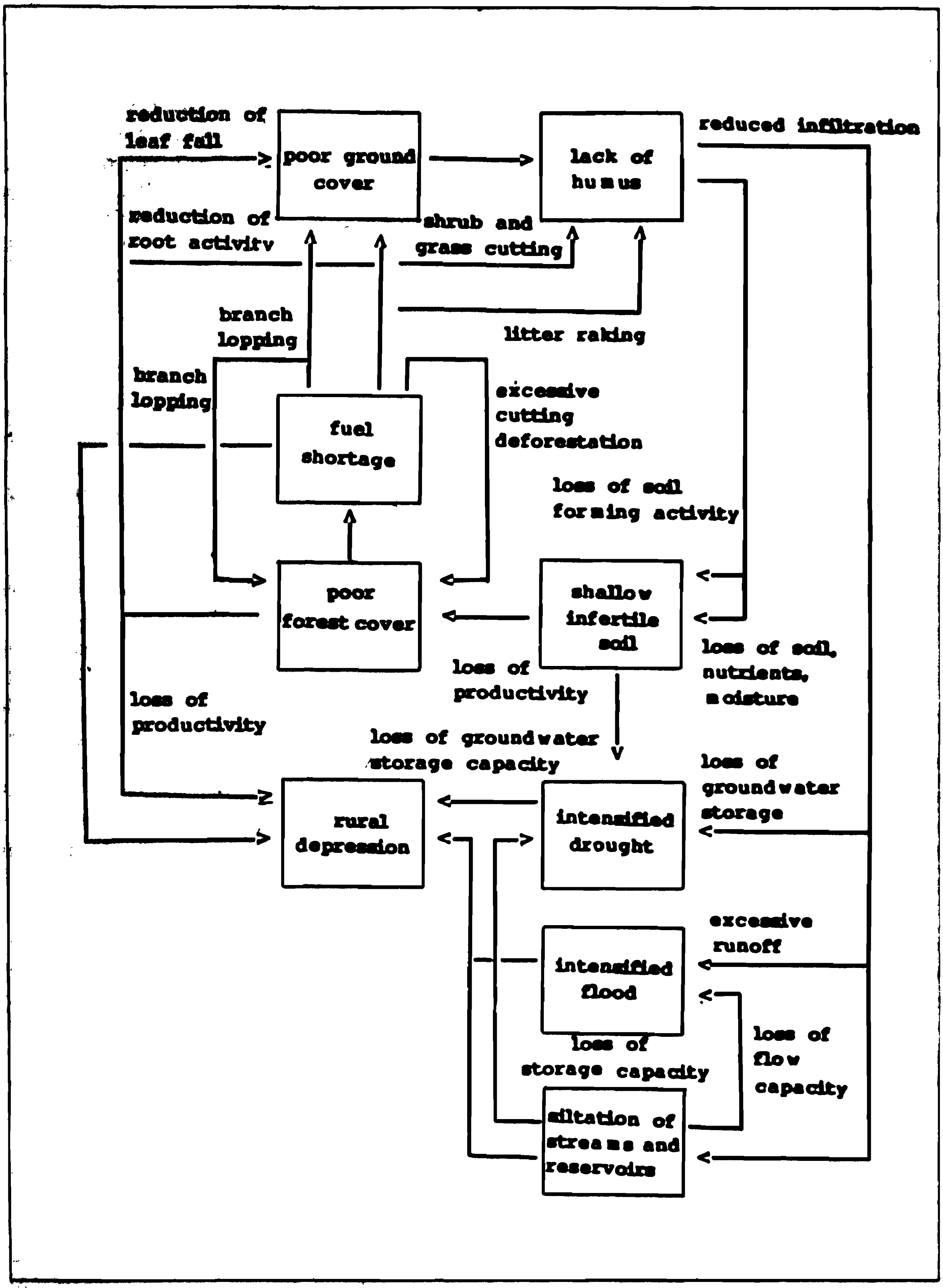

Fig. 1. Cycle of destruction in forest lands. *(Source: FAO: Forestry for Rural Communications)*

The National Forest Policy, 1952 — since revised by the latest National Forest Policy (1988) — spelled out that India should aim at maintaining at least one-third of its total land area under forest; 60% in the hills, 20 % in the plains. Among others, the policy stressed that (1) basis for annual cut should be sustained yield, harvesting only the increment leaving the forest capital intact, (2) Wildlife needs to be protected, grazing regulated, (3) adequate forest laws be promulgated, (4) professional training and research need to be intensified. The policy recommended functional classifications of forests, namely (1) Protection forests, (2) National forests, (3) Village Forests, (4) Tree lands and stressed the need for increasing tree land outside government forests.

The National Forest Policy, 1988 while retaining some of the basic tenets of the previous policy, has especially stressed the need to maintain ecological stability, and the genetic diversity of the country through forest management. The salient features of the new Forest Policy are:

(1) Maintenance of environmental stability through preservation and restoration of ecological balance.

(2) Conservation of the national heritage of the country by preserving the remaining natural forests and protecting the vast genetic resources for the benefit of posterity.

(3) Meeting the basic needs of the people, specially fuel-wood, fodder and small timber for the rural and the tribal people.

(4) Maintaining the intrinsic relationship between forests and the tribals and other poor people living in and around forests by protecting their customary rights and concessions on the forest.

Important forestry–related legislation in force are the Indian Forest Act 1927; the Wildlife (Protection) Act 1972 and the Forest(Conservation) Act, 1988. These Central laws, applicable to all States and Union Territories, are supplemented at these levels by rules framed under the provisions of the Act as well as local legislation approved by the Centre. Proposals for revising the Indian Forest Act are currently pending with the Government of India.

Forestry practices in India have had a long history of more that thirteen decades. In the early years the new department undertook forest survey, settlements, demarcation and consolidation. Forest policies were conceived, laws were enacted and working plans were prepared to improve stocking and forest regeneration. In the early years of forestry the major concern was to regenerate the forests, to meet the demand of raw–material requirements of industries and earning revenue for the Government. Expectedly, in this type of production and management system, the small–scale spatially diffused forestry needs of the dispersed rural communities were bypassed. The concern for environmental issues were not addressed in the ambience of 'nature's bounty'

Following the stress on economic self–sufficiencey since Independence, forestry development activities concentrated primarily on industrial timber production. Apart from large demand for long rotation species (Sal, Teak etc.) much effort was made for raising extensive short-rotation fast-growing plantations (mostly Eucalyptus) for meeting pulp and fuel-wood requirements. Following the recommendations of the National

Commission on Agriculture (1976), Forest Development Corporations were established in most States and Union Territories to operate 'commercial' forestry in a more business-like manner. Simultaneously, a programme of Social Forestry was also launched to extend the scope of tree planting on non-forest lands through people's participation. These latter efforts were intensified in 1985 when the National Wasteland Development Board was established.

Current Forestry Perspective

Current forestry perspective were conditioned by several concerns, each of which has given rise to a variety of policies and strategies. The dynamics of their logic has to be understood because they have an important bearing on the current programme.

A primary concern that emerged during the decade of the 'Seventies' related to the progressive denudation of the tree cover both within and outside the forest preserves for a variety of reasons.

The second and more important reason was diversion of forest lands to non-forestry uses, such as extension of agriculture and human settlements, river valley projects, industrial townships, etc.

Finally, the adverse impact on environment and ecology caused by progressive denudation of tree covers was also better articulated about this time.

On the basis of emerging scenario it is possible to identify certain trends, first, intangible environmental and ecological benefits flows, rather than the tangible revenue oriented commercial aspects of forestry have become more important. Second, the role of forestry in alleviating rural poverty and meeting rural energy and other needs, is now keenly felt. Thirdly, the potential of private tree planting for fulfilling commercial and industrial wood requirements is now better recognized. Fourthly, mere active and meaningful popular participation in jointly managing the State forests or whatever of it is still left have been recognized and adopted in most of the States as a major input in State Forest Management.

Thrust Areas Of Forestry Investments

With the increasing recognition of importance of forestry in the overall rural development process as well as for long-term environmental security as envisaged in the National Forest Policy, the range of possible investment areas has considerably expanded. There are also the traditional areas of production and protection forestry. All such areas could be grouped into five major areas of concern to forestry. These are:

1) Primary ecological control which includes soil and moisture conservation, watershed management, eco-development in fragile areas, conservation of bio-diversity, wildlife management, etc.
2) Rural development-related forestry which includes rural fuel-wood plantation, social and farm forestry, agro-forestry, agro-pastoral forestry, wood supplies for village level industries and other downstream activities.

3) Production forestry which includes capital and technology-intensive production forestry and plantations for industrial uses.
4) Recreation and tourism, which include development of urban and recreational forestry, development of parks and gardens, wildlife sanctuaries, etc.
5) Forestry institutions which includes research, training, education, extension and human resource development within the forestry sector.

These can further be disaggregated into a number of important sub-sectoral activities as narrated below:

1) Soil and moisture conservation measure, in fragile areas.
2) Expansion of Social Forestry.
3) Development of production forestry and its management.
4) Rehabilitation of degraded forests through a system of joint management for a sustainable production system.
5) Wasteland development.
6) Conservation and development of mangrove eco-system.
7) Wildlife management and conservation bio-diversity.
8) Development of urban and recreational forestry, parks and gardens etc.
9) Strengthening research, education, extension and human resource development.

Environmental Considerations for Development Projects: Forestry & Non-Forestry Projects

The incorporation of environmental protection as a component of administrative, planning, legislative and executive, wings of National Governments is quite recent. In many countries, including India, the concept of sound environmental management to achieve "sustainable development" is gaining ground. However, due to somewhat rapid development of the concept the environmental field shows lot of confusion and perplexity. In most of the countries environmental management is generally attempted through Environmental Impact Assessment (EIA) and supporting enabling legislation.

In India, even through Pollution Control Laws are in vogue for a long time, necessary legislation requiring submission of EIA report for every new projects (e.g. industry, irrigation, power project, mining etc.) were enacted only in 1986. Through EIA, implementation organizations can have reasonable knowledge of environmental impacts of the projects, before launching. This is based on the expectation that the socio-economic benefit of any development project should not be compromised by adverse impacts particularly those occurring during launching phase and afterwards. Experience show that through proper study and planning such adverse consequence can be eliminated or at least reduced to an acceptable level or offset through appropriate design innovations. In fact, EIA is being gradually projected as an integral part of the project feasibility studies. In the standard project preparation the sequence of planning phase is operated as shown in Table 2.

Environmental and natural resource planning now require that for every stage of the project preparation cycle there should be corresponding steps related to environmental analysis. It is important that environmental assessment and project feasibility studies are integrated as a single study.

In this exercise environmental aspects are considered in two steps:

1) Initial Environmental Examination (IEE). This identifies the nature and extent of potential impact of a project, whether controlled measures would be needed. In case of indication of significant potential impacts from the IEE, a more detailed study — a full-fledged EIA — is launched to confirm the suspect significant impacts to plan necessary control measures. The intention is to restrict environmental analysis only to significant impacts, requiring special attention during project planning and implementation.

2. Environmental analysis for development project involving forest lands are generally of two broad categories – those involving non-forestry project – and those related to forestry projects *per se* (logging, clear-felling, yarding, log hauling saw milling, etc.)

Methodologies Adopted

A large number of methodologies have been developed over the years, for different types of projects situations, level of expertise, quality of data base and available resource. In short the major approaches are as follows:

Ad-hoc method: In this method broad areas of possible impacts are suggested, no specific parameters are investigated.

Checklist method: It presents a specific list of environmental parameters to be investigated for possible improvement.

Matrix method: It allows the identification of cause–effect relationship between specific project activities and the environmental characteristics of the project area.

"Fill in the blanks" checklist: It is essentially a checklist based on a questionnaire.

Item by item: In this method all likely impacts are identified and accompanied with a small description for facility of decision making.

Which particular method would be best suited for environmental analysis of a particular project will depend on many factors particularly nature and size of project, time and resources availability. In general, however, leading international agencies follow the checklist methods with satisfactory results and reasonable cost and time requirement for forestry projects. However, for non-forestry project involving forest clearance for setting up of capital and technology intensive complex industrial enterprise, more sophisticated method are employed.

Diversion of Forest Land for Non-forestry Purposes

Forest (Conservation) Act, 1980 its subsequent amendment in 1988 and rules made thereunder must be reckoned as a land mark policy instrument, reflecting Government's concern for forest degradation and related environmental problems and a step to put a check on the misuse and diversion of forest lands for non-forestry purposes. The main features of the operative part of the act is prohibition of the following actions related to forest land without clearance from the Central Government.

1. Denotification of forest lands.
2. Diversion of forest lands for non-forestry purpose.
3. Leasing out of forest lands.
4. Clearance of natural forest for reforestation and regulation of forestry operations only under the provision of management plan approved by the Government of India.

Although forests are under "Concurrent List" of Constitution of India, since 1976, these powers so long vested with the State Governments.

Section 2(ii) of the said Act vests the power with the Central Government. For this purpose GOI has laid down elaborate procedures and guidelines, before such approval is accorded. The underlying idea is that environment, economic and social impact of such diversion has to be analysed in great detail and permission is accorded only when the sanctioning authority is satisfied that the purpose for the diversion of forest land for any development project will not only bring in adequate tangible and intangible benefits, the forest loss notwithstanding, but will in no way compromise such benefit due to adverse environmental impacts. There are also provisions for adequate compensation in monetary terms as a trade off. These include:

1. Payment of Compensation for loss of forestry income by the requisitioning agency.
2. Making available suitable land for compensatory afforestation to offset loss of forest cover by the requisitioning agency.
3. Payment of compensation for environmental loss due to diversion of forest lands to be used for conservation purpose like catchment area treatment, etc.

There has been much sterile debate regarding application, enforcement and ultimate impact of this Act in safeguarding environmental and ecological security for sustainable development, given that its operation will be restricted to notified recorded forest lands only which is a mere 23% or odd of the total geographical area of the country. Nevertheless to the extent these measures assist in arresting thoughtless diversion of forest lands, its objectives would well be fulfilled. These polemics apart, it must be acknowledged that it is perhaps the first conscious and institutionalized endeavour on the part of the Government to address environmental issues whose safety is dependent on and inter-connected with presence of adequate and well managed forest lands. The details of Government of India rules, procedures etc. under the provision of the said Act is attached as Annexures I, II, III and IV.

Economic Aspects of Environmental Assessment

The global awareness about environmental issue, not withstanding, EIA still assumes a low priority. This is partly due to lack of resources and the present state of the art.

As regards, cost, time and level of expertise required for EIA fixed figures could be predicted, given the large number of site and situation specific issues. However, for some developing countries, where reliable data are available, it revealed that for small and simple agricultural project, the time required varied from one man-month to as much as 30 M/M for large and complex projects. The related costs also ranges between 0.01% to 0.48% of the total project cost.

The details apart, it is clear that contrary to popular notion the costs are reasonable and quite affordable, given the overall benefits generating from such exercises.

Suggested Readings

1. Asian Development Bank, 1987. Environmental Guidelines for Development Projects: Forestry, Manila.
2. CHOWDHURY, A.B. 1992. Environment & Resources of Tropical & Temperate Forests of India. International Book Distributors, Dehra Dun, India.
3. CHOWDHURY, A.B. 1992. Himalayan Ecology & Environment. Ashish Publishing House, New Delhi, 110 026, India.
4. CHOWDHURY, A.B. 1992. Mine Environment & Management. Ashish Publishing House, New Delhi, 110 026, India.
5. ESCAP, 1985. State of the Environment in Asia & the Pacific, Bangkok.
6. KHOSHOO, 1986. Environmental Priorities in India & Sustainable Development. Proceedings of 73rd Session of Indian Science Congress, New Delhi.
7. REES, Colin P. 1987. Environmental Consideration in Forestry, The Need for Natural Resources Planning. ADB, Manila, Philippines.
8. World Bank. 1991. West Bengal Forestry Project: Staff Appraisal Report, Washington.
9. World Bank. 1991. Forest Sector Review Paper, Washington.

Annexure I

(TO BE PUBLISHED IN PART II, SECTION 3, SUB-SECTION (i)
OF THE GAZETTE OF INDIA, EXTRAORDINARY)

GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT AND FORESTS
Dated: New Delhi the 21st May, 1992.

NOTIFICATION

G.S.R. In exercise of the powers conferred by sub-section (I) of section 4 of the Forest (Conservation) Act, 1980 (69 of 1980), the Central Government hereby makes the following rules further to amend the Forest (Conservation) Rules 1981, namely:-

1. (1) These rules may be called the Forest (Conservation) Amendment Rules, 1992.

   (2) They shall come into force on the date of their publication in the Official Gazette.

2. (i) In the Forest (Conservation) Rules 1981 (hereinafter referred to as the said rules), for rule 4, the following rule shall be substituted, namely:-

   "4 (1) Every State Government or other authority seeking the prior approval under section 2 shall send its proposal to the Central Government in the from appended to these rules:

   Provided that all proposals involving clearing of naturally grown trees in forest land or portion thereof for the purpose of using it for reforestation shall be sent in the form of Working Plan/Management Plan.

   (2) Every proposal referred to in sub-rule (1) shall be sent to the following address, namely:-

   Secretary to the Government of India,
   Ministry of Environment and Forests,
   Paryavaran Bhavan,
   Lodi Road,
   New Delhi-110003.

   Provided that all proposals involving forest land upto twenty hectares and proposals involving clearing of naturally grown trees in forest land or portion thereof for the purpose of using it for reforestation shall be sent to the Chief Conservator of Forests/Conservator of Forests of the concerned Regional Office of the Ministry of Environment and Forests"

   (ii) In rule 5 of the said rules, for sub-rule (1) the following sub-rule shall be substituted, namely:-

(1)The Central Government shall refer every proposal received by it under sub-rule (1) of rule 4 to the Committee for its advice thereon if the area of the forest land involved is more than twenty hectares.

Provided that proposals involving clearing of naturally grown trees in forest land or portion thereof the purpose of using it for reforestation shall not be referred to the Committee for its advice"

(iii) For the Annexure appended to the said rules, the following Form shall be substituted, namely:-

FORM

Form for seeking prior approval under section 2 of the proposals by the State Governments and other authorities. (See rule 4).

1. Project details:
   - (i) Short narrative of the proposal and project/scheme for which the forest land is required ....
   - (ii) Map showing the required forest area, boundary of adjoining forest and item-wise break-up of the required forest area for different purposes (to be authenticated by an officer not below the rank of Deputy Conservator of Forest)....
   - (iii) Total cost of the project....
   - (iv) Justification for locating the project in the forest area giving alternatives examined and reasons for their rejection.
   - (v) Financial and social benefits....
   - (vi) Total population benefited...
   - (vii) Employment generated...
2. Location of the project/scheme:
   - (i) State/Union Territory...
   - (ii) District....
   - (iii) Forest Division, Forest Block, Compartment, etc. ....
3. Item-wise break-up of the total land required for the project/scheme along with its existing land use.
4. Details of forest land involved:
   - (i) Legal status of the forest (namely, reserve, protected/unclassified, etc.)...
   - (ii) Details of flora and fauna existing in the area....
   - (iii) Density of vegetation....

(iv) Species-wise and diameter class-wise abstract of trees...

(v) Vulnerability of the forest area to erosion, whether it form a part of a seriously eroded area or not...

(vi) Whether it forms a part of national park, wildlife sanctuary, nature reserve, biosphere reserve, etc.; and if so, details of the area involved; (Specific comments of the Chief Wildlife Warden to be annexed)...

(vii) Item-wise break-up of the forest land required for the project/scheme for different purposes....

(viii) Rare/endangered species of flora and fauna found in the area...

(ix) Whether it is a habitat for migrating fauna or forms a breading ground for them...

(x) Any other significance of the area relevant to the proposal....

5. Details of displacement of people due to the project:

(i) Total number of families involved in displacement...

(ii) Number of Scheduled Castes/Scheduled Tribes families involved in displacement...

(iii) Detailed rehabilitation plan...

6. Details of compensatory scheme:

(i) Details of non-forest area/degraded forest area identified for compensatory afforestation, its distance from adjoining forests, number of patches, size of each patch...

(ii) Map showing non-forest area/degraded forest area identified for compensatory afforestation and adjoining forest boundaries...

(iii) Detailed compensatory afforestation scheme including species to be planted, implementing agency, time schedule, cost structure, etc.....

(iv) Total financial outlays for compensatory afforestation scheme...

(v) Certificates from competent authority regarding suitability of area identified for compensatory afforestation for afforestation and management point of view. (To be signed by an officer not below the rank of Deputy Conservator of Forests)...

(vi) Certificates from Chief Secretary regarding non-availability of the non-forest land for compensatory afforestation (if applicable)...

7. Details regarding Transmission Lines (only for Transmission Line proposal):

(i) Total length of the Transmission Lines ...

(ii) Length passing through forest area...

(iii) Right of way.....

(iv) Number of Towers to be erected.....

(v) Number of Towers to be erected in forest area ......

(vi) Height of transmission towers.....

8. Details of Irrigation/Hydel Projects (only for Irrigation/Hydel Projects):

(i) Total catchment area...

(ii) Total command area.....

(iii) Full Reservoir Level.....

(iv) High Flood Level......

(v) Minimum Drawal Level.....

(vi) Break-up of area falling in catchment area of the project (Forest land, cultivated land, pasture land, human cultivation and others).....

(vii) Area of submergence at High Flood Level...

(viii) Area of submergence at Full Reservoir Level...

(ix) Area of submergence 2 metres below Full Reservoir Level...

(x) Area of submergence at 4 metres below Full Reservoir Level (For medium and major Projects only).....

(xii) Detailed catchment area treatment plan ...

(xiii) Total financial outlays and details regarding availability of funds for Catchment Area Treatment Plan ...

9. Details regarding Road/Railways Lines (only for Road/Railways lines proposals):

(i) Length and width of the strip..required and forest area required...

(ii) Total length of the road ...

(iii) Length of the road already constructed...

(iv) Length of the road already passing through the forest...

10. Details regarding Mining proposals (only for mining proposals) :

(i) Total mining lease and forest area required...

(ii) Period of mining lease proposed...

(iii) Estimated reserve of each mineral/ore in the forest area and in the non-forest area...

(iv) Annual estimated production of mineral/ore...

(v) Nature of mining operations(open cast/underground)...

(vi) Phased reclamation plan

(vii) Gradient of the area where mining would be undertaken......

(viii) Copy of the Lease Deed (to be attached only for renewal purposes)...

(ix) Number of labourers to be employed...

(x) Area of forest land required for -

(a) Mining...

(b) Storing Mineral/ore...

(c) Dumping of overburden...

(d) Storing tools and machinery...

(e) Construction of buildings, power stations, workshops, etc.....

(f) Township/housing colony.....

(g) Construction of road/ropeway/railway lines.....

(h) Full land use plan of forest area required.....

(xi) Reasons why any of the activities referred to in (a) to (h) above under the project for which forest land has been asked for cannot be under taken/located outside forest area.....

(xii) The extent of damage likely to be caused and the number of trees affected on account of mining and related activities .....

(xiii) Distance of the mining area from perennial water courses, national and state highways, national parks, sanctuaries and biosphere reserves...

(xiv) Procedure for stocking of the topsoil for reuse.....

(xv) Extent of subsidence expected in underground mining operations and its impact on water, forest and other vegetation.....

11. Cost benefit analysis...

12. Whether clearance for environmental angle is required (Yes/No).....
If yes, weather, requisite details for the same have been furnished (Yes/No).....

13. Whether any work in violation of the Act has been carried out (Yes/No).....
If yes;

(i) Details of the same including date of commencement.....

(ii) Officers responsible for violation of the Act...

(iii) Action taken/being taken against erring officers...

(iv) Whether work in violation of the Act is still in progress .....

14. Any other information.....

15. Details of Certificates/documents enclosed.....

16. Detailed opinion of the Chief Conservator of Forests/Head of the Forest Department concerned covering the following aspects, namely:

(i) Out-turn of timber, fuel-wood and other forest produce from the forest land involved:

(ii) whether the district is self-sufficient in timber and fuel-wood; and

(iii) the effect of the proposal on

(a) Fuel-wood supply to rural population

(b) economy and livelihood of the tribal and backward communities.

(iv) specific recommendations of the Chief Conservator of Forests/Head of the Forest Department for acceptance or otherwise of the proposal with reasons thereof.

Certified that all other alternatives for the purpose have been explored and the demand for the required area is the minimum demand for forest land.

Signature of the authorized officers of
the State Government/Authority.

N.B.1. While furnishing details of flora and fauna, the species should be described by their scientific names.

N.B.2. If the space provided above is not sufficient to specify any information, please attach separate details/documents."

(R. Rajamani)
Secretary to the Government of India
(No. 5-5/86-FC).

Footnote

The principal rules were notified vide Number G.S.R. 179 dated the 20th July, 1981 and subsequently amended vide:

(1) G.S.R. 14, dated the 28th December, 1987.

(2) G.S.R. 640, (E), dated the 26th June, 1989.

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Annexure II

Category of proposal for which cost - benefit analysis is applicable.			
Sl. No.	**Nature of proposal**	**Applicable/ not applicable**	**Remarks**
1.	All categories of proposals involving forest land less than 5 ha. in plains and less than 2 ha. in hills.	Not applicable	These proposals are to be considered on case by case basis and value judgement.
2.	Proposals for defence installation purposes and oil prospecting. (Prospecting only)	Not applicable	In view of National Priority accorded to these sectors the proposals would be critically assessed to help ascertain that the utmost minimum forest land above is diverted for non-forest use.
3.	Habitation, Establishment of Industrial units, tourist lodges/ complex and other building construction.	Not applicable	These activities being detrimental to protection and conservation of forests as a matter of policy, such proposals would be rarely entertained.
4.	All other proposals involving forest land more than 5 ha. in hills including roads, transmission lines, minor medium and major irrigation projects, hydel projects mining activity, railway lines, location specific installations like micro-wave stations auto repeater centres, T.V. towers etc.	Applicable	These are case where a cost-benefit analysis is necessary to determine whether diverting the forest land to non-forest use is in the overall public interest.
5.	Environmental Losses: (Soil erosion, effect on hydrological cycle, wildlife habitat, micro-climate upsetting of ecological balance.		Though technical judgement would be primarily applied in determining the losses, as a thumb rule stocked forest (density 1.0) would be taken as Rs. 126.74 lakh to accrue over a period of 50 years. The value will reduce with density, for example if density is 0.4 the value will work out at Rs. 50.696 lakh. So if a project which requires deforestation of 1 ha. of forest of density 0.4 gives monetary returns worth over Rs. 50.696 lakh over a period of 50 years, may be considered to give a positive cost benefit ratio. The figure of assumed environment at value will change if there is an increase in bank rate; the change will be proportional to percentage increase in the bank rate.
6.	Suffering to oustees		The social cost of rehabilitation of an oustee (in addition to the cost likely to be incurred in providing re idence, occupation and social services to him) be worked out as 1.5 times of what he should have earned in two years had he been not shifted.

Annexure III

Sl. No	Parameters	Nature of proposal		
		Roads, Tr. lines and Railway lines	Minor Irrigation projects, quarrying of stones/ metals	Medium & Major Irrigation, hydro-electric, large mining & other Misc. projects
1.	Loss of value of timber, fuel-wood and minor forest produce on an annual basis, including less of man hours per annum of people who derived livelihood and wages from the harvest of these commodities.	To be quantified & expressed in monetary terms.		
2.	Loss of animal husbandry productivity, including loss of fodder.	- do -		
3.	Cost of human resettlement.	- do -		
4.	Loss of public facilities and administrative infrastructure (Roads, buildings, schools, dispensaries, electric lines, railways etc.) on forest land, which would require land if these facilities were diverted due to the project.	- do -		

Annexure IV

Sl. No	Parameters	Nature of proposal		
		Roads, tr. lines & Railway lines	Mining Projects	Irrigation/ hydel projects & Others.
1.	Increase in productivity attributable to the specific project.	To be quantified & expressed in monetary terms.		
2.	Benefits to economy	Value judgement		
3.	No. of population benefitted.	- do -		
4.	Employment potential.	To be quantified & expressed in monetary terms.		
5.	Cost of acquisition of facility on non-forest land wherever feasible.	- do -		
6.	Loss of (a) agriculture & (b) animal husbandry production due to diversion of forest land.	- do -		
7.	Cost of rehabilitating the displaced persons as different from compensatory amounts given for displacement.	- do -		
8.	Cost of supply of free fuel-wood to workers residing in or near forest area during the period of construction.	- do -		

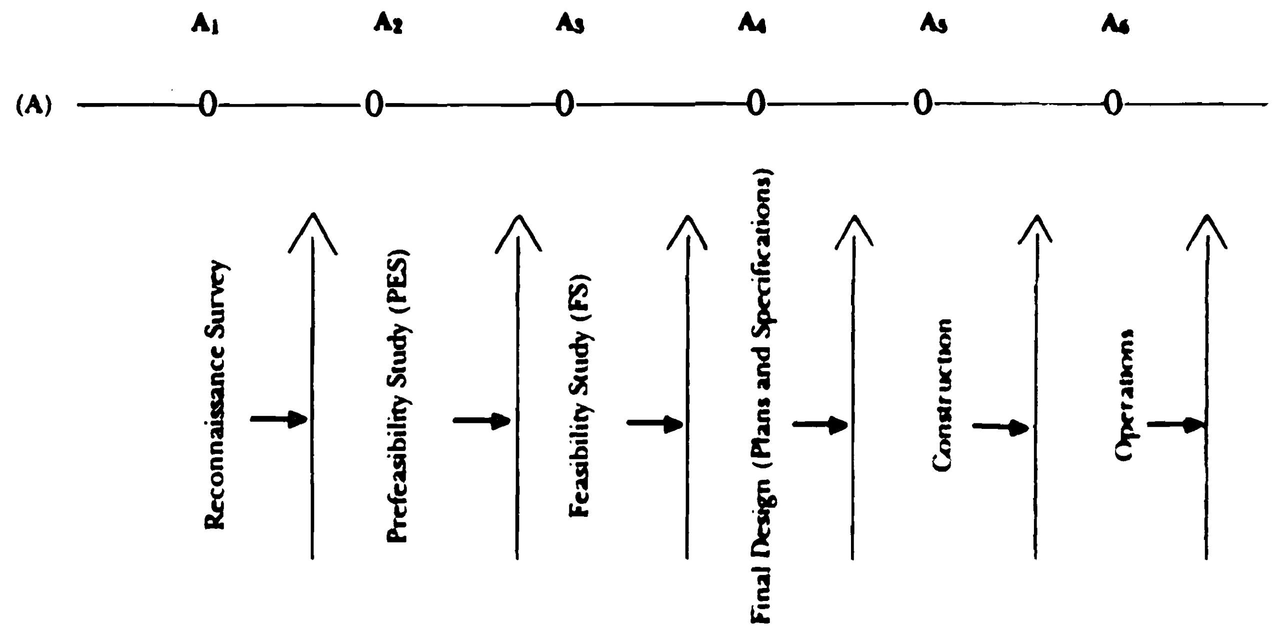
Table 1

Environmental Trends – South Asian Region		
	Period	
	1960 – 1980	1980 – 2000
I. Terrestrial Eco-systems		
A. Forest Lands		
i) Forest cover	decrease	decrease
ii) Extinction of species	increase	significant increase
iii) flooding & drought	increase	significant increase
B. Agricultural Lands		
i) Soil erosion	significant increase	significant increase
ii) Water logging & salinity	significant increase	significant increase
C. Grazing lands		
Desertification	significant	significant increase
II. Aquatic Eco-systems		
A. Fisheries		
i) Water pollution	increase	significant increase
ii) Fish yield	decrease	significant increase
B. Mangrove forests		
Disappearance	increase	increase
C. Coral areas		
Destruction	increase	increase
III. Environmental Health		
A. Water supply & Sanitation		
i) Urban drinking water	significant increase	increase
ii) Rural drinking water	significant increase	increase
iii) Urban sanitation	significant decrease	significant decrease
B. Urban deterioration		
i) Air pollution	significant increase	significant increase
ii) Water pollution	decrease	significant decrease
ii) Solid waste	increase	increase
iv) Noise pollution	increase	increase
C. Rural deterioration		
i) Pesticide mobility	increase	increase
ii) Malaria incidence	increase	increase
iii) Schisto soniasis	increase	increase

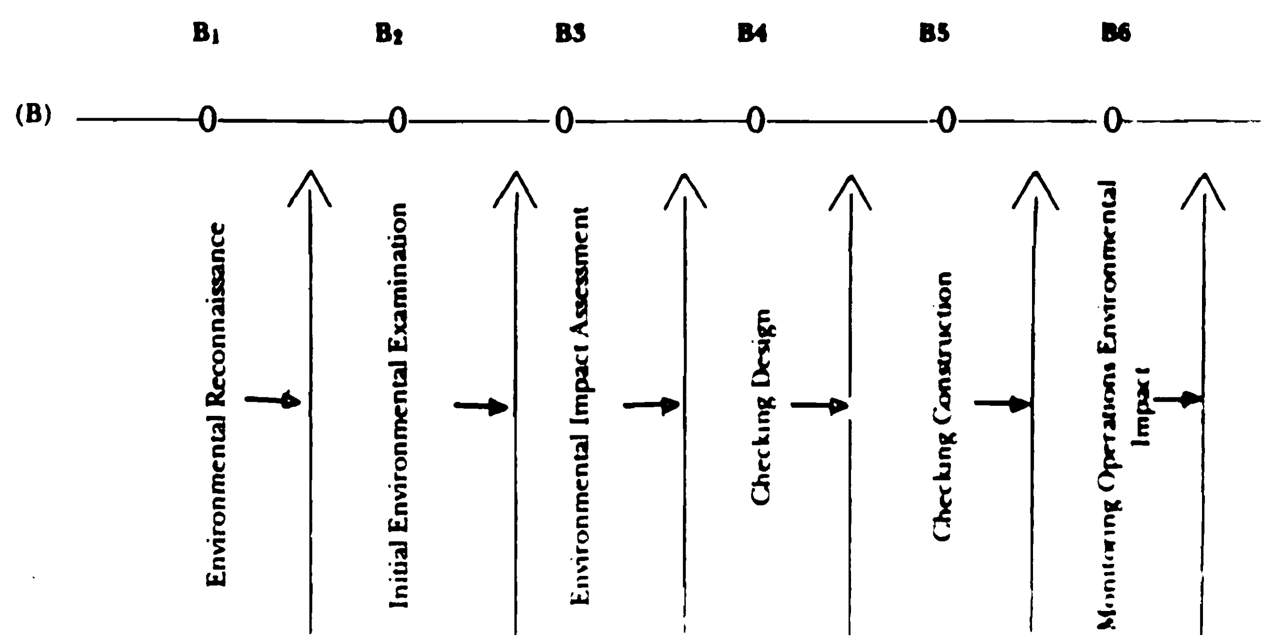
(Source: ESCAP. Bangkok)

Table 2

Role of Environmental Assessment in Project Planning and Implementation



Conventional Approach For Planning, Designing and Implementation Development Projects



Corresponding Environmental and Natural Resource Planning

ISLAND ECOSYSTEMS

A.K. DAS*

Introduction

Islands represent fragile, ecologically sensitive and biogeographically significant ecosystems. Most importantly, these are treated as nature's laboratories for demonstrating the process of organic evolution, adaptive radiation and speciation. In fact, Charles Darwin developed the primary concept of organic evolution by natural selection largely based on data derived from the biota of Galapagos islands, located about 1000 km west of South America. He published his epoch-making book "On the Origin of Species by means of Natural Selection" in 1859. Surprisingly, after studying the biota of the other side of the globe in the Malayan Archipelago another very eminent naturalist, Alfred Russel Wallace, a contemporary worker with Charles Darwin, also wrote a classic book "Island Life" and put forth identical views on organic evolution as conceived by Darwin, stressing natural selection as the prime factor. Since then, island biota with its simplicity and diversity has drawn attention of naturalists, biologists and biogeographers throughout the globe. As a result, considerable information and data are now available on the subject, revealing clearly the need and significance of conservation of this fragile and precious ecosystem. In view of the above, the Ministry of Environment and Forests, Government of India, has notified some environmental procedures and guidelines to conserve island ecosystems of India, which will be discussed (*vide* Annexure).

Definitions and Classification of Islands

From geographical point of view islands are defined as land masses surrounded by water barriers. Biogeographical definition of islands is simply an extension of their geographical definition and states that islands are water surrounded pieces of land masses where fauna is simplified when compared to that of a continent (Udvardy, 1969). However, ecological definition of islands is somewhat different. Any patch of habitat isolated from similar habitats by different inhospitable terrain traversed only with difficulty by the organisms of the habitat patch may be considered ecologically as an island (Simberloff, 1974). Besides actual (i.e., geographical and biogeographical) islands, ecological island also include ponds, lakes, bogs, dunes, mountain tops, etc., as well as areas fragmented by human land use. However, in the present context, insular ecology and biota deals with those of actual islands only.

Wallace (1880) categorised islands biogeographically into two distinct types – continental islands and oceanic ones. According to him, continental islands are detached fragments of continents consisting of complex continental rocks and always inhabited by terrestrial mammals and amphibians. Oceanic islands on the other hand are originated in the ocean, consisting of volcanic rocks and corals and not inhabited by terrestrial mammals and amphibians. This distinction may hold good geographically but not so zoologically since there will be various degrees of mixture of both continental and

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oceanic fauna on some islands. In view of this, Darlington (1966) made some arbitrary classification of islands, which he thought to be useful to understand the pattern of distribution of island life, more specially vertebrate animals. He grouped islands under three broad categories, namely. Recent Continental Islands (either tropical or non-tropical), Fringing Archipelago (all tropical) and other islands, and Archipelago (not arranged by climate). According to Carlquist (1965), if an island biota contains phylogenetically primitive forms with poor dispersal ability it may be continental in origin. In addition to this, continental islands may possess some subsequent immigrants and introduced species by human agency. On the other hand, oceanic islands are usually inhabited by immigrants which have reached by long distance dispersal (waif biota). Thus continental islands may harbour both harmonic and disharmonic flora and fauna where as oceanic islands will possess waif biota.

Ecological and biogeographical importance of Island fauna

Irrespective of continental or oceanic nature of insular fauna it is necessary to get insight into the following aspects in order to understand their ecological and biogeographical significance.

- How the biota have migrated to the islands crossing water barriers of variable distance, *i.e.*, mode of dispersal.
- How those migrating species have become established on the island *i.e.*, strategy of colonisation.
- What ecological and evolutionary changes of the established species could occur on the island.

Dispersal of animals : Dispersal of animals from continent to islands and from one island to another presents special problems since oceans are most effective barrier. Many of the world's prominent islands occur on continental shelf and are separated from mainland only by shallow seas. Some such islands may be temporarily connected to mainland by land bridge during glaciation or during cyclical rise and fall of sea level enabling dispersal of island animals from nearby mainland source or from other island.

For example:

- British isles to Europe;
- Japan to Korea and Siberia;
- Sumatra, Java and Borneo to Malaya;
- New Guinea and Tasmania to Australia.

However, continued dispersal of animals to both oceanic and continental islands may take place by several means as follows:

- Flying animals such as large birds and bats may reach islands by means of their own power of flight.
- Light bodied animals, such as, spiders, insects (especially flying insects) and, smaller birds and bats may reach island by being carried passively by wind.
- Small insects, spiders and micro-organisms may be carried away to a very long distance by occasional storm and gale.

- Some mammals (such as rats), lizards and some insects (*e.g.*, cockroach, wood-roach, wood boring insects) may reach islands on 'rafts' and through country boats and ships.
- Animals capable of migrating on islands from mainland or from another island may in their turn carry eggs and resting stages of other animals attached to their bodies.
- Resistant eggs of many animals may be safely transported to different human inhabited islands from continent or other islands, being attached with vegetation and vegetables brought for commercial purpose (*e.g.*, some land molluscs).
- Many animals, more particularly tame and pet animals (*e.g.* monkeys) and animals used as food stuffs (such as, pig, deer, etc.) reach even more distant islands being carried by roaming sailors and other human agency.
- Pre-reproductive adults of many species of flying insects may be carried along in large number by wind currents (Johnson, 1963) during their dispersal flight.

Colonisation: Land animals which succeed in reaching an island may have to face the inhospitablity of the beach and other initial hazards before finding a suitable habitat in which they can survive.

However, once they are able to cross these hazards, their further course of adaptation and establishment would depend upon number of factors.

(a) Site and topography of the islands: It is likely that larger is the size of the island greater is the variety of habitats to support more variety of forms of life. Furthermore, larger islands with more topographic diversity (such as, presence of hills) offer greater opportunities for colonisation and speciation within islands than do smaller islands.

For colonisation of terrestrial mammals limiting effect of the area of an island is very important.

(b) Degree of isolation: Variety of island life depends very much upon the frequency at which colonising animals and plants reach the island, whatever may be the diverse habitat available on that island. In other words, diversity of island biota is strongly affected by the degree of geographical isolation of the islands. The chances of faunal colonisation are expected to decrease as distance of islands from faunal source (mainland) is increased. For this reason, number of animal and plant species on Pacific islands become progressively lesser as their distance from Asian mainland (which is their source) gradually increases.

(c) Presence of stepping stone islands: Stepping stone islands are expected to be more important to species whose propagules tend to be dispersed actively or on floating "rafts" Even minute islands as stepping stone can significantly enhance the biotic exchange provided they can support population of the species in the first place. If stepping stones are large and located near recipient islands then they can increase the flow of colonising propagules by many times.

(d) Equilibrium between rate of immigration and rate of extinction: The number of species found on an island largely depends on this factor.

Ecological and evolutionary changes following colonisation

When a species invades an island it has to encounter an environment which is different from its previous one in varying degree. Moreover, it has to face new kinds of predator, prey and parasites. In this situation and in order to establish successfully in new environment the colonising species usually responds either by shifting its ecological preference or by undergoing ecological expansion or contraction.

Character release and character displacement: The phenomenon whereby a species broadens its ecological range by way of changing dietary mode, behaviour or morphology is termed 'ecological expansion' or 'character release' For example, three insectivore species of the genus *Tenagra* co-exist on the island of Trinidad. But they have reduced competition amongst them because they haunt for insects on different parts of vegetation. One species *(T. guttata)* searches insects mainly on leaves, other species *(T. gyrola)* on larger twigs and the third one *(T. mexicana)* on smaller twigs. This sort of ecological release leads to another phenomenon termed "character displacement" whereby congeneric species on and island develop mutually exclusive ecological range. Once character displacement between two congeneric species is established they could become sympatric

Speciation, ecological shift and adaptive radiation: When colonising propagules establish a population on an island or archipelago the population remains isolated from the mother population for sufficiently long period and may be genetically adapted to local conditions. At this stage, a second wave of immigrants may arrive the perceive the first isolate as a separate population. Such invasion and re-invasion may occur not only due to chance colonisation but also due to alternative connection and separation during cyclical rise and fall of sea level. Thus cycles of isolation – invasion-isolation-re-invasion may promote speciation among island fauna. Moreover, limited dispersability may lead to creation of many small isolated populations on islands. If these populations live under substantially different environment they may in the course of time undergo genetic differentiation and eventually achieve the status of subspecies and finally species.

Endemic subspecies/races and species are frequent among insular fauna. The more isolated islands of the archipelago tend to have greater number of subspecies.

Adaptive radiation takes place on an island or archipelago where a small number of migrants meet a broad spread of ecological spectrum. This situation promotes character release. The character release represents ecological shift. Series of ecological shifts coupled with morphological diversity leads to adaptive radiation. There are several examples of adaptive radiation among island fauna, such as, Honey creepers of Hawaiian islands, Darwin's finches of Galapagos archipelago, the frogs of the Seychelles, the gekkonid lizards of New Caledonia and ants of Fiji and New Caledonia.

Other evolutionary changes: Evolutionary plastic groups such as birds, reptiles, insects and land molluscs often show changes in form, size and colour in insular environment. Such changes include gigantism, dwarfism, melanism, etc. There may also be changes in wing size in birds. Flightlessness may evolve in volant groups of animals on islands.

Why island ecosystems are ecologically sensitive and precious

1. As discussed earlier, islands and archipelagos are living laboratories on earth where evolution *vis-à-vis* speciation and adaptive radiation is likely to take place rapidly in small isolated populations.
2. Islands provide living demonstration of evolution through wonderful examples, such as, Darwin's finches on Galapagos islands and Honey creepers on Hawaiian islands.
3. Islands harbour simple, impoverish and large percentage of endemic biota.
4. Some islands act as stepping stones, facilitating dispersal of biota to other islands/places. Any environmental stress on such islands will not only reduce/exterminate biota of those islands but also cause hindrance to the dispersal of biota to other islands/places with subsequent effect.
5. Coastal areas of many islands harbour corals/coral reefs and mangroves which are the reservoirs of very rich biodiversity.
6. Insular ecosystems are fragile. Hence environmental stress on such ecosystem may cause irreparable loss to biodiversity. Paine (1966) experimentally demonstrated that removal of a predator star fish, *Piaster* caused reduction of number of species from 15 to 8 in the food subweb at Mukkaw Bay, Washington. This experiment has revealed how chance extinction of one species in a simple island community may have a severe consequence, leading to the extinction of several other species.

Biodiversity of Andaman and Nicobar islands – An Indian example

The Andaman and Nicobar islands are the summits of a submarine mountain range, lying on the great tectonic suture zone that extends from the eastern Himalayas along the Burma Border to the Arakan and finally Sumatra and the Lesser Sundas. This archipelago consists of 352 islands and, comprise main island chains of Andaman and Nicobars, Ritchie's archipelago and the two outlying volcanic islands – Narcondam and Barren. The northernmost part of these islands (North Andaman) is isolated from Cape Negrais in Southern Burma by the North Preparis Channel (255 m depth and 285 km wide). The southernmost part (Great Nicobar) of this archipelago is also separated from the Acheen Head of Western Sumatra by the Great Channel (1600 m depth and 189 km wide). Besides, there are two other deep channels, namely, the Ten Degree Channel with 900 m depth and the Sombero channel with 250-275 m depth which isolate the Andamans from the Nicobars and the middle Nicobars from the Great Nicobar respectively. Since it is now universally accepted that Pleistocene sea level lowering never exceeded 160 m (Gascoyne *et.al.* 1979) it is quite evident that a permanent water barrier isolated these island chains from any adjacent mainland as well as some segments of this chain long back (some 100 million years ago, during the upper Mesozoic).

These islands possess undulating topography with mountains of variable heights and rich tropical rain forests, forming the terrestrial ecosystem. Moreover, mountainous parts of the southern islands get around 300 cm rain fall annually. In insular environment this type of vegetation with undulating topography and abundant rainfall offers a wide gamut of ecological habitats from the coast to the mountain top, ideal for supporting rich and diversified terrestrial fauna migrating from mainland source or from other islands (Hamilton, 1964). Further, such habitats in the islands are very much suitable for their subsequent establishment and evolution.

This archipelago also supports richest coral formations in its marine ecosystem and luxurious mangrove-fringed coasts at the interphase between the terrestrial and marine ecosystems. It is well known that coral ecosystem itself is one of the richest ecosystems sustaining a innumerable variety of life forms like crabs, molluscs, echinoderms, fishes, etc. Over and above, mangrove ecosystem is an important reservoir and feeding, breeding and nursery grounds of a large number of animals species, both terrestrial and aquatic. It is, therefore, quite inevitable that this archipelago would harbour a rich faunal biodiversity.

So far 6,323 species and subspecies of animals (2,366 terrestrial and 3,757 marine) representing major faunal groups have been reported from these islands (Table 1, on following page).

It needs mention here that many areas in these islands still remain either unexplored or under explored. Consequently our knowledge on animal species diversity, more particularly terrestrial invertebrates and, beach inhabiting and coral reef inhabiting animals is far from complete. In view of this and considering habitat diversity as discussed earlier it can safely be inferred that much more animal species would be available in this archipelago when planned island-wise and ecosystem-wise survey is complete and fauna thus collected is studied.

The table clearly reveals that faunal endemism is significantly high in this archipelago in terrestrial animals. Amongst mammals, the Crab-eating Macaque, Wild pig, Palm Civet and all the Spiny Shrews (*Crocidura*) and the Tree Shrews (*Tupaia*) which could reach these islands have become endemic. Even considerable number of species/subspecies of bats (11 out of 26) and rats (11 out of 14) which possess high degree of dispersal ability have also achieved endemic status.

Birds of these islands are interesting not only due to their high percentage of endemism but also for their restricted distribution within the island chains. The Narcondam Horn bill which is found only in Narcondam island is the typical example. Some endemic subspecies of birds are found to occur on one particular island or on few adjacent islands. For example, three endemic subspecies of White-headed Myna, namely, the Andaman White-headed Myna (*Sturnus erythropygius andamanensis*), the Nicobar White-headed Myna (*S. erythropygius erythropygius*) and the Katchal White-headed Myna (*S. erythropygius katchalensis*) occur in these islands. Among these, the first one occurs in several adjacent Andaman islands while the second and the last ones are restricted to Car Nicobar and Katchal islands respectively. Therefore, any severe threat to their habitat in Car Nicobar and Katchal islands will lead to exterminate two subspecies of this Myna for good.

There are several such examples of birds in these islands, of which distribution of Megapode, *Megapodius freycinet* is very noteworthy. This unique bird is represented with two subspecies in this archipelago. One subspecies, the North Nicobar Megapoda (*M. freycinet nicobariensis*) is restricted to Nicobar group of islands lying north of Sombero Channel (except Chowra and Car Nicobar). The second one, the South Nicobar

Megapoda (*M. freycinet abbotti*) is endemic in the Little and the Great Nicobar islands. Such significance can also be attached with many reptiles and invertebrates of these islands which need elaborate analysis.

Table 1

Biodiversity and fauna endemism of Andaman and Nicobar islands			
Animal group	**No. of species/ Subspecies**	**No. of endemics**	**Endemic %**
Terrestrial fauna			
Mammalia	52	32	61.6
Aves	246	99	40.2
Reptilia	76	24	31.6
Amphibia	18	3	16.7
Mollusca	110	77	70.0
Arachnida	94	38	40.4
Hemiptera	146	22	15.0
Diptera	214	24	11.2
Coleoptera	878	92	10.5
Lepidoptera	426	52	12.2
Isoptera	40	19	47.5
Odonata	36	4	11.1
Annelida	30	9	30.0
Total	2366	495	
Marine fauna			
Mammalia	3		
Reptilia	12		
Pisces	820	2	0.2
Echinodermata	336	4	1.2
Mollusca	932	18	1.9
Crustacea	586	6	1.0
Polychaeta	184	4	2.2
Anthozoa	326	2	0.6
Porifera	72		
Meiofauna	486	102	21.0
Total	3757	138	

The terrestrial fauna of the Bay islands also display several evolutionary changes such as dwarfism, gigantism, etc. For example, Serpent Eagles of these islands, belonging to the genus *Spilornis* display dwarfism where as Green Imperial Pigeon, *Ducula aenea* and Red-cheeked Parakeet, *Psittacula longicauda* show gigantism on these islands.

Further to mention that these islands are the only place on the globe where two species of Serpent Eagles of the genus *Spilornis* exist sympatrically. Although these eagles are sympatric still they are reported to be ecologically separated. In the Andamans sympatric species *S. cheela davisoni* occupies mangrove fringed creeks while *S. elgini* is found more inland. On the Great Nicobar island *S. klossi* inhabits closed type of tropical forest while *S. cheela malayensis* occupies forest clearings near the coast.

It has been discussed earlier that coral reef ecosystem of this archipelago is very precious as biological resource. Coral reefs are important not only commercially but also ecologically since they act as a buffer against the impact of heavy wave action on the shore, protect the beaches from soil erosion and thus check loss of littoral vegetation. In the past coral reefs played a great role in the formation of many islands of this island chain. Now also they might be playing the same role slowly and steadily.

Threats

The biodiversity of these islands is threatened mainly due to habitat destruction/alteration, population influx and indiscriminate exploitation of biological resources. Pollution, although much less in these islands compared to mainland, has also a role to play in this regard in some islands. Oil spills which were observed on Nicobar waters in recent time may pose a severe threat to marine biological resources, if such incident is not checked for future, particularly during the movement of oil tankers in this region.

Habitat alteration is caused mainly by agriculture and its associated activities, logging operation and plantation of some exotic plants (e.g., rubber plantation and red oil palm plantation). The impact of these activities is mainly on the forest ecosystem. Forest coverage which was initially about 86 per cent of the land area has reduced considerably due to clearing of forests for human settlement, developmental activities, road construction and agriculture. An area of 48,000 ha forest area has been cleared for agriculture, plantation and horticulture (Saldanha, 1988). It has been estimated that the area of intact natural forest cover of Andamans has been reduced to half during the last 100 years as a result of which 20 per cent of the species are threatened to extinction (Rodgers and Panwar, 1988).

The widespread cutting of mangroves in these islands in recent years for the purpose of fuel, fodder, and other domestic or industrial needs poses a considerable threat to animal communities of this ecosystem. The annual wood requirement of 34 wood-based industries in these islands was estimated to be around 1,89,200 cu. m (Saldanha, 1988). Since the beginning of this century quality wood of these islands has not only been lavishly exploited for local consumption but also exported to mainland India in sufficient quantity.

Sand quarrying on nesting beaches, poaching of eggs and pollution have greatly endangered sea turtles like Green Sea Turtle (*Chelonia mydas*), Hawksbill (*Eretmochelys imbricata*) and Olive Ridley (*Lepidochelys olivacea*).

The rare and unique bird, Megapode.(*Megapodius freycinet*) is also severely threatened. A census report of the Nicobar Megapode (*M. freycinet abbotti*) submitted by ZSI Scientists in 1988 reveals that this bird is thriving only in Great Nicobar island (the population estimated at around 357-400 pairs). During their visit these scientist could not locate any mound in Camorta, Katchal and Kondal islands which are reported home range of this bird.

The population influx and increased tourism in these islands are responsible for indiscriminate destruction of marine biological resources. Corals are extensively collected for presentation, decoration, fancy sale and educational study. In some islands large quantity of living corals were used for the construction of roads. The construction of jetties, wharves, harbours and dredging activities deposit large quantity of silt which destroy the ecologically sensitive corals in those areas. One NGO organisation, Society for Andaman and Nicobar Ecology (SANE) reported in 1987 that Military Engineering Service (MES) had been extracting thousands of cubic metres of coral off Kamorta islands, near Naval Helipad at INS Kardip, for use in construction of shore protection pillars (Kothari, 1989).

A considerable quantity of corals, molluscs and echinoderms are collected for trading purposes as well as during the educational tours by the College and University students coming from the Mainland. The collection is indiscriminate and no closed season is observed.

Suggested Readings

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ANNEXURE

ENVIRONMENTAL PROCEDURES AND GUIDELINES OF GOVT. OF INDIA, MINISTRY OF ENVIRONMENT & FORESTS CONCERNING ISLAND ECOSYSTEMS OF INDIA

Environmental Clearance

Government of India (Ministry of Environment & Forests) notifies certain areas as ecologically sensitive/fragile areas from time to time. All developmental projects which are to be located in these notified area need to obtain environmental clearance from Central Government irrespective of whether they are listed under Schedule I of the EIA notification or not. Some of the identified ecologically sensitive/fragile areas notified under the Environment (Protection) Act, 1986 so far include:

- Identified coastal areas as per Coastal Regulation Zone (CRZ) Notifications.
- Forest, Wildlife Sanctuaries, National Parks, Wetlands, Mangroves, Biosphere Reserve, Hill and Mountain areas, etc.

Conservation Of Natural Resources

Some Important Guidelines Laid Down In Forests (Conservation) Act And Rules For Diversion Of Forest Land For Non-forest Purposes

These guidelines ensure that ecological considerations are in no way undermined while examining investment proposals. The guidelines specify certain criteria for the siting of an industry, which state that no project should be in the vicinity of:

- National Parks, Wildlife Sanctuaries and Core areas of Biosphere Reserve.
- Scenic landscapes, areas of geomorphological significance, unique and representative biomes and ecosystems, heritage sites/ structures and areas of cultural heritage and importance.
- Fragile ecosystems such as mountains, areas rich in coral formations as well as marine, coastal, desert, wetlands, riverine and island ecosystems.
- Area rich in biological diversity, gene-pool and other natural resources.

Conservation Of Coastal Areas

Under the EPA, 1986, the Government of India has declared the coastal stretches of seas, bays, estuaries, creeks, rivers and backwaters which are influenced by tidal action in the landward side up to 500 m from High Tide Line (HTL) and the land between the Low Tide Line (LTL) and HTL as the Coastal Regulation Zone (CRZ).

Certain activities are prohibited in the CRZ, such as:

- Setting up of new industries or expansion of existing industries except those directly related to water front or directly needing foreshore facilities.
- Manufacturing, handling, storage or disposal of hazardous substances.
- Setting up and expansion of units/mechanisms for disposal of waste and effluent, etc.

Coastal Areas Classification And Development Regulation

For regulating development activities, the coastal stretches within 500 m of HTL on the landward side are classified into four categories as: Category I (CRZ – I); Category II (CRZ – II); Category III (CRZ – III); Category IV (CRZ – IV).

Coastal stretches in the Andaman & Nicobar, Lakshadweep and small islands except those designated as CRZ – I, CRZ – II or CRZ – III are included in CRZ – IV.

Category – IV (CRZ – IV): The development or construction activities in this area shall be regulated by the concerned authorities at the State/Union Territory level in accordance with the following norms:

Andaman & Nicobar islands:

(i) No new construction of buildings shall be permitted within 200 m from HTL

(ii) The buildings between 200 and 500 m from the HTL shall not have more than two floors (ground floor and 1st floor), the total covered area of all floors shall not be more than 50 per cent of the plot size and the total height of construction shall not exceed 9 m.

(iii) The design and construction of buildings shall be consistent with the surrounding landscape and local architectural style.

(iv) Corals and sand from the beaches and coastal waters shall not be used for construction and other purposes.

(v) Dredging and underwater blasting in and around coral formations shall not be permitted; and

(vi) In some of the islands coastal stretches may also be classified into Categories CRZ – I or CRZ – II or CRZ – III, with the prior approval of Ministry of Environment & Forests and for such designated stretches, the appropriate regulations given for respective categories shall apply.

Lakshadweep and small islands

(i) For permitting construction of building the distance from the HTL shall be decided depending on the size of the islands. This shall be laid down for each island, in consultation with the experts and with the approval of the Ministry of Environment & Forests, keeping in view the land use requirements for specific purposes vis-à-vis local conditions including hydrological aspects, erosion and ecological sensitivity.

(ii) Other regulations are same as those mentioned under item (ii) to (vi) of the A & N islands.

CRZ – I to III: These are also briefed as follows for general information:

Category – I (CRZ – I):

(i) Areas that are ecologically sensitive and important, such as national parks/ marine parks, sanctuaries, reserve forests, wildlife habitats, mangroves, coral/ coral reefs, areas close to breeding and spawning grounds of fish and other marine life, areas of outstanding natural beauty/ historical/ heritage areas, areas rich in genetic diversity, areas likely to be inundated due to rise in sea level consequent upon global warming and such other areas as may be declared by the Central Government or the concerned authorities at the State Union Territory level from time to time.

(ii) Area between Low Tide Line and Hide Tide Line.

Category – II (CRZ – II): The areas that have already been developed up to or close to the shore line. For this purpose, "developed area" is referred to as that area within municipal limits or in other legally designated urban areas which is already substantially built up and which has been provided with drainage and approach roads and other infrastructural facilities, such as water supply and sewerage mains.

Category – III (CRZ – III): Areas that are relatively undisturbed and those which do not belong to either Category I or II. These will include Coastal Zone in the rural areas (developed and underdeveloped) and also areas within municipal limits or other legally designated urban areas which are not substantially build up.

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MARINE ECOSYSTEMS

N.V. SUBBA RAO*

Introduction

The first living creature heard its lullaby in the tossing waves while swinging in the cradle of sea. Over the years this simple form of life evolved and diversified into myriad forms which established intricate relationships with each other and with the environment around. Life originated in the sea about 3,000 million years ago and by about 350 to 400 million years ago it invaded land. Oceans have certain characteristics which permitted the occurrence of life-developing phenomenon and proliferation into many forms. The interaction of land, sea water and freshwater has led to diversity in ecosystems along the coast. The living organisms have exploited these ecosystems and in the process have added to their genetic and species diversity. The ancestry of all living creatures can be traced back to marine environment, and this watery world covers 71 per cent of the earth's surface. The body of the latest species that arrived on the scene, that is man, is composed of about 71 per cent water and the blood that circulates in it is a solution somewhat similar to sea water.

It is estimated that of the total earth's surface 65 per cent constitute open ocean, 8 per cent coastal zone and 27 per cent uplands. Approximately 51 percent of the total ocean area has over 3000 meter depth. It is well known that the narrow coastal zone is an area of high biological diversity. Till recently deep sea, which constitute a major part of oceans, was considered to be biologically insignificant. But the discovery in 1967 of high species diversity communities living in the bottom of deep sea has enhanced the importance of marine environment as a repository of rich biological diversity (Groombridge, 1992).

The Extent Of Marine Ecosystems

The seas around India: The Indian Ocean with its waters stretching over 75 million sq. km. and having an average depth of 4 km., ranks third after the Pacific and Atlantic Oceans. But unlike these two oceans, it has thickly populated land masses on three sides. It has two arms, extending northwards, which form boundaries for India on its west and east coasts, respectively. The Arabian Sea (latitudes 0º and 25ºN, longitudes 50º and 80º E) whose waves strike the west coast of India occupies an area of 6.225×10^6 km^2. The Bay of Bengal (latitudes 0º and 23º N, longitudes 80º and 100º E) occupies an area of about 4.087×10^6 km^2 (Jones and Banerjee 1973; Qasim, 1977). The Indian Ocean is often categorized into western, central and eastern parts. The bottom topography of the Indian Ocean is distinguished by the presence of two ridges, namely Carlsberg ridge in the western part, and East Indian Ocean Ridge or Ninety Degree East Ridge in the eastern part. The total area of the seas bordering India, namely, Arabian, Laccadive, Bay of Bengal and Andaman Sea together form only 3 per cent of the total ocean area of the globe. In comparison India has 2.4 per cent of earth's land mass.

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The Bay of Bengal together with the Andaman Sea has some physical, chemical and biological properties which differ from those of the Arabian Sea. The Andaman Sea occupies an area of 602 x 10^5 sq. km. and has a volume of 6.6 x 10.51 c u.m. with maximum and average depths of 4,360m and 1,096m respectively (Anon, 1981). The continental slope on the eastern side of the Andaman islands is steeper than on the western side where it is irregular. The environmental parameters in the Arabian Sea and Bay of Bengal are very much influenced by river discharges and hence the difference between the two in certain characteristics.

India has a long coast line, of about 7,916 km, stretching along ten states and two archipelagos (Table 1). The coast is indented by a number of rivers, which form estuaries at their confluence with the sea. The complex coastal ecosystems comprise of estuaries, lagoons, mangroves, backwaters, salt marshes, mud flats, rocky shores and sandy stretches. Besides, there are three gulfs, one on the east coast, Gulf of Mannar, and two on the west coast, Gulf of Kachchh and Gulf of Kambath. The two island ecosystems, namely Lakshadweep and Andaman & Nicobar Islands add to the ecosystem diversity in India. Gulf of Mannar, Gulf of Kachchh and the two islands ecosystems have rich coral reefs harbouring valuable marine biodiversity.

Table 1

State-wise details of coast length, continental shelf and EEZ.

State	Coast Length (Km.)	CONTINENTAL SHELF					Area of EEZ (sq. km.)
		Average distance (Km.)	Maximum width (Km.)	Up to 50 m (sq. km.)	50 to 200 m (sq. km.)	Total up to 200 (sq. km.)	
West Bengal	264	68.4	50	9,935	12.927	22.862	32.320
Orissa	482	68.4	150	17,066	6,563	23.629	97.720
Andhra Pradesh	980	32.0	40	16,607	14.437	31.044	1.39.580
Tamil Nadu (& Pondicherry)	1000	43.1	100	23,255	18,157	41.412	1.97.120
Kerala	560	64.4	80	12.569	23.372	35.941	1.47.740
Karnataka	320	94.3	100	7,936	17,537	25.473	87,080
Goa	135	90.8	100	2,849	7,135	9,984	43,500
Maharashtra	600	174.6	270	25,512	79,246	1,04,758	1,31,680
Gujarat	1,663	66.2	350	64,810	34,563	99,373	2,14,060
Lakshadweep	-	-	-	-	-	4,336	1,78,666
Andaman & Nicobar Islands	1,912	-	60	-	-	16,036	5,19,590
Total	7,916	-	-	1,80,539	2,34,329	4,14,868	17,89,056

* *Data collected from different sources: Jones & Banerjee (1973), Bhakta (1983), and also Maps.*

The extension of land into the sea is continental shelf and it has variable width along the Indian coasts. The continental shelf area is the sea bed and submarine area extending from coast up to 200m. depth. The shelf has an average width of 32 km. along Andhra coast, but it is wider, being 175 km., off Maharashtra coast (Table 1). The total shelf area which is divisible into in-shore (up to 50 m depth) and off-shore regions (between 50m and 200m depth) occupies an area of about 4,14,868 sq. km. (including the islands). The total shelf area of India represents about 0.55 per cent of the surface area of the Indian ocean. Exclusive Economic Zone (EEZ) is an area beyond and adjacent to territorial waters with a limit of 200 nautical miles from the base line. The Indian EEZ has 1.8 millions sq. km. area (majority of literature records mention 2 million sq. km. of EEZ) and represents about 2.7 per cent of the Indian ocean. In India the EEZ on the West coat (including Lakshadweep) constitutes maximum (42.5 per cent) followed by Andaman and Nicobar Islands (29.7 per cent) and east coast (27.8 per cent).

The slope of the continental shelf influences the movement of water and the geological structure of the adjacent land mass. The interaction between land and sea involves mechanical, physical and chemical processes, which produce characteristic shapes of coast line. The physical feature of the land bordering the sea, influence of wind and water currents, salinity variations, light intensity, temperature fluctuations and a number of other related environmental factors, individually and cumulatively influence marine productivity and thereby biodiversity. The marine environment bordering the Indian landmass is characterized by ecosystem diversity, which offer ideal habitats and ecological niches for a flourishing biodiversity. Biological richness of coastal ecosystems in the tropical Indo-Pacific region, has been stressed by many authors and India is not exception to this. Among the 40 countries bordering Indian Ocean, India holds a special position.

The marine environment encompasses coastal ecosystems/wetlands, littoral seas and open ocean. Each one of these has special physical, chemical and hydrographical characteristics and biodiversity shared among all, and some specific to a particular ecosystem only.

Shore-types of India: India has different types of shores. The environmental factors operating in a particular area are determined by the type of shore. It determines the composition and distribution of biological diversity. There are four basic types of shores along Indian coast (Krishna Murthy & Subba Ramaiah, 1974): i) sandy shores, ii) rocky shores, iii) coral formations and iv) estuarine regions.

More than half of the Indian coast line is sandy. A major part of the east coast of India is sandy. The sandy coast may be wholly sandy or may be interspersed with rocks. The grain size, beach profile and moisture content of sandy coasts determine the vertical and horizontal distribution of biodiversity in the inter-tidal interstitial zone. The rocky shores may be formed out of igneous or sedimentary or metamorphic rocks depending on the region. The rocky shores may consist of silt covered rocky flats, steep rocky formations, or over-hanging cliffs. The west coast of India is predominantly rocky, silt-covered rocky flats occur especially on the Gujarat coast near the Gulf of Kambath and Gulf of Kachchh. Another common type of rocky shore is limestone rocks covered with a thick sand deposit and with well-defined shallow tide pools. From Bombay down to Kanya Kumari there are steep rocky shores, often with overhanging cliffs formed of green to black basalt. These rocky shores on the west coast are interrupted by sandy areas, rivers, creeks and backwaters. There are small stretches of rocky formations along coasts of Tamil Nadu and Andhra Pradesh.

Coral reef shores occur around Andaman and Nicobar islands, Lakshadweep, off Palk Bay, Gulf of Mannar and Gulf of Kachchh. Corals were also reported off central west coast near Ratnagiri and Malwan coast, Gaveshani Bank of Mangalore. Estuarine shores are more on the east coast than on the west coast.

(a) Coastal Wetlands – Backwaters, estuaries and lagoons: Coastal wetlands of India may be recognized into estuaries, mangroves, coastal lagoons, pools or salt marshes into which sea water occasionally enters. Besides these natural ecosystem, man's activities have added a number of brackish water farms into which sea water is regulated. In all these there is a mixing of saline and fresh-water. In all, the saline or saltwater is received from the sea but the source of the fresh-water may differ depending on the concerned wetland. It is generally added from rainfall, canals and rivers.

A sizable stretch of the Indian coasts are occupied by estuaries. There are 14 major, 44 medium and 166 minor river systems in India. The catchment area of all these rivers totals about 3.12×10^6 km^2 (i.e. 95% of the land area measuring 3.276×10^6 km^2). The annual freshwater discharges of all these rivers put together is about 1645 km^3, of this 75% flows into Bay of Bengal. The 14 major rivers account for 83% of the total catchment area and 85% of the annual run off into seas around India (Qasim & Sen Gupta, 1984). Some of the estuaries are small and have a poor flow during summer months so that a sand bar forms across the mouth blindly ending the estuary. The estuaries support vast tracks of mangrove vegetation which add substantially to the organic production. A number of small estuarine may have no mangrove vegetation. Ecology of estuary is greatly influenced by the presence of mangroves.

There are typical estuaries on the east coast formed by the Ganga-Brahmaputra, Mahanadi, Brahmani, Subarnarekha, Godavari, Krishna, Pennar, Cauvery, Vellar etc. On the west coast typical estuaries environment is formed by the rivers Narmada, Tapti, Sabarmati, Mahi, the Zuari-Mandovi, Netravathi, Korapuzha, etc. There are specialized estuaries or lagoons such as Chilka lake and Pulicat lake on the east coast, Kayankulam, the Vembanad lake, Ashtamudi, and Cochin backwaters on the west coast. There are some 41 estuaries in a small state like Kerala. About 30 of these are coastal lakes or lagoons which are locally known as 'Kayals'

There are regional differences in the estuaries on the east and west coast of India. In spite of great annual precipitation in the Arabian Sea, its salinity is higher than in the Bay of Bengal, because of high rate of evaporation in the west coast rivers. On the east coast rivers flowing into the Bay of Bengal cause reduction in the salinity from average 30% to 18% (Krishnamurthy, 1985).

There are several estimates regarding the total area under estuaries and backwaters. The total estuaries and backwater area of India was calculated to be 30,000 km^2 or about 1% of the total catchment area (Qasim & Sen Gupta, 1984). The surveys by Marine Products Export Development Authority have concluded that the total brackish water area in India is over 1.5 million hectares and the table shows approximately 2 million hectares. West Bengal has a maximum area with 4,00,000 ha, of which 33,210 ha of brackish water are under traditional method of culture at present. Another 47, 000 ha are expected to be added during 8th Plan under semi-intensive culture method (Sengupta, 1994). Gujarat has vast tracks of tidal mud flats spread over about 3,70,000 ha. Although Kerala has a small coast line it has about, 2,00,000 ha of brackish water. A total of 93,000 ha of brackish water is available in the states of Maharashtra (80,000 ha), Karnataka (8000 ha) and Goa (5,000 ha). The state of Andhra Pradesh, which is leading in aquaculture has 172 brackish water bodies, which have a total water spread of 63, 962 ha. Brackish water area in Orissa was 50,000 ha. and of this 31,600 ha was found suitable for prawn farming (Sakthivel, 1988). The total area under estuaries and backwaters in India is about 37,450 km^2 as given by Dwivedi (1973) and presented in the following table.

Table 2

State-wise data of estuaries and backwaters

State	(in lac hectares) Backwaters	Estuaries
Andhra Pradesh	2.5	4.0
Goa	0.19	-
Gujarat	4.6	5.0
Kerala	2.5	0.5
Karnataka	1.0	0.5
Maharashtra	0.81	-
Orissa	0.1	3.75
Tamil Nadu	1.0	0.5
West Bengal	5.0	5.0
Total	18.70	19.25

A Directory of Asian Wetlands (IUCN, 1989) gives the estimates for mangroves (0.4 million ha, estuaries 3.9 million ha and backwaters of 3.5 million ha. Jhingran (1991) estimated about 3 million ha of open estuaries, brackish and backwater areas.

(b) Coastal Wetlands – Mangroves: Indo-Pacific region has the largest expanse of mangrove forests. Mangroves in fact form a part of the total estuarine ecosystem but because of its unique nature it deserves a separate treatment. India has over 4260 sq. km of mangrove vegetation, which is the fourth largest after Indonesia, Australia and Malaysia. Mangroves play a significant role in the sustenance of coastal fisheries of tropics. These serve as feeding, breeding and nursery grounds for fishes, crustaceans and molluscs. These are natural buffer zones between land and sea. They receive inorganic materials from the land and in turn produce organic materials, not only directly in the form of green vegetation but also indirectly as feed for marine organisms.

In India lush mangrove vegetation grows in the Gangetic delta in the Sunderbans, Mahanadi, Bhitarkanika, Godavari, Krishna and Cauvery on the east coast, and in Vembanad lake (Kerala), in Sharavati river mouths and river Coondapur (Karnataka), along Goa coast in Zuari-Mandovi estuary, Ratnagiri coast (Maharashtra) and in Gulf of Kachchh (Gujarat) on the west coast. Andaman and Nicobar Islands, especially the former harbour a rich mangrove vegetation, and is next to Sunderbans in the area. A National Committee on Wetlands, Mangroves, Coral Reefs constituted by the Ministry of Environment, Forests & Wildlife has identified 15 mangroves as important conservation areas. There are several estimates of the extent of mangrove forests in India. The figures vary from 3,565 km^2 to 6,000 km^2 According to the satellite imagery (1987-89) interpreted by Forest Survey of India, mangrove forest in India is spread over an area of 4,256 sq. km., about 0.13 per cent of India's geographical area. The state-wise estimates of mangroves are presented in the following table:

Table 3

	State	Mangrove area (in sq. kms.)	Remarks
1.	Andaman & Nicobar	913	1000 sq. km. (Blasco, 1927) 1500 sq. km. (Saldanha, 1992)
2.	Andhra Pradesh	405	
3.	Goa	3	
4.	Gujarat	412	520 sq. km. (Parulekar & Untawale, 1978)
5.	Karnataka	1	
6.	Kerala	-	
7.	Maharashtra	114	
8.	Orissa	192	
9.	Tamil Nadu	47	
10.	West Bengal	2109	Total Sunderbans area, 4200 sq. km.
	Total	4256	

Besides mangroves, there are important coastal wetlands, namely Chilka Lake (Orissa), Pulicat Lake, Point Calimere (Tamil Nadu) and Rann of Kachchh (Gujarat).

Taxonomic Composition of Biological Diversity

Coastal Wetlands: Among coastal wetlands estuaries, mangroves, and coastal lagoons, are biodiversity-rich areas, where as the other brackish habitats have only a few specialized species. But backwaters support an important economic activity of aquaculture.

Some of the Indian estuaries were sampled for their hydrological features, productivity rates and fishery potential. Systematic sampling for biodiversity components was carried out in only a few large estuaries on the east coast. More intensively studied estuaries on the east coast are Hooghly-Matlah, Rushikulya, Godavari and Vellar, where as on the west coast Zuari-Mandovi estuary, received considerable attention. Fishery data is available for estuaries of Karnataka. However, precise figures are not available for a number of major faunal groups and for taxonomically less known groups and microscopic forms. The incomplete inventories of described/recorded species from a few estuaries may provide a poor basis for assessing the total estuarine biodiversity.

Estuarine ecosystem is a unique one formed by an interaction of sea, freshwater and land. It has a dynamic environment with fluctuating salinity and temperature regimes, alternating exposure and immersion by tides. Substrate type, wave size, currents etc. are other important environmental factors. Biotic components like food-supply, prey-predatory relationship are other contributing factors to estuarine biodiversity, which constitute essentially marine or freshwater species and a few characteristic species. These are a few permanent resident species of the coastal wetlands. Composition of estuarine fauna depends more on its physical characteristics than on its geographical position. The most important physical parameters appear to be depth, permanence of the mouth, salinity regime, turbidity and nature of bottom sediments. The paucity of estuarine fauna is attributed to the unpredictable and unstable nature of environment, fluctuating salinity and low level of available spatial diversity. Tropical estuaries are however, known for their faunal diversity. In spite of the rigorous and dynamic nature of environment there are taxa, which have successfully colonized the coastal wetlands in India. One of the favourable factor is the abundant food supply. In tropics organisms have developed increased osmoregulatory capabilities to cope up with the salinity changes. Although the overlying waters experience very much fluctuation in salinity, the bottom sediments have less salinity fluction. The mud dwellers at the bottom carry on 'the business as usual' It is perhaps due to this that estuarine benthic communities have permanent residents among them, while the pelagic communities include mostly migratory forms. Based on their salinity tolerance estuarine species are distinguished into five categories, namely oligohaline, true estuarine, euryhaline marine, stenohaline marine and migrants. The last category includes pelagic crustaceans, fishes and other vertebrates.

It is generally commented that there is a reduction in the species number in estuaries compared to adjacent seas and in-flowing river system. But as far as Indian estuaries are concerned the statement is partly true. There are lesser number of species than in the adjacent seas, but the upper riverine ecosystem does not harbour as many species as in its estuary. It has been observed that as the distance increases from the sea the number of species decrease. Salinity becomes an important regulating factor.

Out of the 32 animal phyla, 15 are represented by their taxa in estuary. They may constitute either migratory or resident species. The former include pelagic crustaceans, coelenterates (medusae), Cephalopod molluscs, fishes, reptiles, birds and mammals. Amphibians are generally absent in estuaries. The benthic macro fauna comprise resident species of polychaetes, molluscs, echiuras, sipunculas, and mud-burrowing fishes. Among invertebrates, sponges, phoronids and echinoderms generally do not prefer estuarine ecosystem. In India estuaries species diversity seems to be maximum in Molluscs.

About 245 species belonging to 76 genera under 54 families were catalogued. Another important taxa, polychaeta are represented by a total of about 167 species belonging to 97 genera under 38 families. Maximum species diversity has been observed in the Hooghly-Matlah estuary (Subba Rao,1995).

Micro-organisms and meiofauna of Indian estuaries are not properly investigated. Estuarine mud may contain a rich variety of bacteria, flagellates, ciliates, nematodes, ostracods, harpacticoid copepods, rotifers, gastrotrichs, arachnianelids, etc.

Littoral and Open Seas: Survey and inventorisation of marine biodiversity has been of recent origin. Eleven of the 80 living species of cetaceans have been discovered in this century, the most recent in 1991. One of the largest shark species, for which a new family Megachasmidae has been erected was discovered in 1976. A new animal phylum Loricifera was described from meiobenthos in 1983 (Raven & Wilson, 1972).

Recent researches, especially of the last three decades have generated some data on the areas of upwelling, marine productivity, fishing grounds etc. But species inventory of biodiversity in seas adjacent to India are far from complete. Studies in the past were concentrated on biodiversity in the littoral seas, especially inter-tidal zone of certain selected localities. The deep sea environment was never sampled systematically to obtain any clue to its biodiversity. The large area of deep ocean zone may be harbouring a number of species, probably endemic and hitherto unknown to science.

The amount of life produced on land per unit time is very small compared to the huge quantity of living matter produced in the sea. It is estimated that there are more living things in the sea than on land (excluding arthropods). About 150,000 animals species are described from the world seas and about 1000 new species are discovered every year. The data is, however, incomplete as there are a number of taxa occurring in the sea, about which we lack even basic knowledge. It was estimated that one sq. m of marine sediment contain 30-50 species of Foraminifera in tropical latitudes.

At the global level it is estimated that 90 per cent of marine species live in about 50 million sq. km. of the total 352 million sq. km. But as mentioned earlier deep sea environment also has rich biodiversity. At a broader level all the kingdoms of living organisms have their representatives in the marine environment. It has many habitats, conditions of life and food sources. Open sea with its surface photic zone and deeper aphotic regions provide different planktonic environments. There are eutrophic coastal and upwelling zones and oligotrophic ocean centres. Neritic zones favour autotrophs because they derive vitamins from terrestrial sources. Benthic habitats exhibit difference in physical and chemical conditions depending on the type of substratum, depth and illumination, oxygenation and water movement.

Plants (Kingdom Plantae) are restricted by the availability of light in the sea and their diversity in the sea is lesser than in the terrestrial ecosystems. The higher plants/flowering plants are totally absent in the sea. The two kingdoms, namely Protista or Protoctista and Animalia, include many branches of the evolutionary tree of life. The taxonomic status of the groups representing the evolutionary branches of Protista is in a fluid state. As many as 50 phyla are recognized under this kingdom (Sleigh, 1991). It includes all algal and protozoan groups as well as the flagellate fungi. Bacteria (Kingdom Monera) have successfully evolved in both aerobic and anaerobic habitats. In both planktonic and benthic situations there are mutually dependent, small communities of organisms particularly bacteria and protists. The primitive eukaryote Protista which evolved along with bacteria pursue autotrophic, phagotrophic, and free-living or parasitic mode of life.

In planktonic environments common protists are ciliates (Phylum Ciliophora), tintineds and naked oligotrichs, floating omnivorous-amoeboid forms (Phylum Actinopoda), certain foraminifera and radiolaria. Among the open sea protists the most important bacterivorous flagellates are choanoflagellates and chrysophytes, followed by haptophytes and dinoflagellates under phylum Dinophyta. All these organisms which passively float in ocean waters are treated under the broad category of plankton, which are further distinguished into phytoplankton and zooplankton. Phytoplankton which converts the inorganic carbon into organic compounds in the presence of sunlight serve as 'mobile food vans' to a number of consumers. These include a number of taxa under Protista such as diatoms, dinoflagellates, Coccolithophates, Silicoflagellates, and blue green algae; and bacteria. Plankton occur everywhere in the sea differing only with respect of species composition and relative abundance. The nutrient-rich coastal waters are dominated by diatoms, whereas the nutrient-deficient oceanic waters contain dinoflagellates in abundance. A total of 260 species of diatoms were reported from the Indian seas. There is generally a gradual decline in phytoplankton abundance from coastal to oceanic water.

The primary consumers include zooplankton comprising of different animal taxa (Kingdom Animalia). Of the 32 recognized animal phyla, 30 have their representatives in the sea. Majority of these are represented in the plankton either in juvenile or adult phase of their life history. Sponges, coelenterates, molluscs, and echinoderms have planktonic larvae, which help in their dispersal. A number of crustaceans, such as copepods, caldocerans, mysiids and other taxa, namely rotifers, chaetognaths, hemichordates and protochordates have plantonic adults. Copepods are primary grazers in the sea and convert plant material into animal meat.

Distribution pattern of various zooplanktonic groups and biodiversity of Indian seas, from the fishery point of view were investigated (Rao, 1973; Qasim and Kureishy, 1986). Some of the hydromedusae, namely *Liriope tetraphylla, Cunina tenella, Pandeopsis scutigera, Phialucium condesum, Helgicirrta mucifera* are common in both Bay of Bengal and Arabian sea. *Aglaura hemistoma* and *Solamundella bitentaculate* are abundant in the Arabian Sea (Vanucci & Nayar, 1973) High densities of copepods were observed in the northern Arabian Sea, off Tamil Nadu coast and the northern Bay of Bengal, including Orissa coast.

The areas of divergence and up-welling are rich in zooplankton. During south-west monsoon high densities of euphausiids and mysiids were observed off the Arabian coast, and off Madras, extending up to hundreds of kilometres. During this period rich chaetognath fauna was observed in the western Arabian Sea and the entire Bay of Bengal. Euphausiids, chaetognaths and planktonic molluscs are abundant during south-west monsoon. But copepods are more abundant during north east monsoon. As many as 23 and 21 species of appendicularians were recorded from the Arabian Sea and Bay of Bengal respectively.

Free swimmers or nekton are important components of marine biodiversity and constitute important fisheries of the world. The dominant taxa in the nekton are fish, others being crustaceans, molluscs, reptiles, and mammals. Out of a total of 22,000 species (25,000 according to some) of fish species 13,000 are marine. It was estimated that about 4,000 species occur in the Indian Ocean, of which 1800 species are from the Indian seas. Majority of the nektonic species are found in the coastal waters. It was estimated that the oceanic fishes were represented by 40 species of sharks and 250 species of bony fishes.

Among reptiles, sea snakes and turtles are important and represented by 50 and seven species respectively. These are generally oceanic forms but majority of these often swim near to the shore and visit the shore at some part of their life. About 26 species of sea snakes belonging to one family Hydrophiidae and five species of sea turtles were reported from seas around India. Oceanic islands seem to harbour more reptiles in their marine environment. All the sea snakes known from India and four species of turtles are known from the islands of Andaman and Nicobar. Nesting sites of Laticauda, an amphibious snake were reported from the shores of North Andaman islands (Whitaker, 1985). Turtles visit the shore during breeding time to lay their eggs. The shore visit of these turtles especially the Olive Ridley is a spectacular sight on the sandy beach at Gahirmatha, near Bitharkanika in Orissa. The Andaman and Nicobar Islands have best nesting beaches for the leatherback (*Dermochelys coriacea*), the hawksbill (*Eretmochelys imbricata*) and the green turtle (*Chelonia mydas*), and also the Olive Ridley (*Lepidochelys olivacea*) (Bhaskar, 1993). These selected sandy beaches on the east coast of India and in the islands are visited annually by these turtles to lay their eggs.

The seashore offers a veritable feeding- and breeding ground for a number of birds. It is difficult to define precisely the avian component of marine biodiversity. There are some specialist species which are exclusively dependent on marine ecosystem, while a few are generalists without much dependence on it. From the available data it has been inferred that there are 12 families, 38 genera and 145 species of sea birds, which occur in the coastal ecosystems.

Marine mammals belong to three orders, Sirenia, Cetacea and Carnivora. About 120 species are estimated to occur in World seas, and of these 29 are reported from seas around India. But majority of these are oceanic forms and occasionally a few individuals may get stranded on the shore. Sea cow, *Dugong dugong* occurs in near shore waters.

Nektonic biodiversity has less number of macro invertebrates, which comprise only a few species of molluscs and crustaceans. The former are represented by Cephalopods, which include about 600 species known from the world seas. About 200 species of cuttle fish, squid and octopus were reported from the Indian Ocean, and of these about 50 species are oceanic forms. These constitute important bioresource of the Exclusive Economic Zone.

Benthic biodiversity is more significant than any other form of marine life. All the major invertebrate animal phyla have successfully colonized the benthic habitat. This habitat is dominated by animals which live fixed at a particular point/place or have limited range of mobility. These are "sitters" unlike "go-getters" of nekton as far as their foraging activity is concerned. Sponges, corals, serpulid polychaetes, barnacles, oysters, mussels, clams, sea-lilies etc. are sessile and some of them even look like plants. Mobile benthic animals belong to different taxa, such as flatworms, annelids, crustaceans, molluscs, echinoderms, fishes and a host of other animals, Majority of the species occur within the Exclusive Economic Zone. About 100 species of echinoderms reported from the Gulf of Mannar National Park occur within 20m depth. Of the total echinoderm species reported from India 59 per cent occur within 100m depth of EEZ.

The microbenthic protistas, whose size vary from 10 to 200 um include a diversity of ciliates, which live as bacterivores, algivores, carnivores and omnivores. The sediments harbour a number of rhizopod amoebae, and the most prominent and ecologically important group foraminifera. Many of the flagellate groups of the phylum Dinophyta occur in the sediments also. The diversity of Protista in Indian seas is imperfectly known and many species, even phyla remain undescribed.

The influence of benthic standing crop on the demersal fin-fish and crustacean fisheries has been studied (Parulekar et al 1982). Majority of the studies were concentrated on biomass production. The fauna of the continental self constitutes about 56% of the macro fauna, but on the slope and deep sea meiofauna contribute 78 to 83%. But species composition is yet to be analyzed. The richness of biodiversity in the EEZ can be visualized from a specific study at Visakhapatnam coast. While assessing the phytal fauna of Sargassum, Sarma (1974) listed a total of 132 invertebrate species, which included Crustacea (42 species), Polychaeta (29 species) followed by Molluscs (23 species), Foraminifera (14 species) and others (14 species). It gives an idea about the importance of heterospecific associations in the marine environment.

Thus all living organisms, starting from the microscopic and primitive prokaryotes to highly evolved and largest living animal whale (a mammal) are represented in the ecosystems. Traditionally all living organisms were grouped under two Kingdoms, Plantae (Plants) and Animalia (animals). But the application of new techniques and approaches in their study have provided new insights into structure and function of these organisms. An understanding of the molecular structure and evolutionary relatedness among living organisms have led biologists to recognize four Kingdoms, namely Monera (Prokaryotes), Protista, Plantae and Animalia. A detailed analysis of the taxonomic composition of the marine biodiversity in India is still an uphill task as there are a number of gaps. These are more evident in the first two Kingdoms mentioned above. As plants are represented by a few species, there is some dependable data. Due to the inherent difficulties in their collection, preservation and identification, animal taxa are also less perfectly known. Since hitherto man has been concerned more about his own survival than the ecosystem survival, sufficient data has been generated on taxa of consumptive value. However, an attempt has been made to present a table on the species diversity in the Indian seas with information culled from various sources. It includes species only described or reported from Indian seas, without however, going into their validity or present taxonomic status. Table 4 only gives an idea of marine biodiversity in India but it should not be construed as a real figure of the species diversity. Grassle estimated about 10 million species, and even this figure was treated as conservative by Groombridge (1992). It is expected that marine biodiversity of India may include about 0.25 to 0.3 million species of different living organisms.

Table 4

Marine Biodiversity of India		
Name of the group		No. of species
Algae		425
Protista		
1.	'Sarcomastigophora and Ciliophora	750
Animalia		
1.	Porifera	500
2.	Cnidaria	790
3.	Ctenophora	10
4.	Platyhelminthes	350
5.	Gastrotricha	88
6.	Kinorhyncha	99
7.	Annelida	440
8.	Mollusca	3370
9.	Bryozoa	170
10.	Entoprocta	8
11.	Phoronida	3
12.	Brachiopoda	3
13.	Arthropoda	
	a) Crustacea	2430
	b) Pycnogonida	16
	c) Merostomata	2
14.	Sipuncula	38
15.	Echiura	33
16.	Tardigrada	5
17.	Chaetognatha	30
18.	Echinodermata	765
19.	Hemichordata	12
20.	Chordata	
	a) Protochordata	116
	b) Pisces	1800
	c) Amphibia (In estuaries/mangroves)	3
	d) Reptilia	26
	e) Aves	145
	f) Mammalia	29
	Total	12456

Data not available for other phyla

Biotic Relationships in the Marine Environment

There is an amazing interdependence among various taxa that constitute biodiversity. The number of species and life habits are varied, and their relationships very complex. There is no precise knowledge of what eats what or of the rates of production or their efficiencies. The complex food relations that exist in the sea are aptly termed 'food web' Marine food webs involve the entire chain of living processes within the vast oceans. Phytoplankton represents the first link in the complex marine food webs. Herbivores feed on phytoplankton and open the chain to carnivores. Phytoplankton is eaten by copepods, which in turn form the menu of fishes. It has been estimated that about 10,000 kg. of diatoms are eaten to make 1,000 kg. of copepods, which go to produce 100 kg. of small fish. In turn it produces 10 kg of big tuna. Ultimately this one kg, of tuna adds to 0.1 kg. weight in man. Thus one lakh kilogram of plant tissue will have to be produced in the sea to add one kilogram of man's weight.

Ocean produces more animal protein than that is available from terrestrial sources. Most of its production dies a natural death and is absorbed back into the ocean's web of life. The inorganic matter that gets deposited on the bottom of the sea floor are decomposed by detritus feeding bacteria. The organic chemicals and minerals are again made available to the life processes. Each component of biodiversity competes with other partners for the essentials of life, but at the same time through its processes of activity, growth and death, is providing things that are essential for the well-being of other creatures. Organisms cycle nutrients and other chemicals in the ecosystem through production, consumption and decomposition. The processes are delicately balanced and overplaying of any one of this may disturb the ecological balance. If this balance is disturbed by the internal factors of the ecosystem it tries to restore the balance. In the marine ecosystem man's interference as an external consumer may trigger off reactions that disturb the biotic relationships. Hence the sustainable exploitation of the living resources has to be based on an understanding of the biotic relationships in the ecosystem.

Values of Marine Biodiversity

Coastal region is a scene of great biological importance. Besides providing food, living space, sport and scenic beauty coastal regions are in heavy demand for a number of other purposes. They serve as water front sites for power plants and other industry, which draw large volumes of water for cooling, as sinks for wastes, for traffic channels, harbours, marinas, etc.

Coastal biodiversity has an immense resource value. Coastal wetlands support molluscan, prawn, crab and fin fish fisheries. it was estimated that about 49% of India's marine fish catch originates from estuaries. About 41 species of prawns, 20 species of crabs and over 200 species of molluscs were recorded from Indian estuaries. About 10 species under the genera, *Penaeus Metapenaeus* and *Parapenaeopsis* constitute important fisheries in estuaries and backwaters. *Penaeus indicus*, is the dominant species in all lagoons on the east coast. Chilka lake and Godavari estuary are major capture fishery centres of P. monodon and Pulicat lake is a good nursery ground for the same. Majority of these wetlands are areas of recruitment of lush density of post larvae and juveniles. In

Hooghly-Matlah estuary there are six species of commercially important prawns. Molluscan resources comprised mostly bivalves, which occur in beds in several estuaries along the west coast. On the west shell beds are found in the estuaries of Maharashtra, Karnataka and Vembanad lake. A standing stock of about 6700 tonnes of shell resources were estimated for Karnataka estuaries (Rao, 1987). Clams, namely *Meretrix casta*, *M. meretrix*, *Villorita cyprinoides*, *Paphia malabarica*, *Katelysia opima* and oysters, *Crassostrea madrasensis*, *C. cucullata* and cockle, *Anadara granosa* are some of the species which contribute to shell fisheries in India.

Marine living resources are very valuable and supply the much needed animal protein. Sea food production is about two per cent of the total world food production per annum and 15 per cent per person. About 90 per cent of this is fin fish and the rest consists of molluscs, crustaceans and whales. Fish constitute about one per cent of our total diet on an average or about 17 per cent of the animal protein.

There are several estimates of the potential fishery resources of India's Exclusive Economic Zone. The estimates range from four million tonnes (by Fishery Survey of India) to 10 million tonnes (by NIO). Tuna resources alone in the Indian ocean were estimated to be around eight to 10 million tonnes and India has a potential of three million tonnes. According to some estimates pelagic fisheries are alone estimated to be between four and six million tonnes. Of the 3.5 million tonnes of fish catch from Indian ocean, 44 per cent constitute pelagic fisheries, 14 per cent demersal and 11 per cent crustaceans. Indian ocean fisheries are least exploited, the present level of exploitation being less than 16 per cent of the harvestable resource. The average catch in the Indian ocean is about 0.9 tonnes per sq. km. while it is about 4.0 tonnes in the Pacific and 2.7 tonnes in the Atlantic, a few years ago. India accounts for about 40 per cent of the fish landing of the Indian Ocean.

In general, all the estimates point to one aspect that potential fishery resources are far above the present level of exploitation as far as India is concerned. EEZ of India has the estimated potential for 1,80,000 tonnes of Cephalopods but the annual production of squids and cuttle fishes amount to about 35,000 tonnes on an average during last few years. But at the global level alarm signals have already been sounded cautioning that over exploitation is injurious to the long range interests of fisheries.

Fifty per cent of the sustainable fishing yields of India's exclusive economic zone, about 4.5 million tonnes, lies in the in-shore zone of less than 50 metres depth, i.e. only 9 per cent area of the EEZ. The in-shore zone potential of kilogram per hectare yield is 10 times more than that of off-shore zone, the latter have a total potential of 3 million tonnes.

During the year 1993-94 sea food exports from India have touched an all time high. Products worth about Rupees 2503.62 crore ($798.25 million) were exported. It is expected to cross $ 1000 million mark this year. Of the sea food exported 25 per cent came from shrimp farming with the rest from capture fisheries. The increase in exports were mainly due to shrimp, especially farmed shrimp, frozen squid and cuttle fish. It is estimated that the country has the potential of earning at least $ 3000 million every year. Besides direct values, much of the marine biodiversity has several indirect values. Some of the species of squids and sea hares (molluscs) have specialized nervous system, which may provide crucial insight into our own nervous system. Shark's liver has changed little in 400 million years. It has architectural similarity to that of man and can serve as a model for research. Extracts from horse shoe crab's blood provide sensitive diagnostic tools for detecting minute traces of endotoxin.

Marine biodiversity has definite existence value and provide pleasure without being consumed or without being traded. Marine ecosystem harbour a range of genetic stocks that are not available on the land and that add vitality and diversity to life supporting system.

Conservation Status, Threats and Problems

Although marine ecosystems have a larger coverage than the terrestrial ecosystem, these are poorly represented among world's protected areas. Only about 100 of the 1162 National Parks of United Nation List include or adjoin reef ecosystem. In India 3 out of the 503 protected areas (National Parks 75, Sanctuaries 421 and Biosphere Reserves 7) are with reference to marine ecosystems. These are Gulf of Mannar, Gulf of Kachchh, Marine National Park of South Andaman Island. The Protected areas (a total of about 101) of the Andaman & Nicobar Islands cover substantial areas of marine waters also. In general marine resources of the EEZ are considered open access resources. Coastal zone management and conservation of marine diversity are of recent origin. The first Marine Sanctuary was constituted by the State Government in 1980 in the Gulf of Kachchh to cover an area of 456 sq. km. from Okha to Jodiya having a core area of 162.9 sq. km. Marine National Park (1982). The second Marine National Park was notified on May 24, 1989 in Andamans and it covered an area of 281.5 sq. km. Gulf of Mannar was declared a Marine National Park by the State Government, which was later declared a Biosphere Reserve. It is the first marine Biosphere Reserve and covers an area of 10,500 sq. km.

These three protected areas could afford protection to only a part of large ecosystem and to only a few species of animals and plants. Integrated system plan has to be developed for the management of these protected areas. Trained marine biologists should be given the responsibility of developing and monitoring the management action plans. The protected areas are used by Fisheries Department, Forest Department, Department of Ports, Tourism etc., and it goes without saying that there should be effective coordination among all the concerned departments.

The need for the protection of the marine environment and conservation of its resources was realized very early, as evidenced by various acts and regulations promulgated by the Union and concerned State Governments of India. Although not directly aimed at marine resources, the Fisheries Act, 1987 prohibits use of explosives and poisons for fishing. The Major Ports Act, 1963 and the Coast Guard Act, 1978 include measures to preserve and protect marine ecosystems from pollution. The Merchant Shipping (Amendment) Act, 1983 guards against discharge of oil or oily mixtures by ships anywhere into the sea. Exploitation of marine living resources is promoted, regulated and controlled by the establishment of Marine Products Export Development Authority, 1972 and by promulgating the Maritime Zones of India (Regulation of Fishing by Foreign vessels) Act, 1981. The most comprehensive one to prevent human impact on the coastal zone and littoral seas was the Coastal Regulation Zone Notification, 1990

Despite the above mentioned acts and regulations marine ecosystems are subjected to over-exploitation of their resources. In many areas of the globe, exploitation has far exceeded the reproducing capacity of marine life and the recovery ability of marine ecosystems. The catches have declined in the case of Atlantic Cod, Atlantic Herring, Mackerel, Flounder, Haddock and Pollock. In the Pacific, yellow croaker, mackerel, salmon and many other heavily fished species are not only faced with the danger of commercial extinction but also biological extinction. Stellar's sea cow, the Caribbean monk seal, the Atlantic grey whale have already been exterminated. In India there has been a decline in the catches of spiny lobster. Over-fishing will have significant effect on the species with slow rates of growth and reproduction, such as mammals and elasmobranchs.

The problems in marine biodiversity are mainly due to the unequal growth in fishery technology and fundamental biological studies. Technology has improved to locate the fishing grounds. Remote sensing Technology locates fishing grounds with the help of ocean colour sensing and sea surface temperature. Potential fishing zone maps are generated after analysis of oceanographic features such as thermal boundaries, fronts, eddies, surface currents and up-welling regions and transferring them on to Naval Hydrographic Maps.

The improvement in gear technology and growth of large fishing fleets subsidized by Government have also helped in increasing the catches in capture fisheries. But knowledge on marine biodiversity, especially its interaction with the ecosystem and the impact of exploitation of marine resources on the overall resource base is far from satisfactory.

It has been reported that fishing operations with latest technology are causing damage to the ecosystem. Along with increase in the targeted fish catch there has been an increase in the by-catch also. A number of untargeted fish and other biota are removed from their habitats and discarded as waste. It was estimated that world wide shrimp fishermen discard up to 15 million tonnes and other fishermen up to five million tonnes per year (Weber, 1994). In tropical waters shrimp trawlers probably have the highest rate of by-catch bringing in up to 90 per cent or more of "trash fish". Unselective nature of capture techniques destroy immature fish and other non-targeted marine species. Gill nets used to catch fish bring in their haul a host of other animals such as dolphins, turtles etc.

Although the ecosystem approach considers relationships among resources and their uses, special emphasis should be given to maintain the genetic diversity of key species. In general it can be said that marine species are not as vulnerable as their counterparts on land. Majority have wider distribution in the Indo-Pacific. But many were harvested without realizing the impact of over exploitation on the species survival and on the ecosystem. Pearl oysters were almost decimated in the Gulf of Kachchh and Gulf of Mannar. Sacred chank population is also on the decline.

Exploitation of marine species for their bioactivity has to be undertaken with utmost care and concern for biodiversity. We have not acquired enough information on the biology of many species and in our enthusiasm we may pave the way for their extermination. *Ischnochiton comptus* (Gould) which occurs on the west coast has become a rare mollusc due to collection made for screening tests.

Besides over-exploitation, pollution from land-based sources is another major threat to marine resources. It was estimated at the global level that 70 per cent of the marine pollution is due to land based sources, while 10 per cent each is contributed by maritime transport and dumping at sea activities. In an interesting study on world wide Tanker oil spills it was estimated that for every million tonnes transported 12 tonnes account for spills within 80 km. off the coast.

In the world scenario it was reported that six out of ten people live within 60 kilometres of coastal waters and two-thirds of world's cities with population of 2.5 million or more are near tidal estuaries. Within the next two decades it is expected to double. It is estimated that two-thirds of Indian population live along coast.

There are 40 and 23 small and medium towns and cities on the West coast and East coast respectively. More than 1.5. million people derive their subsistence through activities related to marine environment i.e. mostly fishing. Recent spurt in aquaculture activities increased the demographic pressure and the related environmental manipulations.

In densely populated areas there is considerable pressure on coastal resources. In such situations it is necessary to reduce access to resource and develop alternative means of livelihood. New management partnerships between government and users have to be explored and devised. Aquaculture mitigates the problem to some extent. But the products of aquaculture are either 'luxury' or 'semi-luxury' items, not within the reach of men who are actually involved in it.

The population influx and increased tourism in some coastal places are responsible for indiscriminate destruction of marine resources. Corals are extensively collected for presentation, decoration, fancy sale and educational study. In some islands large quantity of living corals were used for the construction of roads. The construction of jetties, wharves, harbours and dredging activities deposit large quantity of silt which destroy the ecologically sensitive corals in those areas. One NGO organization, Society for Andaman and Nicobar Ecology (SANE) reported in 1989 that the Military Engineering Service (MES) had been extracting thousands of cubic metres of coral off Kamorta islands, near the Naval Helipad at INS Kardip, for use in construction of shore protection pillars (Kothari, 1989).

A considerable quantity of corals, molluscs and echinoderms are collected for trading purposes as well as during the educational tours by the College and University students. The collection is indiscriminate and no closed season is observed.

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IMPACT OF MAN ON MOUNTAIN ECOSYSTEM

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Introduction

The influence of mountains on the climate, vegetation, animal life, socio-economic conditions and geographical problems of the surrounding regions has attracted the attention of man since long. But it is only very recently that the impact of human activities on mountain ecosystem has aroused the interest of investigators in different parts of the world. In the so called technologically advanced countries, the massive interference by man has caused irreversible changes in the upland and lowland ecology which have influenced human welfare directly and indirectly. These human activities include ruthless destruction of forest cover, overgrazing, hunting of wild animals for fur, wool, musk and other valuable productive, construction of large scale hydro-electric installations, tunnels, impounding of massive volumes of water by gigantic dams, construction of high altitude mountain roads, air-fields and large scale and ill planned quarrying. These activities have brought about the total loss of biological productivity of virgin lands, and have induced irreversible changes in the natural vegetation cover in addition to massive destruction and impoverishment of flora and fauna, extensive soil erosion, water pollution and silting up of general Himalayan river system, as well as destructive flood in the sub-Himalayan tracts.

In recent year people have become aware of the perils of this ill planned and uncontrolled interference in the mountain ecosystem, the most deleterious of these perils being the serious threat to the biodiversity. As a result during the last couple of years a great deal of attention has been paid to find ways and means to conserve the global biodiversity. Earth Summit meetings, conventions, seminars and symposia are being held in different parts of the world to make the nations aware of the rapidly depleting floral and faunal wealth, and to formulate some universal policy which would go a long way in arresting the ever accelerating rate of depletion. In spite of the recently generated awareness of the hazards of the environmental degradation caused by different anthrophic factors, precious little is being done in concrete terms to reverse the trends. The industrially and technologically advanced countries who caused the maximum damage to the environment want the developing countries of the third world to do the job without even caring to share the financial burden.

The author, who has been studying the ecology of the high altitude insects and high altitude biology for the last four decades, particularly in the North West Himalayas, had the rare opportunity of observing the far reaching changes that have taken place in the mountain ecosystem consequent to the induction high technology in the delicately balanced and extremely fragile high altitude biome. In the succeeding few pages I would endeavour to share my experience with those who care for and love mountains. The findings presented in the succeeding pages are based on the observation in the Kulu and Lahaul-Spiti valleys (Himachal Pradesh), and which should be equally applicable to the other parts of the Himalayas.

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What is High Altitude?

Before proceeding any further it would be ideal to define what actually represents High Altitude. A great deal of confusion seems to exist in the minds of research workers about what really constitutes "High Altitude". In accordance with the concept, by High Altitude it is meant in biology the elevated regions on high mountain, above the tree-line or the timberline. It may be defined as regions of open vegetation above the upper limits of closed forest, where the general environment, the flora and the fauna are markedly different from those of the forests or the steppes. It is an ecologically highly specialized zone, which is characterized by stunted shrubs with extensive root systems, low growing herbs, grassy alpine meadows, cushion-like growths of not only the Bryophytes but even Angiosperms like *Thylacospermum rupifragrum* (Caryophyllaceae). The mere absence of trees or forests which may be absent even at very low altitudes, and disappear even very near the sea level in the northern latitudes, as a criterion for determining the lower limits of high altitude zone can be misleading, if emphasis is not laid on the altitude. It is only above the timberline altitude of about 3,000 m to 3,500 m above m.s.l. that significant differences in the environment appear. This treeless, seasonally snow-covered and wind swept belt up to the permanent snowline is often referred to as the Nival Zone, the region above the Nival zone being referred to the Eolian Zone. The High Altitude Biome thus comprises upper Eolian Zone and lower Nival Zone. For a review of divergent views one may refer to the recent publications by Mani (1978, 1990).

The timberline is by no means a sharply defined line but represented an oscillating zone altitude, in which the summer mean temperature generally fluctuates about 10-12.0ºC. Troll (1967) and Larsen (1975) have given detailed accounts of the timberline in general and on mountains in particular. Directly related to the high altitude is the progressive intensity of cold, aridity and attenuation of the atmosphere. In defining the high altitude zone biologist often fall into the error of over emphasizing the role of only the low temperature, by completely ignoring other ecological factors, This approach inevitably leads them to erroneous comparisons between the high altitude ecology and high latitude ecology. These workers have apparently overlooked the causative factors which underline the atmospheric cold in the two cases. It would be logical to draw attention to the fact that the Arctic zones of the northern latitudes are basically *lowland* areas of low temperature and dense atmosphere, but the high altitude is a region of low temperature and gradually thinner atmosphere. The rare faction of air at high altitude apart from bringing about the fall in temperature, deficiency of oxygen, etc., also at the same time increases the intensity of insolation and solar radiation.

The high altitude zone, however, does not exist in isolation from the forest belt and the valleys below, but is directly affected by what happens in the valley, and in turn any ecological changes taking place in the high zone exert profound influence on the lower zone.

Changes in the Land-use Practices

The advent of apple culture give rise to unsatiable hunger for land for horticulture and agriculture. The farmers and horticulturists started nibbling at the lower limits of the forest belt to create more land for cultivation which resulted in the ascent of forest line, thus denuding the mountain slopes of their natural forest cover. This newly reclaimed land within 15-20 years became covered with extensive orchards of apples, apricots, plums, cherries, pears, and hybrid varieties of wheat, barley and paddy. The development of horticulture brought in increased use of chemical fertilizers and highly toxic synthetic pesticides and insecticides. In the initial years bumper crops of fruits and grains brought in unimagined prosperity to the local farmers, who pursued this forest destruction urge with greater fervour. This practice reduced the forest cover on one side and let loose these residues of chemical fertilizers and pesticides which got washed drown from the steep mountain slopes into the River Beas in the valley polluting the entire river system with toxicity endangering aquatic fauna and flora on the other side.

These chemicals used indiscriminately killed not only the target pests but also their natural enemies like parasitic Hymenoptera, some birds and lizards, completely altering the pest:parasite equilibrium. It will be interesting to record here that apart from disturbing the long established equilibrium, the chemical approach of pest management destroyed millions of pollinator insects like honey bees, bumble bees, carpenter bees etc. In the first week of April 1992, at a place called Bajaura (Kulu Dist.), it was observed that thousands of bees belonging to *Apis dorsata* and *Apis cerana indica* were found dead below the apple trees which were sprayed by insecticides the previous evening. This mass killing of pollinator species has started exhibiting adverse affects on the fruit setting. The farmers have already started complaining about the gradual decline in fruit production in the valley.

The seepage of toxic chemicals into the R. Beas has also adversely affected the pollinator of Ephemeroptera (May-flies), Plecoptera (stone-flies), Trichoptera (caddis-flies) and Megaloptera: Corydalidae (Alder-flies) which constitute an important link in the food chain of endemic fish and introduced exotic fish the Trout *(Salmo feno)*. The river Beas which used to abound in Trout about 25 years ago now presents a dismal picture with trout becoming almost extinct in the main river (in spite of the effects of the fisheries department), being confined to only some side streams like Tirthan and Sainj and Nullahas.

Similarly the birds like Brown Dipper *(cinculus pallasii)* and plumbers Redstart *(Rhya cornis jugliginosus)*, which not many years ago used to be abundantly available along the river diving for insects larvae in the water or darting at the freshly emerging imagos, have become so scarce that one has to wait for hours to sight one or two pairs.

Destruction of Gulaba Forest and its Consequences

One of the most beautiful virgin forest, the Gulaba Forest, once covered the western slopes of the mountain spur of the Pir Panjal Range to the south of famous Rohtang Pass (13, 050 above m.s.l.) on the left bank of R. Beas in its catchment area. It harboured stately deodars (*Cedrus deodara*), Oak (*Quercus semecarpifolia*), Alder (*Alnus nitida*), horse chestnut (*Aesculus indica*); and *Rhododendron campanulatum* and Birch trees (*Bultela utilis*) in its upper reaches.

In the latter part of the fifties and early sixties, heavy modern machinery was inducted into these higher altitude for the construction of high altitude road connecting Manali (Himachal Pradesh) with Leh (capital of Ladakh region of J.& K.). This road, which is one of the highest highways in the world, undoubtedly represented an engineering marvel which unfortunately was used by politician - contractor - forester combine to ruthlessly destroy the once beautiful Golaba Forest. Heavy machinery was moved into the region, thanks to the availability of new road, and a forest which must have taken thousands of years to achieve grandeur was decimated within months, thus denuding mountain spur in the fragile catchment area. This brought about increase in the soil erosion resulting in the silting of river and the reservoir formed by the construction of a Dam at Pandoh, about 110 kms downstream. The irony of the situation is that the forest was being destroyed almost simultaneously with the construction of the Dam. It would seem that the right hand of the Government did not know what its left was doing.

Alarmed by threat to the longevity of the Dam by the excessive silting some remedial measures have been taken at reafforestation by planting some fast growing species of plants like poplar, willow and silver fir. Before, the new forest could take hold of the situation another phenomenon known as Biological Invasion of the denuded slopes has already manifested itself.

This original forest floor vegetation suffered extensive damage after the forest canopy was destroyed as a result of soil erosion. The vacuum thus caused was taken advantage of other plant species which originally were confined to the periphery of the forest, and that too as strugglers. The entire denuded mountain slopes have been invaded by *Polygonum chinensis* (Polygoneaceae) and three species of *Impatiens*, namely, *I. glandulifera* and *I. bicornuata* in the upper reaches and *I. scabrida* in the lower parts. These intruder species apart from suppressing the original forms have also adversely effected the soil biota.

Unplanned Tourism and its consequences

With the emphasis on using tourism as an industry in the Himalayan region, the authorities that be, seems to be interested in making a fast luck, and the newly found prosperity particularly by the middle and upper middle class had provided further impetus to such thinking. During the last 10-15 years the Kulu Valley and Lahaul Spiti region have started attracting hoards of Indian and foreign tourists. A booming hotel industry has come into existence as if in a jiffy. The small dreamy village Manali (6,500 feet above MSL) situated on the right bank of the R. Beas boasted of only two Dhabas in the early sixties, and two Govt. Rest Houses, viz. The Civil Rest House and the Forest Rest House (now converted into Circuit House) besides a Guest House run by a British. After 1980 Hotel-building activity started in a fury (the J.K. situation further added to the ferocity), and now the place has more than 450 hotels of all types including 5-Star Hotels, and the construction activity shows a no sign of relenting. The dreamy village is lost to posterity and it has been converted to a jungle of concrete monstrosities.

Though the multi-storey hotels have come into existence no proper sewage disposal system have been developed. All the sewage and garbage is just dumped into the R. Beas, under the very nose of the authorities, thus further polluting the already polluted water rendering it unfit for human consumption. During the tourist season i.e. May-June and again in September-October, caravans of cars, taxis, mini buses and luxury buses unload thousands of tourists into the town literally choking the place with human load and vehicular pressure. Traffic jams become a routine affair and the emission from the exhausts of vehicles makes it difficult to breath. Every tourist wishes to visit Rohtang Pass and it was estimated that in June 1994, on an average 672 vehicles drove up to the Pass everyday. One can imagine how much emission of obnoxious gases like carbon monoxide and particulate carbon are introduced in the atmosphere. Before the opening up of the road (mentioned earlier) the Rohtang Pass used to be covered with a multitude of beautiful flowers after the melting of the snow. These flowers included the Primulas, Buttercups, Marsh Marigold, Iris, *Meconopsis*, *Erigeron*, *Anemone*, *Polentilla* spp to name few. But now, these flowers have become rare and their place have been taken over by the garbage the tourists deposit on the Pass — once an alpine meadow of rare beauty the Rohtang Pass has been converted into "*Garbage yard*" of Kulu Valley. A place where a tired trekker used to inhale crisp and clear air to refresh himself now presently a carbon monoxide loaded air to the tourists to breath in — though the obnoxious gas is contributed by his own vehicle.

In the last week of September 1989 a D.S.T. sponsored Workshop on the Mountain Ecology was organized at Manali, for about forty young Scientists from all over the country. The participants were asked to list the items in the garbage from within 100 metres of the sources of R. Beas situated on Rohtang Pass within half an hour. A staggering 89 items, both degradable and non-biodegradable were listed. These items included plastic bags, ropes, shoes, chappals, combs, brushes, broken mugs and jugs, used contraceptives, feeding bottles, nipples, batteries, discarded transistor cassettes, films, tooth-paste, tubes, tooth-brushes, iron rods, nails, horse-shoes, empty tins, jam bottles, bear bottles, broken bottles of different colour and shapes which once held whiskey, rum, colas, gunny bags, pieces of canvas, human excreta, used sanitary towels, and many others. The tourists probably offered these item as gifts to Gods — the Kulu Valley being called the Valley of God.

The Rohtang Pass and the Martin Meadow to the south of the Pass at a lower altitude are dotted with "Dhabas" and Country liquor shops. They make lot of money but provide no sanitary convenience, as a result of which the tourists foul the surrounding areas. The Department of Tourism is either unwilling or incapable of overseeing these aspects of Tourist Industry.

Tourism and Wild-life: The growth of tourism has started posing a serious threat to the wild-life. In spite of all the Statutory Regulations for the conservation and protection of wild-life the menace of poaching continues to persist. Either it is the laxity on the part of the wild-life managers or indifference the wild-life is becoming impoverished. The wild animals like musk-dear (*Moschus moschiferus moschiferus*);Goral (*Nemorhoedus goral goral*); Bharal the blue sheep (*Pseudois nayaur nayaus*); Himalayan Ibex, the Pashmina goat (*Capraibex silurica*) appear to attract the attention of poachers, many of them being the genuine tourists. Personnel of the Road Building Organization stationed in remote and inhospitable regions are also tempted to match their firing skill against these animals to the detriment of the latter. In the inner higher Valley of the Himalayas the dynamiting of the glacial torrential streams for killing fishes is routinely indulged in both by professional poachers and others. It may be pardonable if some are living under harsh conditions resorts to this practice for food. But those who hunt wild life for fun, wool, skins, and head trophies for commercial purposes must be dealt with, without any mercy. Every day reports in the press about apprehending such people along with their "booty" is an ,unconvertible evidence that destruction of wild-life continues to be a serious menace.

The establishment of the National Animal Park in the Kulu District, covering the Tirthan Stream, Sainj Stream, Parbati River, and Pin Valley region of Spiti, is a welcome step in the right direction. But unfortunately in this very region, in comparison to one Angler with valid licence the author counted 16 others who were indulging in the fish catching without any legal permit. All those poachers frankly admitted that they sell their catch to big hotels in Manali. The point is emphasized here that the mere establishment of Parks would not help, unless stringent measures are taken against poachers and their patrons.

Induction of Technology and its impact on the inter-valley migration of human population

The twin valleys of Lahaul-Spiti situated to the north of the Kulu Valley are separated from the latter by the mighty snow-clad Pir Panjal Range. This range isolated the valleys from the rest of the world for centuries. These valleys characterized by the wind swept desolate arid world of rocks, snow, glaciers and harsh climate conditions represent the most inhospitable terrain with extensive areas absolutely uninhabited. For more than six months in the year the region remains snow bound, with very little door activity. This cold desert yielded meagre agricultural production and live-stock products which supported a very small population on subsistence level. The topographically induced economic deprivation was further accentuated by the geographical isolation till after the Independence. Then in the sixties, the geopolitical compulsions forced the country to embark upon an ambitious and massive programme of high altitude road construction in some of the wildest elevated regions of the world. One of these high altitude road, traversing the Lahaul Valley, connects Manali in the Kulu Valley with Leh (as already mentioned). The construction of this road and other associated technological activities have had far reaching changes in the ecological and socio-economic structure in Lahaul. The land-use changes were rapid and drastic and included reclamation of new areas for cultivation, partial or total mechanization of farms, introduction of quick-growing, cold resistant and high yielding new cash crops, attempts of afforestation and growth of semi-urban agglomerations. All these activities ushered in the era of economic prosperity which surpassed the wildest imagination of the local population.

As a consequence of this god-sent prosperity, contrary to generally held views, the native population experienced in explosive rate of growth. On of the most important single contributory factor for this population explosion is the corroding of the ancient practise of polyandry, which kept the population level very much with the manageable limits. For instance in 1901 the total population was only 12, 392, for both the valleys, and it increased to only 15,338, in 1951, thereby exhibiting only 22.3% growth in the first half of this century. There after formed 1951 to 1981, it jumped from 15,338 to 32,100, demonstrating a growth of 109.28% during the last thirty years. This rapid growth of population changed the pattern of inter-valley migration of populations (Table 1).

Table 1

Statement showing the growth of population in Lahaul-Spiti Valley				
Year	Total	Male	Female	Percentage growth
1901	12,392	6,221	6,171	23.7%
1911	12,981	6,522	6,459	
1921	12,836	6,440	6,396	
1931	13,733	6,903	6,830	
1941	14,594	7,601	6,993	
1951	15,338	7,936	7,402	
1961	23,682	13,259	10,423	102.2%
1971	27,568	15,168	12,400	
1981	23,100	18,171	13,929	

The newly acquired prosperity seems to have powerfully encouraged higher education. Apart form an appreciable rise in the general literacy level, the Lahauli youth has gone en masse for University education far off in the plains like Chandigarh, Kurukshetra besides Shimla. The young university graduates, on return to Lahaul, inevitable look down on the traditional Polyandry of the elders. Every educated young man preferred a separate wife for himself. In spite of the resentment of the elder generation, polyandry has thus received a serious set back and more wives are being brought into the family than ever before. This radical change in the social set up should perhaps explain the sudden population explosion shown in Table 1. It is evident that compared to 1951, the population has almost doubled in 1961, a trend which continued in 1981. There might be other possible contributory factors like the influx of Tibetan refugees, but do not appear to be significant, because these refugees were settled elsewhere since 1970. The primary cause, therefore, for the sudden increase is the disappearance of polyandry.

Another interesting trend observed in the younger generation of the Valley is there pronounced reluctance to live in their native villages. They visit their homes only during summer, rather more as tourists that as sons of the soil. The people of Lahaul, under pressure of population and newly-acquired prosperity have steadily poured into Kulu Valley. With scant or no avenues for the investment of their resources in Lahaul, they have started investing their money by buying up orchards and by constructing hotels in Manali. The increased demand fun land for new orchards has been met by destruction of forests in the side valleys. These conditions have resulted in an "economic invasion" of Kulu valley, the carrying capacity of which has already been exhausted.

A reference to Table 2 will clearly show that in the Lahaul Tehsil, in spite of overall increase in population, there is a negative (−) decadal variation, thus revealing an outward movement of population. If this trend continues there is possibility of clash of ethnic interests between the Kulu population and outsiders.

Table 2

Decadal variations in the Population of Lahaul-Spiti			
Tehsils	**1971**	**1981**	**Variation**
Udaipur	6,167	7,937 (+)	28.70%
Lahaul	14,205	13,801 (–)	2.8%
Spiti	7,196	10,362 (+)	44.0%

Concluding Remarks

In conclusion it will be worthwhile to record that the induction of technology in the mountain ecosystem is bringing about for reaching changes not only in the floral and faunal picture, but also in the life style of the people to the extent of modifying the demographic structure of the region. Many of these changes, however, may not prove beneficial to the Biodiversity of the area in the long run.

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BIOMONITORING OF TERRESTRIAL ECOSYSTEM

S.C. SANTRA*

Introduction

In recent years, monitoring of the environmental quality of air, water and land using biological forms is gaining momentum. Such a biomonitoring system appears to a unique method for early warning of environment quality.

Different groups of organisms, are now utilized for such biomonitoring purposes, these include phytoplanktons and mollusca and fishes etc. in the aquatic system; lichen, mosses and higher plants in terrestrial system and soil micro-arthopods, earthworms, algae and fungi in soil system. Such indicator organizations (plants and animals) provide a direct method of studying the effects of the prevailing environmental pollution on living organisms (Table 1).

Unlike aquatic environment, terrestrial environment provides basic requirement for maintenance of diverse life forms. All the factors of environment (i.e., climatic conditions) played a great role in specialization and distribution of life forms on earth surface. The component of terrestrial ecosystem thus varies greatly in various climatic zones – viz. Mountain ecosystem, Desert ecosystem, Forest ecosystem, and Agricultural ecosystem, etc.

Again terrestrial ecosystems are very much affected by the biotic interference, *viz.* grazing by man and other animals, industrial and other human activities, and also by the calamities. There are two major terrestrial environmental changes which affect the terrestrial life form distributions, *viz.* air pollution and pollution of land by mining and other industrial waste disposal activities.

Quite a good number of plant and animal forms which are often used for assessment of environmental quality. These are often called environmental quality monitoring agent or bioindicators.

In fact, the principal advantages of biomonitoring are many, which are stated below:

(a) Indicator plants provide a direct method of studying the effects of the prevailing air pollution on living organisms.

(b) These plants also provide a measure of integrated effects of all 7 environmental factors, including air pollutants and weather conditions.

(c) If is possible to study the relationships between concentration of air pollution's and its effects when both are measured at the same site.

(d) If provide possibilities of determining spatial and temporal trends in the occurrence and intensity of effects of several air pollutants on natural and cultivated plants.

(e) It sometimes enables the analysis of polluting compounds measuring accumulation within plants.

(f) It acts as a sensitive early warning system which may simulate prophylactic measures to prevent or diminish disastrous effects of air pollution.

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Monitoring of Terrestrial Environmental Quality

Lichens as biomonitors: The intimate physiological relationship between lichen thalli and the environment is very interesting. The perennial nature of lichens and their sensitivity to disturbance, depends on nutrients and chemicals that derived from their substratum. An ability to concentrate compounds from weak solutions, and also the range of species with different requirements and sensitiveness, indicate that lichens act as a continuous monitors of the environment. An appreciation of their qualities as biological monitors, and the study of the parameters limiting the occurrence of particular species, has led to their use as indicators of a variety of environmental factors.

Some naturalists in the early nineteenth century had already recognized that there was a link between the sparseness of the lichen vegetation in towns and air pollution. In 1866, on the basis of studies in Paris, Nylander suggested that lichens could act as indicators of the intensity of that pollution. But since the late 1960s, it was fully established that lichen could be used as biological monitoring of air pollution.

Table 1

Use of Indicator Species For Monitoring Environmental Contaminants

Taxa	References
Lower plants	Burton M.A.S. 1986. Biological monitoring of Environmental Contaminants. MARC, London
Lichens	Skye E. 1979. Annual Reviews of Phytopathology 17: 325-41.
Higher plants	Manning, W.J.R. and Feder, W.A. 1980. Biomonitoring Air pollutants with plants. Applied Science Pub., London.
Coelenterates	Hanna, R.G. and Muir, G.L. 1990. Environmental monitoring and Assessment, 14: 211-22
Aquatic Invertebrates	Thomas, W.A., Goldstein G., and Wilcox, W.H. 1973. Biological Indicators of Environmental Quality. Ann Arbor Science Pub., Michigan.
Terrestrial Invertebrates	Alfred, D.M. 1975. Great Basin Naturalist 35: 405-406.
Earth Worms	Czarnowska, K and Jopkiewick, K 1980. Bioindication-3. Univ. Halle-Witenberg Wiss-Beitr. 20: 69-74.
Bees	Samiullah, Y. 1986. Bee Craft 68: 5-11

The most important gaseous air pollutants affecting lichens are gaseous pollutants SO_2 and particulate containing heavy metals.There are basically three ways in which lichens have been used to monitor air pollution.

(1) To measure actual pollutants accumulated in the thallus, taking advantage of their proven capacity to absorb and store phytotoxins and using this information to extrapolate the presence, location and transport distance of the pollutant;

(2) To map all (or selected) lichen species around a pollution source to measure the effect, intensity and distribution of pollution by recording their presence or

absence or morbidity. Photographic documentation can supplement this approach; and

(3) To transplant healthy lichens into polluted areas and measures deterioration of the thalli.

The simplest way to use lichens in pollution monitoring is to map the occurrence and distribution of species around a pollution source and to relate, when possible, the floristic or phytosociological characteristic of the lichens to ambient SO_2 (or other pollutants) concentrations. For examples, it has been established that the common indicator species *Hypogymnia physodes* in Europe dies off when SO_2 exceeds 60-70 µg/cubic metre of air. This method gives a rough estimate of the distance and direction of pollution fallout. When lichens have been killed off near a pollution source or do not occur in the area for some historical or ecological reason, it is still possible to take advantage of their sensitivity as biomonitors by using transplants. LeBlanc and Rao carried out a study at the heavy polluted Sudbury, (Canada), site and used discolouration of *Parmelia sulcata* as a measure. Death of transplant was closely correlated with previously established zones of SO_2 concentrations.

Lichens are able to sink heavy metals of varied kinds. Assays of the metal contents of lichens have been used extensively in the monitoring of heavy metal-fallout from smelters, automobiles or from other particulate generating industries. *Peltigera* species have provide especially useful for such studies and can permit at massive metal levels, withstanding for example even 90000 ppm of iron. Radio nuclides derived from nuclear detonations can also be sinked by lichens and thereafter accumulated in animal system through food chain. Thus simply through analysis of selected lichen species, the atmospheric level of radioactive elements could also be monitored.

Only through plotting the distribution of individual species in an urban area, the relative sensitivities of species to pollutants can be ascertained. The proximity of a species to the pollution sources is of great value and results from such surveys are most clearly displayed as lines indicating the inner limits of species with different sensitivity. Further it was appreciated that lichen vegetation on trees in urban areas could be divided into zones easily recognizable in the field. Three zones were most commonly distinguished *viz.*

(a) an inner "lichen desert" with no lichens or at least no foliose or fruticose species;

(b) an intermediate "struggle or transition" zone where foliose and fruticose species lichen begin to appear;

(c) an outer "normal Zone" which lichen vegetation unaffected by pollution. In the recent years, identical studies were carried out in Calcutta city to make out zones with various degree of air pollution (Fig.1) (on following page).

In an another study it was reported that lichens are disappearing within the core zone of the highly polluted industrial township of Haldia, West Bengal. At Haldia, emission from industries like Indian Oil, Hindustan Lever, Shaw Wallace, Eureka Chemicals and smoke from marine vessels pollute the atmosphere. As such lichens of this area are affected as noticed through species' distribution survey. Four distinct zones thus can be recognized (Fig. 2).

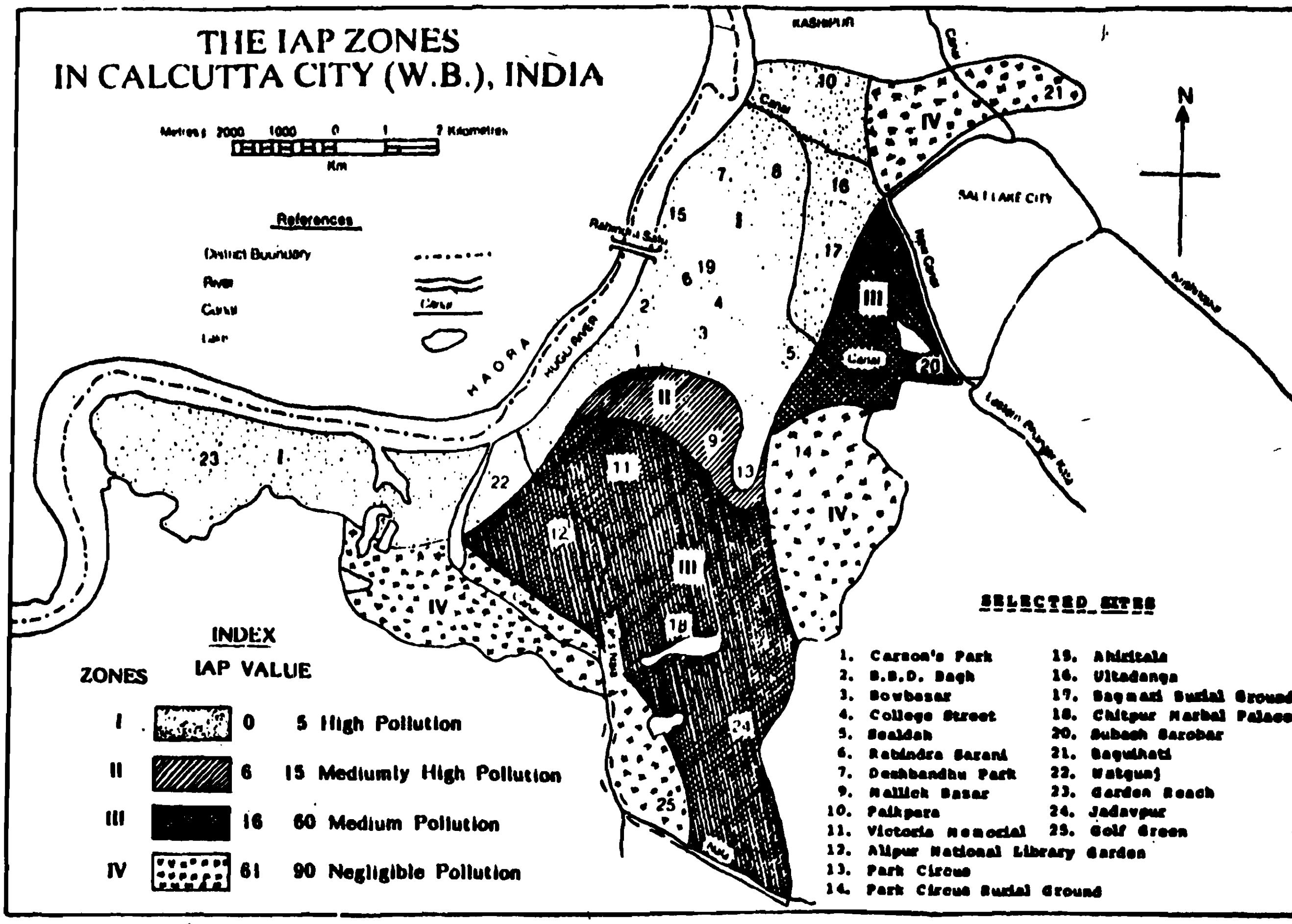


Fig. 1. The IAP (Index Atmospheric Purity) zones in Calcutta city.

Biomonitoring Of Air Pollutants With Higher Plants

Air pollutant injury to vegetation has been thoroughly documented and is well illustrated in several excellent atlases. In fact, plants can act as indicators by accumulating the pollutant or some metabolic products of the plant/pollution interaction in their tissues, plants may also exhibit altered growth rates, changes in rates of maturation, reduction of flower, fruit and seed formation, alterations in the reproductive process and ultimately depression of productivity and yield, For quantitative evaluation of plants responses to pollutants several parameter of leaf injury, productivity and growth responses of sensitive plants were used. Where pollutant uptake was used to measure pollution level either the pollutant itself or metabolite of the pollutant is measured.

During the past fifteen years, several countries used the indicator plants for effective measurements of different pollutants: viz. 'Tobacco variety Bel-W3' in The Netherlands and UK; 'Garden Nasturtium' in Denmark and 'lichens' in GDR.

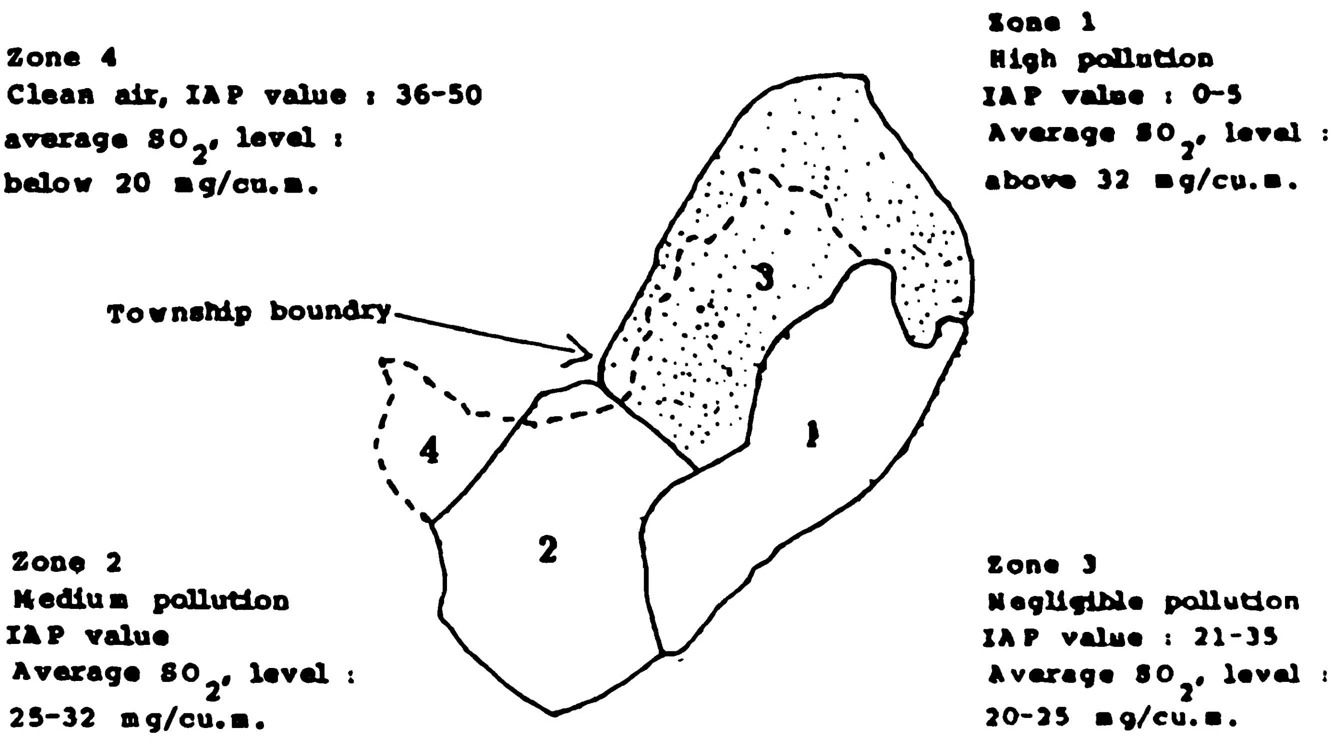
Other than the air quality monitoring in several parts of the World, selected plants were used as indicators of soil water status, or soil reaction (acidic/alkaline) or soil containing various types ore deposits, and thus these plants were often used in geo-botanical prospecting.

In recent years, biochemical diagnosis of pollution effects on plants were often used as a good markers for plants sensitivity testing. On the basis of sensitivity testing, air

Lichens as pollution monitors

Pollution Zone I	Pollution Zone II	Pollution Zone III	Pollution Zone IV
Lecidea granifera	*Lecidea granifera*	*Lecidea granifera*	*Lecidea granifera*
Parmelia caperata	*Parmelia caperata*	*Parmelia caperata*	*Parmelia caperata*
Bacidia convexula		*Bacidia convexula*	*Bacidia convexula*
	Pyrenula nitida	*Pyrenula nitida*	*Pyrenula nitida*
	Graphis scripta	*Graphis scripta*	*Graphis scripta*
		Lecanactis premnea	*Lecanactis premnea*
		Arthonia antillarum	*Arthonia antillarum*
		Catilaria indica	*Catilaria indica*
			Trypethelium tropicum
			Gyrostomum leprosulans
			Ramalina caroana

HALDIA TOWN :
POLLUTION LEVEL INDICATIONS
BASED ON LICHEN POPULATION
DENSITY



Index of Atmospheric Purity (IAP) is computed on the basis of the density of occurence of lichen in the sample sites.

Fig. 2. Haldia town: Pollution level indicators based on lichen population density

pollution tolerance index was (APTI) determined in a number of plants by using the formula, stated below :

$$APTI = \frac{A(T+P)+R}{10}$$

Where,

APTI	=	Air pollution tolerance index;
A	=	Ascorbic acid content;
T	=	Chlorophyll (content);
P	=	Leaf extract pH; and
R	=	Relative water content of leaf.

Through these kinds of studies, pollution sensitive and pollution tolerant species can be easily be screened (Table 2).

Table 2

Bioindicators of SO_2 Pollution in the Atmosphere			
	Sensitive Plants		**Resistant Plants**
1.	Alfalfa *(Medicago sativum)*	1.	Banian *(Ficus bengalensis)*
2.	Mango *(Mangifera indica)*	2.	Sal *(Sherea robusta)*
3.	Apple *(Pyrus malus)*	3.	Neem *(Azadirachta indica)*
4.	Wheat *(Triticum vulgare)*	4.	Ber *(Zizyphus mauritiana)*
5.	Cotton *(Gossypium herbaceum)*	5.	Corn *(Zea mays)*
6.	Barley *(Hordeum vulgare)*	6.	Potato *(Solanum tuberosum)*

Plant Responses to Pollutant Exposure

Plant species differ in their susceptibility to air pollutant, For example, legumes such as soybeans and clover are more susceptible to O_3 than grains yield such as corn or wheat. Correspondingly, different cultivators, ecotypes, and varieties also display different degrees of susceptibility to air pollutants. Susceptibility to pollutants has been known to be under genetic control. Although diverse mechanisms have been proposed to explain this differential susceptibility, no generally accepted mechanisms(s) can explain the differences. In addition, a range of climatic factors such as relative humidity, air temperature, light intensity and even photoperiod has been studied and shown to influence the response of vegetation on pollutants. Similarly, edaphic factors such as soil moisture, soil nutrients, and soil oxygen concentration also influence plant response.

However when plants are used for the monitoring of air pollution effects, a high degree of standardization of the air material and of physical and chemical environmental conditions is a prerequisite.

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BIOMONITORING OF FRESH WATER ECOSYSTEM

S.C.SANTRA*

Introduction

Ecological relationships are manifested in physico-chemical settings of a biotic environmental substances and its interaction with the biotic communities in a given environment, is very complex. Biotic environment and its particular biotic assemblages constitute an "Ecosystem" Thus the understanding of the structure and function of an ecosystem is the matter of concern for ecologists. In any ecosystem the basic biotic components are producers, consumers and decomposers, all of which always interact with the physical environment and so also lead to the changes of the biogeochemical cycle of nutrients. The Sun is the external source of energy in this system.

Among the different type of ecosystems, the water bodies constitute the major type of living environment, as seventy percent of the planetary ecosystem is located in different types of water bodies: as they may be inland water ecosystem, ocean water ecosystem and esthuarine water ecosystem.

Fresh Water Ecosystem

The fresh water ecosystem again constitute, a number of very selected environments like ponds, lakes, reservoirs (natural or man-made) and rivers. Each of the habitants have characteristic biotic communities (flora & fauna). The producers (Flora) of the fresh water bodies are of various kinds *viz.*, phytoplanktons, benthic flora and macrophytic vegetation. The consumers of various levels like herbivores and carnivores constitute zoo-planktons, floating and benthic animals (Fauna). In addition, various categories of transitory vertebrate fauna whose livelihood is maintained in aquatic habitats, may also be included as consumer of the concerned ecosystem.

The phytoplanktons are primarily unicellular or filamentous or colonical algae of different classes, while the benthic flora include filamentous algae or epiphytic algal communities. About 500 taxa were commonly found in fresh water as phytoplanktons of which majority belongs to green, blue-green, golden brown algal groups. Identically a fairly large number (>720 species) of angiosperms are known to exist in fresh water habitats alone. With respect to animals, invertebrates (adult and larvae) and vertebrates, particularly fish, constitute the major component. In addition, the bottom sediments constitute a good number of decomposers dominated by bacteria and fungi. They are responsible for decomposition of organic debris and so also infacilate the release of nutrients.

In comparison to the energy capture efficiency of terrestrial forest ecosystem, the aquatic system is less productive as light penetration in water reduced, so the primary productivity is less (Table 1).

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Table 1

Annual Energy Budget		
	Perennial Grass herb. vegetation	Lake system
1. Incident solar radiation ($G cal/Cm^2/Yr.$):	471.0 x 106	118,872.0
2. Plant utilization ($g Cal/Cm^2/Yr$):		
a) Gross production (GPP)	5.85 x 106	111.3
b) Net production (NPP)	4.95 x 106	87.9
c) Respiration (CR)	0.88 x 106	23.4

According to documents published by the Ministry of Environment and Forests, Govt. of India (1990), about 4.1 million hectares of Wetlands of different categories are distributes in various States and Union Territories of India (Table 2).

Table 2

Distribution of large water areas (Wetlands, >100 ha) in various states/Union territories of India				
States	Natural		Man-Made	
	Number	Area (ha)	Number	Area (ha)
Andhra Pradesh	219	100,457	19020	425,892
Arunachal Pradesh	2	20,200	NA	NA
Assam	1,394	86,355	NA	NA
Bihar	62	224,788	33	48,607
Goa	3	12,360	NA	NA
Gujarat	22	394,627	57	129,600
Haryana	14	2,691	4	1,079
Himachal Pradesh	5	702	3	19,165
Jammu & Kashmir	18	7,227	NA	21,880
Karnataka	10	3,320	22,758	539,195
Kerala	32	24,329	2121	210,579
Madhya Pradesh	8	324	53	187,818
Maharashtra	49	21,675	1004	279,025
Manipur	5	26,600	NA	NA
Meghalaya	2	NA	NA	NA
Nagaland	2	210	NA	NA

Table 2 (contd.)

Distribution of large water areas (Wetlands, >100 ha) in various states/Union territories of India				
States	Natural		Man-Made	
	Number	Area (ha)	Number	Area (ha)
Orissa	20	137,022	36	148,454
Punjab	33	17,085	6	5,391
Rajasthan	9	14,027	85	100,217
Sikkim	42	1,101	2	3.5
Tamil Nadu	31	58,868	20,030	201,132
Tripura	3	575	1	4,833
Uttar Pradesh	125	12,832	28	212,470
West Bengal	54	291,963	9	52,564
Union Territories (Chandigarh & Pondicherry)	3	1,533	3	1.301
TOTAL:	2167	1450861	65253	2589266
NA – Data Not available				

Most of the large water areas are directly or indirectly associated with river systems such as the Ganges, Brahmaputra, Narmada, Tapti, Godavari, Krishna and Cauvery. Now the majority of these water areas, face severe encroachment, siltation, pollution, and aquaculture activities, though the need for conservation of these water areas is very much necessary.

Study of Fresh Water Ecosystem Changes

Nowadays it is quite mandatory to evaluate the impact of developmental activities on aquatic ecosystem what so ever, whether the area lies within the core or buffer zone of the project site. The requirement for data generation is in the form of the following format:

— To identify the water bodies in the study area and highlight the existing ecosystem components;

— To prepare a vegetation profile of the plant communities as riparian system: aquatic weeds or marcophytic vegetation;

— To collect the planktons & benthos and determine the diversities and population load;

— To determine the biological productivity of the ecosystem: seasonally and diversify;

- To evaluate the impact of developmental project on ecosystem components and functioning;
- To suggest the possible mitigatory measures for conservation/eco-restoration of water bodies in sustained manner;
- To assess whether the habitats opossess any endemic and also endangered plant species;
- To assess whether habitat is a rich gene pool of rare species and also whether the areas are active sites for the evolution of species;
- Finally to evaluate the fact, that whether the area needs in-situ conservation or not?

Due to above stated facts, a group of skilled scientific personality are often engaged for preparing the Environmental Impact Statement (EIS) of any such project before undertaking any project by a developer.

During impact evaluation phase, usually the physico-chemical quality of water, soil and air often gets major emphasis in terms of quantitative changes, but in recent years ecological parameters like species richness, density and diversity were equally receiving special importance.

The river valley projects, power plants and industries around big water bodies/rivers; mining around the rivers and other water areas etc. deserve special emphasis for study of aquatic ecosystem.

Aquatic Environmental Pollution

Each aquatic system contains a large number of inorganic and organic compounds in dissolved or suspended state, along with a variety of plant and animal life. All these components (chemical and biological) exist in a dynamic equilibrium in a fixed space and time. It is generally agreed that water bodies, owing to the presence of aerobic autorophic organisms, have been endowed with a remarkable capacity to rejuvenate their vitality. However, with an increase in human activities, the load on the receiving water bodies has increased. Nutrient are increasingly added to water bodies which lead to a great difficulty for purification and this has changed the physical, chemical and biological picture of water bodies.

The pollution of water bodies invariably affects both fauna and flora; hence pollution is essentially a biological problem. Thus studies on the aquatic ecology envolving analysis physico-chemical and biological parameters of the water as both chemical and biological indices are complementary to each other is very essential. Very often water pollution can be determined by assaying biological index alone.

Monitoring of water quality by the indicator organisms: Looking at the relationships between free living aquatic organisms, it is clear that there is a variety of categories of organisms which are potentially present in each aquatic ecosystem, and that these groups differ very much by their increasing levels of organization and morphological complexity.

Thus considering the facts of complexity of the biological party of the ecosystem, the two basic questions are often raised by the aquatic biologists.

— Are the communities, populations or species of aquatic organisms which can serve as indicator of water pollution?

— Is it possible to evaluate the degree of pollution in a body of water by the characteristics of the aquatic communities living there?

Since the middle of the 19th century, fresh water biologists have been concerned with the changes where pollutional conditions bring the change in natural communities of aquatic organisms. Kolenati (1848) and Cohn (1853) noticed that certain organisms show a specific relation to the purity of water, in other words they discovered that some organisms present in polluted water differs from those found in clear water, Later, Mez (1898) in his book dealing with microscopical analyses of water, described four categories of organisms:

— those found in very pure water;

— those present in slightly polluted water;

— those of fairly polluted water; and

— those of very strongly polluted water.

However, Kolkwitz and Marsson (1902) made the definite break – through the concept of "biological indicators of pollution" in their so-called "saprobic system" The saprobic system is based on different zones of organism enrichment, each of which is characterized by specific plants and animals species. They recognize altogether 3 saprobic levels:

(a) Polysaprobic level (a zone with predominance of reduction processes);

(b) Mesosaprobic level (a zone where the reduction gradually ceases and is taken over by oxidative processes); and

(c) Oligosaprobic level (a zone with only oxidative processes).

They also published long lists of species of plant and animals which are thought to be associated with each of these zones mentioned above. In 1962, Liebmann also suggested identical saprobic zonations viz. oligosaprobic, mesosaprobic and poolysaprobic zones, each zone has characteristic indicator species composition (Table 3).

Table 3

Indicators of various saprobic levels (as modified after Liebmann, 1962)					
OLIGOSAPROBIC ORGANISMS (*Indicators of scarcely polluted waters*)		MESOSAPROBIC ORGANISMS (*Indicators of moderate to highly polluted waters*)		POLYSAPROBIC ORGANISMS (*Indicators of extremely polluted waters*)	
Plants	**Animals**	**Plants**	**Animals**	**Plants**	**Animals**
Cyclotella sp.	*Vorticella* sp.	*Oscillatona* sp.	*Stentor* sp.	*Oscillatoria* sp.	*Chironomus* sp.
Synedra sp.	*Planaria* sp.	*Nitzschia* sp.	*Vorticella* sp.	*Spirulina* sp.	*Tubifex* sp.
Micrasterias sp.	Larvae: *Oligoneuria* sp.	*Stephanodiscus* sp.	*Stratiomys* sp.	*Euglena* sp.	*Rotaria* sp.
Surirellâ sp.	Larvae of *Perla* sp.	*Uronema* sp.	*Spirostomum* sp.		*Colpidium* sp.
Tabellaria sp.	*Notholca* sp.	*Closterium* sp.	*Sphaerium* sp.		
Bulbochaete sp.		*Asterionella* sp.	*Cloeon* sp.		
Ulothrix sp.		*Melosira* sp.	*Brachinonus* sp.		

Indicators of various saprobic levels (as modified after Liebmann, 1962)

OLIGOSAPROBIC ORGANISMS (Indicators of scarcely polluted waters)		MESOSAPROBIC ORGANISMS (Indicators of moderate to highly polluted waters)		POLYSAPROBIC ORGANISMS (Indicators of extremely polluted waters)	
Plants	**Animals**	**Plants**	**Animals**	**Plants**	**Animals**
Cladophora sp.		*Scenedesmus* sp.	*Stylaria* sp.		
Euastrum sp.		*Pediastrum* sp.	*Coleps* sp.		
Staurastrum sp.		*Tabellaria* sp.			
Batrachospermum sp.		*Cladophora* sp.			

During the past three decades, several other saprobic levels were suggested by various biologists and several methods have been proposed to quantify the indicator organisms found. In the method proposed by Knopp (1954, 1955), the species found at each sampling point are listed and their estimated frequency is valued, using a scale of 7 degrees :

1 = single findings, 2 = few, 3 = few to average numbers,
4 = average numbers, 5 = average to many, 6 = many, and 7 = abundant.

The indicator value of each species is looked up in the saprobity system of KOLKWITZ, using the 4 symbols: 0, β, α, and φ for oligosaprobic, α– and β– mesosaprobic and polysaprobic respectively. The frequency numbers of all the species are added up for each saprobic zone: ΣO, Σα, Σβ and Σθ. For a visual representation of the state of pollution of a particular biotope, Knopp plots the so-called "positive" values (ΣO and Σβ, representative for no pollution or minute pollution) above the axis, and the negative values (Σα and Σφ) below the axis. Knopp also introduced the concept of relative purity and relative pollution which can be calculated from the summations of abundance of the indicators in the 4 saprobic classes.

$$\text{Relative purity (in \%)} = \frac{\sum(0+\beta)}{\sum(0+\beta+\alpha+\phi)} \times 100$$

$$\text{Relative loading (in \%)} = \frac{\sum(0+\alpha)}{\sum(0+\beta+\alpha+\phi)} \times 100$$

This relative loading is also called and used now as Biologically Effective Organic Load (BEOL). From the specific groups and the total number of groups present, the Biotic Index which ranges from 1 to 10, can be extrapolated. Clean streams score an index close to 10; this index drops to lower values with increasing pollution and the heavy polluted streams average an index of 1-2. However Woodiniss (1978) has extended his Trent Biotic index to cover a range of water qualities from 0 to 15. In the above studies the relative abundance was not considered. In 1970, Chandler proposed a "score system" for 5 levels of abundance survey, which is primarily based on the numbers or organisms taken during 5 minutes sampling with a hand net (Table 4).

Table 4

Levels of abundance considered in score system by Chandler (1970)		
Level	**Number of individuals per 5 min sample**	**Remarks**
Present	1 to 2	May be drift fauna from upstream
Few	3 to 10	Probably, indigenous but rare
Common	11 to 50	—
Abundant	51 to 100	—
Very abundant	more than 100	—

The Chandler score increases with increasing abundance for clear water species whereas it decreases with increasing abundance for pollution tolerant species.

Monitoring of water pollution by Algal Indices Alone: Biological indices particularly the use of algal distribution in different water bodies could also be used for water pollution studies. Some indices are discussed here.

(a) **Nygaard's algal indices:** Nygaard (1949) proposed five indices to evaluate the organic pollution of a water body on the basis of algal groups. These indices have been developed on the basis of the fact that various algal groups have different tolerance to organic pollution and nutrient enrichment. In general, the cyanophytes, the Euglenophytes, the centric diatoms and most Chlorococcales are commonly found in eutrophic waters, but the pinnate diatoms and the desmids are commonly found in oligotrophic water. The trophic state indices value of both oligotrophic and Eutrophic water as suggested by Nygaard is given below:

Table 5

Nygaard's algal indices			
Index	**Calculation**	**Oligotrophic**	**Eutrophic**
Myxophycean	*Myxophyceae* (Cyanophyceae) Desmideae	0.0 – 0.4	0.1 – 3.0
Chlorophycean	*Chlorococcales* Desmideae	0.0 – 0.7	0.2 – 9.0
Diatom	*Centric diatoms* Pinnate diatoms	0.0 – 0.3	0.0 – 1.75
Euglenophycean	*Euglenophyceae* Myxophyceae Chlorococcales	0.0 - 0.2	0.0 - 1.0
Compound	Myxophyceae+ Chlorococales+ Centric diatoms+ *Euglenophycean* Desmideae	0.01 – 1.0	1.2 – 2.5

(b) Palmer's algal indices: Palmer (1969) made a major attempt to prepare a list of genera (60) and species (80) of algae tolerant to organic pollution and then developed indices based on the algal data for rating organic pollution of a water body (Table 6 below and Table 7, on following page). An example of the Palmer's pollution index of algal genera states that if any water sample having the following algal genera viz. *Chlorella, Oscillatoria, Stigeoclonium, Shnedra, Nitzschia, Chlamydomonas* and *Navicula*, the water sample is said to be highly polluted by organic substances.

Table 6

Algal genera pollution index			
Algal genera	**Pollution index**	**Algal genera**	**Pollution index**
Anacystis	1	*Micractinium*	1
Ankistridesmus	2	*Navicula*	3
Chyamydomonas	4	*Nitzschia*	3
Chlorella	3	*Oscillatoria*	5
Closterium	1	*Pandorina*	1
Cyclotella	1	*Phacus*	2
Euglena	5	*Phormidium*	1
Gomphonema	1	*Scenedesmus*	4
Lepocinclis	1	*Stigeoclonium*	2
Melosira	1	*Synedra*	2

Species – Diversity Indices: As the biological communities subjected to change with the change of the environment in which they occur, the relative proportion of abundance of species in a community often provides a good indication of pollution. The diversity indices are calculated from the abundance data of the organisms and serve as a very good indicator of pollution. Some diversity indices are described below:

(a) Shannon Weaver's Index (1949) It is determined by the following formulae:

$$D = -\pi \log e\, \pi$$

Where, D = Diversity index

π = ni/N

ni = number of individuals in species i,

N = total number of individuals in the sample.

log 2 may be used in place of log e to calculate 'D' in order to get the average information context per individual.

(b) Kothe's Species Deficit Index (1962) This index is based on the principle that in a flowing ecosystem the number of species decreases after they are exposed to some pollutant discharge. In this method the number of species of either a particular group (algae or macro invertebrates) or of all the groups are counted at the polluted and non-polluted points and then index is calculated as:

$$\text{Species deficit index} = \frac{A_1 - A_x}{A_1} \times 100$$

Where, A_1 = Number of species at the unpolluted site
A_x = Number of species at the polluted site (downstream)

It gives the data in a percentage linear scale and is very useful in indicating the consequences of point sources of waste water discharges.

Table 7

Algal species pollution index

Species	Pollution index
Ankistrodesmus falcatus	3
Arthrospira jenneri	2
Chlorella vulgaris	2
Cyclotella meneghiniana	2
Euglena gracilis	1
Euglena viridis	6
Gomphonema parvulum	1
Melosira varians	2
Navicula cryptocephala	1
Nitzschia acicularis	1
Nitzschia palea	5
Oscillatoria chlorina	2
Oscillatoria limosa	4
Oscillatoria princeps	1
Oscillatoria putrida	1
Oscillatoria tenuis	4
Pandorina morum	3
Scenedesmus quadricauda	4
Stigeoclonium tenue	3
Synedra ulna	3

(c) **Odum's Species Index (1971)** It is an excellent index to determine the level of pollution in both following and standing water bodies. It is calculated as:

$$\textit{Index value} = \frac{\textit{Total number of species encountered in the sample}}{\textit{Total number of individuals of all the species}}$$

In general, the index was basically designed to work in an aquatic ecosystem, but the recent studies have recommended its use even in terrestrial ecosystems too.

Biology of indicator organisms

Among the aquatic organisms algae (both planktonic and benthic). micro-invertebrates, molluscs and to some extent fish are good water quality indicators. For a considerable period these indicators were studied to evaluate the water quality of rivers, water reservoirs and lakes as they are polluted by industrial or domestic pollutants.

Diatoms are the most important groups among algae, which are used widely for water quality assessment. These are golden brown algae with characteristics cell morphology (usually 2 mm to 1000 mm in size). There are about 200 genera and 8000 species. Kolkwitz and Marsson were probably the first to establish that the occurrence of certain diatom species indicated the presence of pollution. A progressive decrease in the number of individuals in each species is evident with increasing pollution. Other than diatoms, certain blue green are also considered to be good pollution indicator, rather they are pollution tolerant species. Species of Oscillatoria, Spirulina, Microcystis, Gloeocapsa and Chroococcus are the good indicators of organic pollution of water bodies.

Identically green algae like Pediastrum, Scenedesmus, Staurastrum, Cosmarium, Closterium and Desmidium are also very good indicator of organic pollution of water bodies. Among Euglenoids, Euglena and Phacus are considered to be pollution tolerant.

There are several kinds of zooplanktons (mostly micro invertebrates, flagellates in particular), fungi and bacteria are also considered to be pollution tolerant in aquatic ecosystem. Tolerance to metal pollution (As, Hg, Cu, Zn, Cd, Cr, etc.) are reported to be present in certain algal taxa and bacteria too.

For selection of each indicator species the following criteria should be considered:

- the indicator species must be highly susceptible to pollution stress;
- the species must be easily recognizable and must have wide distribution pattern;
- the species preferably known from previous ecological or physiological studies;
- the species should be easily sampled;
- the species should have low genetic and biological variability.

Biomonitoring and management of aquatic ecosystem

Thus "Biomonitoring" i.e. the use of biological life forms, (particularly indicator organisms) are increasingly accepted internationally. It appears to be quite costly effective and efficient too. Although biomonitoring of water pollutants and their effects have given considerable new information, full exploitation of the system for water quality management is yet to come. One reason is that any data to be used by regulatory activity must be stringently tested for statistical reliability, cause specificity, interpretive strength and regulatory efficiency. To introduce these in routine biomonitoring, Henicks and

Schaeffer (1984) have introduced the term "compliance biomonitoring". The main requisite is unequivocal proof of a dose-dependent specific effect on a well defined biological system or sub-systems. The bioassay approach is more useful in regulating effluent levels of toxic chemicals while bioassessment data are needed for overall environmental management. For effective biomonitoring the following points have to be considered:

- proven dose-dependent effect basis,
- applicability to higher levels of biological organization and ecological hierarchy, and
- sensitive reproducible, stable and simple system and methods with least variability.

Suggested Reading

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ENVIRONMENTAL IMPACT ASSESSMENT (EIA) AND FLORA: SOME CONSIDERATIONS

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Introduction

Environmental Impact Assessment, generally referred to as EIA, is a technical exercise to develop a document which indicates the impacts of a proposed project on the surrounding environment in total. This exercise takes into consideration all physical, chemical and biological components in an area demarcated for a developmental project or the zones likely to be effected by the proposed industry and attempts to foresee the changes whether adverse or otherwise and evolve suggestions best suited to the situation in the form of Environmental Management Plan. The present topic restricts to aspects relating to flora while developing this kind of a document. There are distinctly various stages of assessment to improve and to come closer to the realities of impacts that a particular industry/project generates during different stages of its establishment, operation or its ultimate abandonment. At this state, it may be clarified that EIA is not to be considered as a confidential document or meant for restricted circulation but as an analytical report giving details on the possible adversities, repercussions and changes that a project is likely to bring about or cause on the immediate surroundings and its environment (Anonymous, 1994, Erickson, 1994).

Plant Diversity and Relevance of EIA

It is well known that unplanned or ill conceived industrial development has proved to be detrimental to the floristically rich areas in many countries. The value of preservation of biological diversity has been realized as all the species of living organisms are unique in their structural and functional aspects besides their extreme usefulness to mankind. Many organisms particularly of lower groups like fungi which were overlooked by man as of no significance, have proved to be of immense value to mankind as is known in the case of moulds like *Penicillium* which have revolutionised modern medicine through discovery of antibiotics. It is therefore imperative that we do not destroy options for future by wiping out entire biological diversity and their communities from the face of the earth, in the quest for quick economic returns through industrialization and consumerism.

Recent studies have shown that the flora of India has about 45000 species including about 16000 flowering plants, 600 species of pteridophytes, 2700 bryophytes, 500 species of algae, 20000 species of fungi and 1600 species of lichens (Nayar, 1987). Among the flowering plants many interesting groups such as insectivorous plants like *Nepenthes*, *Utricularia* and *Drosera*, parasites like *Orobanche*, *Balanophora*, *Sapria* and *Cuscuta* and a number of epiphytes belonging to Orchidaceæ and the like, the bamboos and wild relatives of cultivated plants make the flora diverse, important and valuable. Besides, the geographical location of India with its peninsular region surrounded by the seas on its three sides, the arid region in the west, and the high mountains all along the northern

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order rendered the Indian landmass a very favourable habitat for endemics which are estimated to be in the order of about 5000 species. There are 58 endemic genera among flowering plants in the peninsular India of which 47 are monotypic or represented by a single species under each genus (Ahmedullah and Nayar, 1986). Such endemics have a very narrow range of distribution. The chances of becoming threatened have been increasing considerably in the recent past and such a reason is attributed to the degradation or loss or habitat of such species resulting from various developmental activities. Habitat destruction or disturbances occur through various factors such as urbanisation, industrialization, clear-felling of prime forest areas for agriculture and other commercial activities, mining and quarrying, pollution of air, water and soil and finally population pressure.

As a result, there is a rise in the number of threatened plants. It is estimated that about 1500 species of flowering plants occur in the country and are in varying degrees of threat for their survival, 630 species have been assessed and details on these species have been incorporated in the three volumes of Red Data Book on Indian plants (Eds. M.P. Nayar & A.R.K. Sastry, 1987, 1988 & 1990) published by the Botanical Survey of India. Such fragile plant wealth needs utmost care and conservation and stipulations for safeguards in EIA become more relevant and appropriate and act as a conservation tool for flora while initiating a developmental scheme or project in any part of the country.

With the present liberalisation policies in operation and developmental schemes fast coming through, EIA should be effectively used as a tool to check the possible impacts of different developmental projects on the floral diversity and thereby any loss of the plant wealth. Primarily when one takes up this exercise the procedures to be followed will vary with the type of project to be initiated. It is obvious that different developmental projects generate varied pressures/benefits, i.e. bad or beneficial, on the surrounding flora.

The following studies may be made with reference to flora to develop database for EIA document.

1. Component species.
2. Variation in natural populations.
3. Seasonal and periodic events (such as flowering, fruiting etc.)
4. Frequency, density and distribution range.
5. Population biology: Reproduction, breeding systems, pollinators, dispersal mechanisms, and establishment into new independent individuals.
6. Community ecology.
7. Species of relevance to local people:
   (a) Medicinal value
   (b) Fuel value
   (c) Food value
   (d) Fodder value
   (e) Plants of minor forest produce.

8. Functional aspects:
   (a) Dependence and interrelationships
   (b) Relationship with wild fauna.

While developing the list of plants available in the project area, one should objectively present the information so that all impacts of industry can be documented. It is, however, not necessary to work on every species of flora in the project area, for the data on above listed criteria. Considerable screening and scoping are essential while presenting such information. Road side species, weeds and species with high relative abundance and wide distribution may be of secondary consideration for impact analyses, as they have no consequence and direct relevance to the project development. However plants with restricted distribution which are endemic in nature are to be identified and listed. Plants with rare occurrence are to be marked out as these species are prone to further vulnerability and consequently to extinction (at least in the area) from the adverse impacts arising out of developmental projects. Some plants require unique habitats having high degree of niche specificity particularly relating to pollination and reproduction and such details are to be recorded.

The methodology of the impact assessment to be adopted varies with the type of industry as different projects generate different kinds of stresses/impacts on the surrounding environment and flora. However, it is difficult to discuss procedures recommended industry-wise to be adopted for EIA studies with regard to flora.

In the first task there are two aspects namely identification of the activities relating to the developmental project and identification of the components to be impacted upon (Royston, 1981). The activities are:

— Preparatory work
— Construction
— Operation
— Abandonment.

Any of these activities either independently or wholly may effect the flora directly or indirectly resulting in clearing operations of vegetation (forests) and thereby its component species during construction of a factory or township. During operational phase of the project, the type of effluent emissions, their quantity, also trigger some changes in the surrounding environment of the project area and consequently bring about some stress on the constituent floral elements and its composition. Such activities and the changes which they bring about or cause should also be identified and studied. Pollution of environment by chemical effluents may drastically modify the nature of the substrate and may bring about a change in the sequence of natural vegetation and its floristic composition of the communities. When suspended solids become consolidated in appreciable measure or quantum in sandy or gravelly type of soils (substrate) in a river bed, plant communities with dissected leaves such as *Myriophyllum* and Ranunculaceæ members which usually grow as original components generally get replaced by floral elements which are either silt-loving or silt-tolerant species such as *Elodea canadensis*, *Potamogeton pectinatus*, *P. natants* and *Gylceria maxima*, etc. The other types of impacts through industries involve change in the nutrient or chemical composition especially in the levels of phosphates, nitrates, trace elements and energy-rich organic compounds, leading to alterations in the floral composition especially in aquatic systems and seasonal aquatic micro-flora. Besides, induced activities such as distribution, uses and disposal of waste products from the industry also bring about certain impact on the flora and harmful effects on plants. The operational demands associated with the project such as power supply, tapping of water in huge quantities from the nearby rivers and construction of roads and movement of trucks etc. for bulk transportation of industrial produce also generate certain impacts on the local habitat and its environment and thereby on the constituent biodiversity. Such possible causes of impacts should be taken into consideration in the EIA studies and possible steps to mitigate the impacts on the biota should be considered in the EIA Report. Raw material requirements of proposed industry involving direct use or consumption of certain species of the flora (such as in timber industry, paper industry, ply wood industry) should be assessed with care and EIA should provide clear estimates for regeneration and continued supply of such raw materials through sustainable steps. Continued supply of raw materials from plantations raised for plant-based industries is to be ascertained and EIA should clearly take into account exploitation of natural plant wealth for production in such industries.

Attention should also be paid to different environmental processes such as soil erosion, flooding etc. While considering EIA for river valley projects large areas usually are lost due to inundation resulting in the total loss of a considerable number of plant species. Such impacts are to be carefully assessed and examined, because such processes bring about the direct and total loss of endemic and endangered species growing in such areas. Results of such impacts can be predicted by examining the floral composition in such areas and appropriate steps to rehabilitate those species in other suitable habitats should be incorporated in the EMP document. Fortunately, no intricate methodologies are involved in prediction of such impacts and the mitigative steps to be taken.

The next step in evaluation involves assessment of species likely to be affected, their particular value to local people, distribution range or their role in ecosystem functioning such as the case with keystone species.

Once data on these aspects is generated and examined, steps needed for mitigating the impacts should be considered to nullify or reduce the adverse causative factors. In the case of flora, such steps include:

- *in-situ* conservation of rare, valuable and endangered species and
- *ex-situ* conservation of such species in botanical gardens, conservatories, seed banks; Development of nurseries of such species for rehabilitation in the unaffected areas of the same ecosystem.

Involvement of local population in such rehabilitation efforts should be considered. Unfortunately most of the project authorities resort to development of green belts around project sites with introduced species which are easy to grow. EMP reports should stress and make it obligatory on the part of the industries to support research on local plant species and their rehabilitation to rescue endemic, endangered and useful species from extinction. Such rehabilitation and post care efforts of plantations of native species would generate employment opportunities to local poor people who are deprived of making their living on minor forest produce obtained from the local flora lost during operational stages of industries/river valley projects. Lastly, EMP should also communicate with the local people with regard to the safeguards outlined in the document for reducing the detrimental effects caused by the project in the surrounding areas.

Suggested Readings

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EIA METHODOLOGY FOR BIORESOURCE IMPACT SURVEY

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Introduction

The human species entered the industrial age with a population of about one billion and with the highest amount of available biological resources for exploitation. Now, in the last decade of 20th century, the situation is totally reversed. On the one hand there is the tremendous explosion of the human species and on the other hand there is the rapid destruction of biological resources or wildlife for his ego, needs and comforts. It has been realized that the change use of agricultural lands, grass lands, mountains, forests, wetlands, rivers, etc., for any of the developmental projects has the greatest and most rapid effect upon wildlife and environment. Thus, in India, according to Environmental Pollution Act, 1986, Environmental Impact Analysis has now become mandatory before the clearance of any developmental project. Biological portion or wildlife is the most important component of environment and presents a special problem in assessing the impact of a project on them. There is no universally acceptable methodology for conducting such study. In the present paper presently an attempt has been made to provide some most preliminary ideas about the methodology of Environmental Impact Assessment with special reference to fauna/wildlife.

Some Definitions

For the proper understanding, definitions of some of the terms used in the text are given below:

Environment: 'Environment' is the sum of all factors (both biotic and abiotic) that influence organisms.

Wildlife: 'Wildlife' means plants and animals in their wild state, embracing all living organisms.

Species: 'Species' are groups of interbreeding natural populations that are reproductively isolated from such other groups.

Population: Individuals of a species in a given locality which potentially form a single interbreeding community are collectively known as population.

Natural Habitat: The specific environment or area in which a particular plant or animal or a group of plants and animals live in and adapted is known as natural habitat of that plant/animal or groups of plants/animals.

Flora: Total plant species or plant life of an area or region.

Fauna: Total animal species or animal life of an area or region.

Biota: Total fauna and flora of a region.

Natural communities: Recognisable associations of plant and animal populations in an area.

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Ecology: Branch of science dealing with interactions between organisms and their environment.

Ecosystem: It is the functional unit of ecology.

Critical species: A species is 'Critical' when it is facing an extremely high probability of extinction in the wild in the immediate future.

Endangered species: A species is 'Endangered' when it is not Critical but is facing a very high probability of extinction in the wild in the near future.

Vulnerable species: A species is 'Vulnerable' when it is not Critical or Endangered but is facing a high probability of extinction in the wild in the medium-term future.

Rare species: A species with small populations in the world that are not at present Endangered or Vulnerable but are at risk.

Schedule I species: According to Indian Wildlife (Protection) Act, 1972, threatened species are included under Schedule I and protected throughout the country, live or dead or part thereof.

Succession: Natural communities are not static but pass through a series of changes. Organisms living in them, modify their environment in such a way that complex communities composed of more specialised organisms arise.

Impact Of Development Projects

Impact of development projects on the environment vary in their directions, intensity and duration depending upon both the nature of action and of existing biotic community. Precise quantitative predictions about the impacts of a project is practically impossible because of the complexity and variability of ecosystems and their recovery capabilities. Impacts on the biotic components are of two types, *viz.*, direct and indirect, and of varying duration, *viz.*, short term and long term. Direct impacts are those that destroy or displace plants and animals. Indirect impacts are those that destroy or disrupt habitats, ecosystems or other physical and biological factors upon which a species depends. Short term impacts relate to the immediate and direct environmental changes that take place during the inception of a project but corrected after the completion of the project. Long term effects are resulted from either major, direct environmental changes or by the chronic disturbances during operational phases of the project. However, it is not possible to generalize the impacts of the different projects on the wildlife. A project may be harmful to certain forms of wildlife, while beneficial to others. When a large dam is constructed, vast areas of prime habitat of a number of terrestrial plant and animal species are lost, while the same dam provides habitat to varieties of fish and other creatures living in and around water bodies, and allows succession to develop new natural communities. Some typical impacts of different project activities on the biota are given in Table 1.

From the study of Table 1 potential negative impacts of development projects on Wildlife may be summarized as follows:

(1) Vegetation destroyed or disturbed.

Table 1

Typical impacts of some developmental activities on biota.					
	Activity		**Types of biota impacts**	**Adverse**	**Beneficial**
1.	Agriculture	(a)	Encourages a few species	+	+
		(b)	Habitat destruction	+	–
		(c)	Loss of native plants and animals	+	–
		(d)	Increase in pest species	+	–
2.	Dams and reservoirs	(a)	Create shore line ecosystems	–	+
		(b)	Potential increase in species type	+	+
		(c)	Habitat destruction	+	–
		(d)	Loss of native plants and animals	+	–
3.	Power plant construction and operation	(a)	Alternation of breeding and feeding activities	+	–
		(b)	Change in form of aquatic life due to heating of adjacent waters	+	–
		(c)	Potential loss of wildlife	+	–
4.	Roads, highways, railroads, airports	(a)	Increase 'Edge effect'	–	+
		(b)	Disturb corridors and natural movement	+	–
		(c)	Increase 'Road Kills'	+	–
5.	Communications and utility towers	(a)	Create new roosting and resting sites for birds	–	+
		(b)	Interfere with migration of birds	+	–
6.	Gas and oil pipe lines	(a)	Interfere with daily and seasonal animal migration	+	–
7.	Industrial, commercial and residential development	(a)	Increase pest species	+	–
		(b)	Habitat destruction	+	–
		(c)	Increase 'Edge effect'	–	+

(2) Wildlife habitat reduced or broken up.

(3) Wildlife destroyed or displaced.

(4) Migration routes for wildlife disrupted or destroyed.

(5) Nesting, mating and other wildlife activities disrupted or destroyed.

(6) Increased 'Road Kills'

(7) Change in species composition and increase in pest species.

(8) Physical properties of air and water changed.

Assessment of Biotic Environment

Before going into the assessment, name should be given to the site to be assessed. Name may be based on the dominant geographic or biotic feature, such as, *Swamp, Dune, Bog, Pines, Sal, Tiger, Elephant, etc.* It may also be named after the project, such as, *Testa Barrage, Purulia Pumped Storage,* etc.

Physical features of the site, viz., topography, rainfall, wind, light, soil, etc., have particular relationship with the wildlife. Less rain fall area, more rainfall area, plain, plateau, mountain, cold area, desert, etc., each support a particular type of wildlife. Changes in any of them will automatically affect the wildlife. Thus, biotic assessment should include a description of totally physical features of the site and its surrounding. A summary of the physical features to be studied is given below.

Physical features of the proposed project site to be included in the biotic assessment

A. Geography: Include present and past use of the land.

- Elevation off-and-on site. Details to be shown on a topographic map.
- Drainage: Water and air including pollution entering from outside.
- Presence of aquatic systems off- and on-site: ocean, lake, river, pond, marsh.

B. Geology and soils: General geological formation of the area with —

- Geologically and biologically important or unique features.
- Dominant rock types.
- Soil analysis-depth, mineral content, profile, pH, etc.

C. Climate:

- Precipitation: Average annual rainfall and snowfall.
- Temperature: Average annual, seasonal changes, extremities.
- Wind-prevailing (direction, speed), storms, tornadoes, etc.

D. Others:

- Utilities
- Noise – highways, aircraft, factories, constructions
- Any special features.

The investigator may obtain the topographic map from the Survey of India or the project authority. Water drainage, forest cover and other geographic features may be plotted in the map from existing available information, survey work or aerial photographs. Geological information are often available with the local universities and Geological Survey of India. To obtain the data on the climatic condition meteorological offices may be requested. Often the District Gazetteer contains much valuable information about the physical features of the site.

The investigator should provide an insight of the existing relationship between wildlife and physical features and indicate the changes in the physical features due to project along with the influences of that on the wildlife. This information will help those who will review the report and those who will use it for decision making.

To collect the data for biotic assessment, existing literature on the fauna and flora of the region should be thoroughly studied.

The investigator should also provide a list of the species from the area which are important from the conservation point of view along with their legal status. For first-hand information on the present biotic situation, actual field survey is to be conducted in and around 25 sq. km of the project site in different seasons of the year. During survey work, observations on the ecological conditions and biota are to be made to reveal the species composition in the different ecosystems, community structure, population structure and status of the species specially of ecological and conservation significance, breeding, feeding, migration and other biological aspects. Often, it may not be possible even for a taxonomist to identify the species in the field. Thus, sample collection of the different species and their identification in the laboratory become must for the proper biotic assessment. It is worthwhile to mention that for the sample collection of botanical or zoological specimens, prior permission from the appropriate authority (generally, the Chief Wildlife Warden of the state) is necessary. However, collection and preservation of specimens are a specialist's job. For the methodology of collection and preservation of biological specimens, literature published by the Zoological Survey of India and the Botanical Survey of India may be consulted.

For identification of the major groups of plants and animals, quite a good number of handbooks and manuals are available in the Z.S.I., B.S.I, or university libraries. However, it is always wise to take the help of taxonomists, so far as the identification of the species is concerned.

Estimation of density or population of the different species of plants and animals is the most important criteria for biotic assessment. Methods of quantitative analysis are two numerous to describe.

Some of the simple techniques for quantitative analysis are briefly described below:

Plants: To determine the density of a plant species (Suppose 'A') in an area, some sample plots are selected at random or systematically. In general, size of the sample plot varies directly with the basal cover area of the plant species for which estimate to be made. Sample plots may vary from 0.1 m^2 to 100 M^2 or more in size. Then the number of different species in the sample plots are counted and density is calculated by the following formulae:

$$Density = \frac{Number\ of\ species\ 'A'}{Area\ sampled}$$

$$Relative\ density = \left(\frac{Density\ of\ species\ 'A'}{Total\ density\ of\ all\ species}\right) \times 100$$

Animals: Quantitative assessment of fauna involves more problems than flora assessment by virtue of the greater variety of animal species, their mobility, and behaviour. It is very difficult to determine the number of animals in a population. Thus, in most environmental impact studies only a estimate of the population is required and methodology for the same varies with the habitats as well as the nature of the species.

Direct Count: Herding animals and flocking birds may be estimated by this method. Direct counts are made in areas of concentrations, such as, feeding grounds, resting areas, rutting and breeding grounds, and in roosts.

Sample plots: This is most suitable for sedentary or attached animals as well as burrowing species. Molluscs, sea-stars, barnacles, etc., may be counted directly in the sample plots, while burrowing species from the number of emergence holes.

Count indices: Count indices provides an index of various species in an area and can be obtained from count of animal signs (pug marks, fæcal matter, etc.) calls or roadside counts. Comparisons through the seasons, between sites or habitats can be made from such indices. Roadside count is the easiest and most useful for the species which frequently cross the road or can be observed from the road. Counting is made by moving a given distance within the sampling area preferably on foot. Suppose, a count was made at every 0.5 km. interval for a distance of 5 km and following observation was made:

Km. from starting	Count of species 'A'	Count of species 'B'	Count of species 'C'
0.5	-	2	-
1.0	-	1	-
1.5	1	-	-
2.0	-	-	-
2.5	2	-	-
3.0	-	1	-
3.5	-	2	1
4.0	-	4	1
4.5	-	-	-
5.0	-	1	2
Total	3	11	4

From the above data, census index can be obtained from the following formula:

$$Census\ index = \frac{N}{Km}$$

Where N = Total number of individuals of a species observed
Km = Total Km travelled

By putting the above data in the formula, one can get the census index for the species:
A = 3/5 = 0.6; B = 11/5 = 2.2; and C = 4/5 = 0.8.

Catch – Mark – Recapture (C.M.R): This is the most suitable technique for the estimate of total population in a given area of a species which can easily be trapped or netted. It requires capturing a portion of population from an area, marking each individual, and releasing them in the same area. After a fixed period of time another sample is collected from the same area by similar methods. Counting of marked specimens, as well as total number in the second sample is made. Estimate of population can be done by the following formula:

$$N = \frac{T}{t/n} \ or \ \frac{nT}{t}$$

Where	T	=	Number originally marked
	t	=	Number of marked animals recaptured
	n	=	Total number of animals in the second sample
	N	=	Population size estimate.

Valuation of the biological resources to be sacrificed for a developmental project is also an important task of the investigator. This will guide the government as well as commercial decision makers in a right way. Three main approaches have been used to determine the value of biological resources of an area:

— Consumptive – use valuation involves assessing the value of resources, like firewood, fodder, game meat, etc. that are consumed directly, without passing through a market.

— Productive – use valuation involves assessing the value of products that are commercially harvested and marketed, such as timber, fish, game meat, ivory, and medicinal plants.

— Non-consumptive – use valuation involves assessing the indirect value or ecosystem functions, such as watershed protection, photosynthesis, soil production, etc.

To some extent, consumptive use and productive – use valuation are possible through local market survey, discussions with the inhabitants in and around the site, Forest Department, authorities of small and large scale industries based on forest produce, as well as by the study of growth rates of different economically important plant and animal populations. However, from the practical point of view, it is most difficult to estimate the indirect values in our country.

After obtaining the data about the biotic environment from primary and secondary sources, assessment may be done in the following sequence of questions and answers arranged in a flow chart fashion (after Shukla and Srivastava 1992):

1. What is the existing vegetation?

   i. Weeds

   ii. Ornamental plants

   iii. Grass land

   iv. Shrub land

   v. Forest

vi. Other vegetation

2. Are there any unique vegetative features?
   i. Rare or endangered species
   ii. Species with high visual, historic or aesthetic value.
   iii. Plants associated with particular habitat features such as stream, acid soil, shade, etc.
   iv. Threats posed by individual plant species or vegetation (for example poisonous, fire potential, disease, etc.)
   v. Wild varieties of domestic stocks.
   vi. Plants of medicinal importance
   vii. Schedule VI species.
3. Should any plant or communities be retained or preserved? Answers to questions 1 and 2 will lead to the answer of this question.
   i. Should specimens of a species be saved?
   ii. Should a representative plant community be saved?
   iii. Should a particular natural habitat be saved?
4. What is the existing animal life?
   i. Mammals
   ii. Birds
   iii. Reptiles and Amphibians
   iv. Fish
   v. Insects and other Arthropods
   vi. Other animals
5. Are there any unique faunal features?
   i. Critical, Endangered, Vulnerable, Rare species.
   ii. Species of high visual, historic or aesthetic appeal
   iii. Schedule I species
   iv. Migratory species
   v. Indicator species
   vi. Threats posed by animal species (for example, poisonous species, disease carrier, crop depredating species, etc.)
6. What natural habitats are present?
   i. Are any of the habitats suitable for threatened or economically important species?
   ii. Are any of the habitats important for wildlife productivity (for example sports of fish, tourism, educational, commercial, etc.)
7. Does the area serve as a corridor for migratory species?

8. Does the area serve as only breeding ground for a species occurring in the region?
9. What is the approximate valuation of the biological resources of the area?
10. What are the population estimates of the species of conservation importance?
11. What types of natural habitats will be destroyed by the project?
    i. Forest
    ii. Grass land
    iii. Wet land
    iv. Rock
    v. Desert
12. What are the sonic problems of the area in relation to wildlife? This factor is to be analysed in respect of present, construction and operational stages.

Assessment Of Environmental Impact

For ideal Environmental Impact Assessment complete knowledge about the ecological relationship is necessary, which is not attainable at the moment. Ecologists have developed considerable data on certain species and their habitats, but achievement of complete knowledge about most of the ecosystems particularly in developing countries will require much more time. However, it is possible to anticipate or predict ecological changes that will result from a project activities with certain degree of accuracy. Information obtained from the survey in and around the involved site before any alternations occur on, as well as, from the secondary sources, can judiciously be analyzed by a qualified investigator for a fairly accurate prediction about environmental impact. Predictions may be further tested by monitoring programme during both the construction and operational phases. By using common sense as well as professional knowledge about plant and animal life, their habitat requirement, ability of biotic community to withstand or respond disturbance, impending changes, and result from similar studies, an investigator can provide a suitable report on the significant impact in the following format (after Shukla and Srivastava 1992).

1. What are the possible negative impacts that might affect the biota of the area?
2. Which biotic habitats will be impacted?
3. Within each affected habitat, which species have biological significance?
4. Are individual specimens involved, and, if so, how they will be impacted?
    i. Do they have historic value?
    ii. Do they have aesthetic value?
    iii. Do they have scientific or educational value?
    iv. Do they have sport commercial value?
5. Will there be short term biotic impacts?
    i. Which species will be displaced from the site?
        a. Will they pose a problem to surrounding areas?

b. Will their displacement create ecological problems?

ii. Which species will be destroyed on site and what will be the ecological consequences?

iii. Which species may invade the disturbed site from adjacent areas?

6. Will there be long-term biotic impacts?

   i. What will be the effects of the loss of native plants and animals on the site and adjacent region?

   ii. What problems may result from the encroachment of weedy species?

   iii. To what extent diurnal and seasonal movement of animals will be disturbed?

   iv. To what extent food and water supply to biotic community will be affected?

   v. To what extent there will be loss of shelter, nesting and breeding ground?

   vi. What problem will result from the loss of fisheries?

   vii. What will be the consequences of the loss of threatened or otherwise significant species from the site?

   viii. What will be consequences of noise-air-water pollution resulting from the project activities.

7. What are all possible positive impacts that might occur as a result of the project?

   i. Will beneficial species be enhanced?

   ii. Can nature preserves be established?

   iii. Will the project reduce pressure on the adjoining forests?

Mitigating Measures

Advent of human civilization and population explosion demand development in various spheres, particularly in respect of shelter, transport, food and energy. Thus, developmental projects are unavoidable. In addition to the suggesting of alternative sites of lesser biotic importance for a project, it is the duty of the investigator to provide a complete listing and description of mitigating measures which will minimize the impact on the biota. From the suggested mitigating measures, project authorities become aware of biological parameters in formulating an approach to the project. A well-designed monitoring programme related to mitigating measures should also be provided in the report.

Arrangement of saving a particular species of plant or animal in the project area is mitigation, but saving a large area or restoring a habitat in which a number of species can function and survive harmonically would be a better mitigation. Biotic conditions of the developmental sites and impacts are different for different projects, varying in extension, intensity as well as quality. Thus, there can not be any uniform mitigating measures for all developmental projects. However, there are certain guidelines in this respect as discussed below.

Maintenance of sufficiently large area of wildlife habitats in and around the developmental site will in turn help in the retention of wildlife species. After the construction phase is over, in some cases wild life habitat may be restored. Establishment of water sources to an area enhances its biotic potential to a great extent. As trees are friends of environment as well as wildlife, maximum efforts are to be directed, as far as possible, for retention of them. Creation of new wildlife habitat by construction of small islands, rock spits in the large dams, plantation in the barren lands, etc., can compensate some amount of biotic loss. Threatened species of mammals, birds and other animals can be saved from destruction by translocation of a part of them to a suitable habitat prior to initiating the project activity, and some of them may be retranslocated after the completion of constructional phase if the situation permits.

It is obvious that large wildlife habitats are often cut into small isolated patches due to project activities. Wildlife diversity and future integrity become limited in these isolated patches. Linking of these patches, by incorporation of specimens plants into small groups as accessways, greenbelts, corridors, will provide great benefits to the wildlife. Construction of tunnels, overbridges, etc., between de-linked wildlife habitats, for exclusive use of animals is also an important mitigating measure.

Existing vegetation of the project site often contains specimens worthy of saving. Retention or re-establishment of those specimens not only helps in the conservation, but also provides elements of familiarity and original charm of the area. Investigator is to identify and mark the specimens for retention. Developmental authorities should take care that grading of the site is not so excessive as to cut away a considerable amount of soil from root areas, or cover the trunk with too much of fill dirt. Some specimens may be removed from the site during preparation and construction phases, and then returned to the site for replanting after completion of construction phase. For compensatory afforestation, suitable areas nearest to the project site to be selected. Many of the projects increase the rate of soil erosion and depletion in the area. Contour planting of crops on slops and hillsides, strip cropping (Planting alternating rows of soil-binding and no-soil binding crop in contour planting), trench or channel digging, etc. may be suggested for mitigating soil erosion and depletion. Regarding selection of plant species for plantation programme care should be taken for their ecological requirement, such as light, water, nutrient, pest *etc.*, as well as their economic aspects. It is always better to get the species list approved by an expert botanist.

Conclusion

We are at a crossroads in the history of human civilization. A road leads towards a chaotic future characterized by over exploitation and abuse of biological resources, while another towards the future safety and well-being of human beings by development along with proper impact assessment of developmental projects and mitigation of negative effects. However, from the foregoing account, it is obvious that huge amount of data collection is a must for proper Environmental Impact Assessment with reference to Wildlife. In the developing countries, base line data required for assessment are to be collected, in most cases, a new, from the proposed site by actual survey, collection and identification. This part of the assessment is the most expensive and time taking affair, and requires more a team effort than individual. Lack of technical facility, man-power and expertise are among the other hurdles of Environmental Impact Analysis. However, certain amount of baseline data on the forest, biota, climate, geology and also expertise are available with some state and central government departments of India as listed by Ghosh (1990). Consultation with these departments, prior to launching of the project and assessment study, will considerably cut down the time as well as expenditure in this regard.

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ENVIRONMENTAL IMPACT ASSESSMENT OF LAND FAUNA

A.K. HAZRA *

Introduction

The existence of man in this organic-cum-inorganic world is inextricably dependent on his capacity to utilise, wisely as well, the earth's resources; and what is most important in maintaining the congeniality and harmony of his living and non-living environment. This is the fundamental rationale of environmental or resource management. About one-fourth of the surface of the earth is occupied by the land. which in turn plays the major role in determining the type and distribution of biomes, the shape of soils, rocks and minerals even underground water. Therefore, the land has a rightful and dominant position in all developmental planning. But the ensuring ill effects of rapid non-planned industrialization, mis-directed agricultural practice and Man's greed for land. Man has forgotten the dictum of Sir Francis Bacon that, "Nature to be commanded, must first be obeyed."

The ways in which man treats his land and environment, produces and utilises and available non-living and living resources and plans his future needs and all socially determined. However, in order that these social decisions are made in such a way that the present and future generations will not have cause to regret them. The decisions should be made on the basis of available information on all environmental aspects. Thus, for example, if the compulsions of our country are to use all the available stock of non-renewable resources, say use of petroleum, at a particular rate of depletion, to know how long these resources are likely to last; what will be effect of this depletion on the environment; and what substitute materials are available to replace the same when resources are exhausted. Similarly, if the decision is to start mining operations or installation of an industry, it is essential to information on:

1. The limitation posed by terrain conditions, prevailing both at the surface and at interpretable depth.
2. The natural resources that can be optimally used for the proposed project.
3. The resources that will be rendered unusable by the processes that are related to industrialization.

The aim of this article is to assess the possibilities of environmental impact on land fauna due to the development, industrialization and mining operations.

Why Depletion of Land resources?

The simple answer for this is to improve the quality of life. The life quality can be represented by a simple equation by Krishnaswamy, 1981:

$$L = \frac{R \times E \times I}{P}$$

Where, L = Society's average level of living,

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R = Function of useful consumption of all kinds of raw materials (metals, non-metal, water, soil, biological products),
E = Consumption of all terms of Energy,
I = Political and Socio-economic as well as Scientific and Technological Ingenuity, and
P = Population.

From this equation let us see the level of average living standard of an Indian. We have high "I", but unfortunately, we also have high "P" and very low side in regard to factors "R" and "E", therefore our standard of living is very low.

The encroachment on land resources is thus very obvious and needs no further clarification.

The pattern of Land use in the World

The total land-area of the world is 148.9 million sq. km. of which only 19 million sq. km. are agricultural area thus giving only 13% of the whole land-mass as being suitable for agriculture.

Table 1

Pattern of Land use in the World (Krishnaswamy, 1980)

Country	Area in million sq. km.	Industrial area %	Agri-culture %	Grassland %	Forest land	Unfit for use (Snow cover, etc.) %
Russia	17.4	3	12	18	34	33
Canada	9.9	1	5	12	42	40
China	9.9	1	12	27	10	50
USA	9.5	5	18	23	32	22
Brazil	7.7	1	5	51	6	24
India	3.28	2	51	7	14	26.5
Argentina	2.7	1	12	40	34	13

From Table 1 it is clear that when India is compared with the developed nations like Russia and America there is high ratio of utilisation of the agricultural area to industrial area. In our case we have consumed most of the forest land for agricultural purposes, due to lack of proper land use pattern act in our country.

Utilisation of Land Resources

Land use in India vis-à-vis World: The following table (Table 2) shows the per capita consumption of metals in the USA which when compared to that of India is 54 times in aluminium 69 times in copper, 90 times in lead, 37 times in zinc, 92 times in tin and 48 times in steel.

Table 2

Per capita consumption (in kg) of some important metals by some countries including India (Krishnaswamy, 1981)						
Country	**Aluminium**	**Copper**	**Lead**	**Zinc**	**Tin**	**Steel**
India	0.50	0.013	0.070	0.159	0.088	14
Argentina	1.16	1.073	1.610	1.102	0.076	160
Brazil	0.90	0.512	0.361	0.482	0.042	77
Mexico	0.53	0.969	1.451	0.312	0.034	78
U.K.	6.83	9.646	4.990	4.959	8.315	361
U.S.A	17.25	8.95	5.431	5.90	8.288	671

The production of base metals and future running targets in India

Concomitant with the requirements of growth the targets for the mining of important commodities like coal, steel, cement have been fixed and it is expected that output will be double by 1997-98 (Table 3).

Table 3

Approximate production of base metals (in tonnes) (Krishnaswamy, 1981)				
Metal	**1978-79**	**1988-89**	**1998-99**	**After 2000 AD**
Copper	24,400	70,900	1,00,000	2,50,000 to 30,00,000
Zinc	30,900	90,200	1,10,000	Over 2,50,000
Lead	10,200	42,000	60,000	Over 1,15,000

Table 4 shows the projected extraction of over for these metals. It is evident that the rate of land depletion will increase with the increase rate of extraction of ores.

Table 4

Rate of Land depletion due to extraction of ores (base metals) (Krishnaswamy, 1981)			
Ore	**Ore Reserves 1975 estimate (m. tonnes)**	**Anticipated 1978-79 to 1981-82 (m. tonnes)**	**Depletion up to 2000 AD (m. tonnes)**
Copper	417	18	220 to 250
Zinc	210	5	40 to 50
Lead	210	3.1	50 to 70

The development of the mining industry in our country, so as to meet growing demands for minerals alone as listed above emphasises the need to ensure the land environment is not adversely affected by such large scale intensified production from land resources. As most mineral resources are non-renewable, the mineral deposits, once these are removed, are depleted for ever. Also, a large proportion of solid mineral resources are used consumptively and end up in waste dumps.

The living natural resources in India

The geographical position in India is unique with major ecosystems on the land e.g. high mountain, tropical rain forests, desert, mangroves, islands etc. which provide characteristic climate and habitat conditions for development of faunal as well floral resources. India had given many valuable plants and animal genes to the world. Besides, about 15,000 flowering plant species, we have 372 species of mammals; 2,175 species of birds, 399 species of reptiles, 181 species of Amphibians, 60,000 species of insects and also Fishes and Molluscs of about 6,693 species. Besides according Ghosh (1989), there is vast unexplored potentiality of array of wild genetic resources in the Himalayas, Western Ghats, Eastern Ghats, North-eastern India and Andaman & Nicobar Islands. A large quantum of living natural resources are directly dependent on soil ecosystems or on the vegetation cover which in turn are land-bound. For this reason, the environmental impact assessment to determine the possible effects of developmental projects on ecology and wild life has now become mandatory and soil systems form an important component of such study.

Impact evaluation on land fauna

Above ground: As stated earlier, India has representative of all major ecosystems within its territorial limits. This habitat productivity is a determinant factor of species diversity and number of individuals in that ecosystem, according to Connel and Orias (1964), high productivity results in high species diversity. Stable environment economics on energy by reducing losses and storing it up in the form of living materials. This enables most species to produce large population. The following table shows productivity in some ecosystems (Ananthakrishnan, 1976).

Table 5

Estimate of Annual net productivity in some ecosystem

	Type of Ecosystem	Climate	Productivity (Kcal/mm/Yr.)
1.	Desert	arid	400 + 200
2.	Forest		
	Deciduous	temperate	4,800 ± 1,200
	Coniferous	temperate	11,200 ± 2,800
	Rain forest	tropical	22,000 ± 4,000
3.	Mangroves	tropical	30,000 ± 4,500

From Table 5 we can initially estimate the primary probable impact on fauna if the project comes under any of those ecosystems.

Underground (Biotic resources of the soil): The health of a fertile soil has been standardised with the following faunal groups (Table 6). These animal groups help in soil aeration through release of oxygen, besides acting as decomposing agents and also serving as food for other soil organisms.

Table 6

Standardised faunal abundance of a healthy soil (Tropical forest floor	
Group	**Abundance**
Protozoa	5,00,000/gm of soil
Nematodes	20,000,000/sq.m.
Molluscs	50,000/acre
Myriapods	10,00,000/acre
Annelids	1000,000/acre
Arthropods	10,00,000/acre
After: Southwick; 1976	

In India the following standard to mesofaunal abundance have been estimated in different ecosystems in some regions of the country (Table 7).

Table 7

Population size of mesofaunal groups in deciduous forest ecosystems of some parts of India (100/m2)					
Region	**Earthworm**	**Symphyla**	**Collembola**	**Acarina**	**Source**
South India	2	1.6	24	46	Prabhoo, 1976
North India	2.6	1	27	51	Singh, 1981
Eastern India	2.1	1	25.5	33	Hazra & Choudhuri, 1986
N.E. India	1.5	2.1	29.8	41.5	Darlong, Alfred, 1988
Himalayas	4	3	68	72	Singh *et al.* 1983.

Faunal Impact Assessment Procedure on Land

At least three observations are to be made in three different seasons (monsoon, winter, summer), and two factors are to be considered in the proposed project areas and some adjoining areas.

A. Abiotic/Physical factors.

Above ground

i. Temperature

ii. Rainfall

iii. Humidity

Under ground (soil)

i. Organic matter
ii. C:N ratio
iii. Phosphate
iv. Nitrate
v. pH
vi. Water holding capacity etc.

B. Biotic (Faunal factors)

Estimation of species diversity and approximate number of individuals:

Above ground for land-based fauna

i. Mammals
ii. Birds
iii. Reptiles
iv. Amphibia
v. Fishes (if streams present)
vi. Insects

Underground land fauna

i. Micro and Macro-orthropod fauna
ii. Earthworms
iii. Molluscs (Land)

How to collect base line faunal data in the Field: (Soil, land-based, aquatic)

Animal group	Procedure
i) Mammals	*Direct method for Big mammals*: Continuous visual observation by employing standard method during day and night. Searching pug-marks, collecting droppings, hair on the migratory route of wild animals in the forest. By hearing sound, sometimes by smell of the animal.
	Small mammals: Can be collected by using traps or nets.
	Indirect methods: By making queries from local people and also by previously published record in that locality if available.
ii) Birds	*Direct method*: By watching with a binocular by the experts, by using a mist net; by using ultrasonographic method.
	Indirect methods: By making queries from local people; from previously published record
iii) Reptiles and Amphibia	Visual observations by knowing their exact habitat or by catching them and also by making queries from local people and also from the previously published record.
iv) Fishes	By using water net, also by searching to the local fish market and also from previously published record.
v) Insects	Collecting by means of insects net, by beating bushes, by searching under rocks and barks of trees. Also from the previously published literature.
vi) Soil fauna	By dividing the forest floor in quadrates then soil samples were drawn randomly by means of soil samples from each quadrates (at least 5 units). The soil cores are taken kept on soil extraction apparatus from 72 hours.

The analysis of species diversity

There are many indices for measurement of species diversity of a particular area. The widely adopted is the log series (Fisher, Corbet and Williams, 1943). The hypothetical total number of species of a habitat is the species equilibrium (ST). During the course of a survey the relationship between cumulative sample of individuals (E) and the number of species (ES) is variable depending on sample size (Southwood, 1978). The log numbers of individual of each species is plotted against the same rank (species sequence) to get a plot that will approximate to a straight line. The index of diversity is therefore, represented as: $ST = \alpha \log (1+N/\alpha)$. Here the relationship between species number and abundance of individuals (N) has two features: i. Species richness: the total number of species present in the (ST), ii. equability or evenness: Pattern of distribution of individuals between species (e.g. – 100 individuals may represent 10 species of 10 individuals each (equitable) or 91 of one (dominant) and one of each of other 9 species). By comparing indices such as this, we can differentiate the habitats where environmental changes have taken place. If the data do not fall in a straight line, there has been some departure from normalcy and the species which have caused this, also could be identified.

Identification of all the faunal groups obtained from the proposed area

According to Ghosh (1990), "The entire foundation for such study of biodiversity invariably is based on taxonomy and systematic. The environmental impact assessment study requires comprehensive knowledge of taxonomy related to all animals and species that the scientists reporting on the proposed site must indicate as to whether the area harbours any rare or endangered species, or whether it supports such biodiversity which should be given a shelter under wildlife sanctuary. Ecological conditions underling the basic concept of animal diversity including biology and other phenomenon like annual migration etc. The impact assessment study, therefore, also demands information on possible migration route of terrestrial animals (elephants, birds and fishes). As such the entire exercise needs a serious scientific study by competent taxonomists and biologists."

Conclusion

It is clear from the above discussion that for the developmental projects particularly in the mining sector, the most mineral resources are not-renewable. The mineral deposits, once removed, are depleted for ever. Therefore, beside the deferment of land by large scale excavation, pollution through waste mineral dumps is an important aspect of mining activity to be considered, open pit operation involved stripping at large volumes of overburden, which must, of necessity be deposited near by. Underground working also produce large quantities of waste rock. This has to be solved in a scientific way. At first the topsoil has to be stripped and kept aside and the waste rock-overburden obtained thereafter, has to be suitably laid out in patterns that merged with the environment and covered later with the top soil that has been set aside earlier, for growing vegetation on waste rock piles. This may be a somewhat costly affair, but for the sake of the protection of land environment the project proponents have to bear it. The disposal of the said wastes obtained during mining operations also presents unique problems requiring unique solutions. The pollution of the surface and groundwater systems from such waste disposal has to be carefully considered in advance and guarded against.

At the end the biological resources on land provide values which are not immediately seen or even felt but which nevertheless have far reaching impact on our living conditions. Above all the greatest value of the biological resources is in being an insurance against any unforeseen, unwanted future, in helping us to adopt to the changing local and global conditions and in providing us options in the future to develop new important products and processes in agriculture, medicine and industry (WII, 1993).

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IMPACT OF LAND DEGRADATION AND POLLUTION ON SOIL BIOTA AN ASSESSMENT

A.K. SANYAL*

Introduction

Land is a living system with its self-replenishing property which is largely accomplished by myriads of soil fauna and micro flora. The healthy soil must have pore space where water and air can circulate and there must be sufficient nutrients. Soil animals burrow in soil, produce a system of pore space and bring material rich in mineral nutrients. Soil animals and micro flora also contribute to the chemical properties of soil through the process of decomposition of organic refuse.

Soil As a Living System

The soil is an unequivocal dynamic system. It is the abode of animals from protozoans to mammals. All the animals, which live regularly in soil, are termed as 'soil animals' irrespective of their contribution in the soil forming process. About 95 per cent of the soil animals is occasional visitor in soil for temporary shelter, food and breeding. The groups of major soil animals which are generally found in soil are protozoans, molluscs, annelids, helminths, arthropods, amphibians, reptiles, birds and mammals. Of these the dominant group in respect of number is arthropod whose number may reach up to 2,500,000 per hectare in mature soil. The quantity and diversity of fauna in soil depend upon various factors such as soil porosity, temperature, moisture, pH, nutrients, vegetation, etc. In soils which are low in nutrients animal population is less in comparison to the soils rich in nutrients.

Land Pollution and Degradation

All the activities of man are land based. Some of these activities generate pollutants and pollute the land. The important factors of land pollution are discussed below.

Solid waste disposal:

(a) **Municipal waste:** In advanced countries and also in the metropolitan cities in India, refuse creates an acute environmental problem. The quantity of refuse produced per year in urban areas in India amounts to about 2 million tonnes. The studies in Calcutta have shown that this quantity is increasing at 1.5 per cent per year. Removal of garbage costs several crore of rupees and composting is also rare. So the garbage is usually left lying in the open and cause unwanted occupation of land. The toxic material is also absorbed into the soil and kills soil inhabiting plants and animals. It also contaminates the surface as well as ground water. The refuse dump provides breeding ground for rats, flies and other disease carriers. It is also a source of poisonous gases which pollute air.

(b) **Industrial waste:** The industrial waste containing toxic chemicals and heavy

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metals are in most cases dumped on land. The Sulphur dioxide and pulverized fly ash containing many heavy metals (Table 1), including arsenic, cadmium, chromium, mercury, lead, manganese, vanadium, fluorine and beryllium and other particulate matters are released from thermal power plants. Also the industrial and automobile emissions contain hydrocarbons, suspended particulate matters and metallic traces. All these toxic material settle on land and pollute it. The result is the disturbance in the biological activity in soil and ultimately the land becomes unproductive.

Table 1

Heavy Metal Contents in Sludges (ppm)		
Metal	**Median (ppm)**	**Range (ppm)**
Cd		60 - 1500
Co	12	2 - 260
Cr	250	40 - 8800
Cu	800	200 - 8000
Fe	2100	6000 - 62000
Mn	400	150 - 2500
Mo	5	2 - 30
Ni	80	20 - 5300
Pb	700	120 - 3000
An	120	40 - 700
Zn	3000	700 - 49000

The flooding of the land by industrial waste water containing unwanted chemicals and metals adversely affect the physiochemical properties of soil by killing the soil fauna and flora.

Agricultural practices:

(a) Unskilled Irrigation: Irrigation is certainly an essential practice in agriculture. But unskilled irrigation can cause serious problems like waterlogging and salination.

(i) Waterlogging – The canal water applied in the field is often far in excess of need. Due to lack of adequate drainage system the excess water is often logged in the field. Further, the canals and distributaries are usually not properly lined and they contribute to water logging through seepage. This results in rising up of water table up to or above the land surface and water stands for most of the year.

In waterlogged land the pore space is filled with water and does not have enough air in it. Without the circulation of air, the oxygen level in the soil falls and carbon dioxide increases. The crops cannot grow on that land and the animals cannot survive there. It can be said that waterlogging turns healthy land into wet desert. The present estimate of water logging land in India is about 8.48 million hectares.

(ii) Sewage irrigation – Sewage irrigation deteriorates soils by reduction of pore space as a result of clogging by colloids in the sewage. This may result in the reduction of permeability and impediment to drainage. As a result of repeated applications of sludge over a long period caused accumulation of heavy metals in soils.

(iii) Salination – All water including rain water and underground water, contain dissolved salts mainly chlorides, sulphates and bicarbonates of calcium, sodium and magnesium. The lands brought under irrigation projects are affected by increased salinity because of the rising ground water table. Similarly in coastal areas the salinity of land is high due to periodic flooding and seepage of salt water. When the salt content exceeds 2,000-3,000 ppm the water becomes toxic for most plants. Too much salt reduces the plant's capacity to absorb water.

The salt-affected land is either saline or alkaline in nature. Saline land contains sufficient soluble salts mainly sodium chloride and sodium sulphate. The saline soils are distributed throughout India and estimated at 5.5 million hectares. The land which contains excessive amount of sodium carbonate and sodium bicarbonate is called alkaline or sodic land. The soil is dense, compact and often with hard layer of calcium carbonate. In this hard soil plant roots can not grow and absorb nutrients. The alkaline soils are found mainly in the Indo-Gangetic plains and estimated at 3.85 million hectares.

(b) Use of chemical fertilizers: The recent studies show that some 7 million tonnes of N,P and K are used per year in India. The extensive use of chemical fertilizers is dangerous for the fertility of soils in long term. It particularly causes nitrate toxicity in soil which ultimately kills the fauna and micro flora and pollute the ground water and water bodies. This fertilizers also contain heavy metals (Table 2).

Table 2

Heavy Metal Content (gg-1) of Fertilisers								
Fertilizer	**Co**	**Cr**	**Cu**	**Mn**	**Mo**	**Ni**	**Pb**	**Zn**
Nitrochalk	0	0	22	24	–	2	–	15
Calcium Nitrate	0.1	–	10	5	–	–	–	1
Ammonium Sulphate	<5	<5	0-800	0-80	<0.05-0.22	<5	200	0-800
Superphosphate	0.02-13	0-1000	1000	2842	35	32	92	70-3000
Potassium Chloride	1	–	0-10	8	<0.05-0.5	<1	<1	0-3
Potassium Sulphate	<5	<5	0-300	80	0.09-33	<5	<50	<50
Farmyard manure	0.03-6	–	0.2-62	11-650	0.20-15.8	11	–	4-360

(c) Use of pesticides: The discovery of toxic chemicals for management of animals and plant pests is certainly a blessing to farmers. But it is now being realized that the toxic chemicals or pesticides have some undesirable side effects and cause environmental pollution. Large amounts of pesticides reach the soil, either as direct application, from fall out from aerial spraying, in rain or dust or from plant or animal remains which become incorporated with the soil. Thus soil acts as a reservoir for these toxic residues from which they move into the atmosphere, water or living organisms.

Of the 1000 pesticides which are in use in the world only nearly 250 are used in agriculture. The most common pesticide residues are either persistent inorganic chemicals, such as arsenic, copper or lead or persistent organochlorine insecticides (Table 3). Among the pesticides normally used those which belong to the organochlorine group such as D.D.T., aldrin, dieldrin have attracted much attention and invited severe criticism for their adverse effects on soil.

Table 3

Persistence Time for some selected pesticides	
Pesticide	**Persistence time**
BHC	11 Yrs.
DDT	10 Yrs
Aldrin	9 Yrs.
Diuron	16 months
Atrazine	18 months
Simazine	17 months
Chlordane	12 months
2,3,6-Trichlorobenzene (TBA)	2-5 Yrs.

Persistent insecticides in soil or forest litter may have a variety of adverse effects on soil fauna and flora as follows.

1. Serious disturbance of microbial activity in soil, affecting the soil fertility adversely.
2. Harmful effects due to killing of beneficial soil organisms such as predatory mites, centipedes and carabid beetles that prey on pests, and the myriads of invertebrates particularly earthworms, enchytraeid worms, collembola, diptera larvae and some acarina. All of these contribute to the breakdown of dead plant and animal organic matter, and thus ultimately increase the soil fertility.
3. Sufficient entry of toxic material into the systems of birds and mammals through the food chain may acquire a lethal dose.
4. Sub-lethal effects on soil invertebrates through alteration of reproductive potential, behaviour and feeding habit.
5. The organochlorine insecticide residues seriously affect the growth of the crop.

The copper- and mercury-based fungicides have high toxicity and tend to remain in the soil. In higher concentrations they can sterilise the soil and reduce the biological activity in the soil. Herbicides have high residual toxicity. So repeated application of herbicides results in harmful effects on soil fauna and flora.

(d) **Shifting cultivation:** It is a traditional and popular method of cultivation in north eastern India. It is also practiced in the tribal areas throughout the country particularly in some parts of Orissa, Madhya Pradesh, Kerala and Andhra Pradesh. It is known as Jhum in Assam, Dahya in Madhya Pradesh and Podu in Orissa. Outside India e.g., in northern Myanmar, Sumatra, Borneo, New Guinea and the African continent similar cultivation practices are also known.

In this method of cultivation the forest is slashed and burnt. It adds to the mineral content of the soil, but it reduces the humus content in the soil. As a result the water holding capacity of the soil is lost and the biological activity is stopped. The productivity of the forest soils become poor and the shifting cultivators move on to a fresh patch of forest. The resulting exposure of the bare soil to rains and wind causes enormous soil loss through erosion, especially on hill slopes. After a few such cycle of cultivation on a particular hill slopes, the land is ultimately converted into a barren field. The recent figures show that over 4.35 million hectares of land are under the practice of shifting cultivation in India.

(e) **Over cultivation:** Intensive cropping removes the most important micro nutrient elements like zinc, iron, copper, manganese, magnesium, molybdenum, boron. These form only one percent of the weight of a plant but control various aspects of a plant's process.

Deforestation: The felling of trees causes less accumulation of organic matter. Due to absence of organic content, the soil loses its water-holding capacity and the soil organisms die. The other most important and adverse effect of deforestation is loss of nutrient rich top soil due to erosion.

Soil Erosion: Soil erosion is a natural and normal process, through which the earth's crust is constantly and gradually eroding away under the forces of weathering. This is geological or normal erosion and is extremely slow. But when human activities accelerate the disappearance of protective cover of natural vegetation and cause soil erosion, it is then called as accelerated or artificial erosion. The loss of top layers of soil through erosion turns the land infertile, unproductive and wasted.

The most important types of erosion are gully and ravine erosion. When rain fall on land without stable vegetation cover, the rain drops mixed with silt flow down the slope and give rise to rills having maximum depth of 3 metres. These steep slopes and undulating terrain are gullied land. The gullies are the first step of land dissection. They gradually become bigger and lead to the formation of ravines. So the ravines are the deep gorge containing systems of running gullies parallel to each other. The soil in the ravenous land is continuously eroded due to rainfall and the land becomes more deep. In India the growth of ravine is estimated to be 0.5 percent annually and total loss of land is nearly 8,000 hectares to ravines every year. Four million hectares of land in India have already been transformed into ravines. The top soil is also removed and flown away by wind.

An estimate in 1972 shows that the amount of soil lost due to erosion contained nutrients priced at Rs. 700 crore in that year in India. It is also known from another report that total amount of soil washed away in India in every six months was higher than the amount of soil required to build brick houses during the period in the country.

Deforestation and overgrazing are the most important factors of soil erosion. Due to absence of stable vegetation cover on the land the soil becomes loose resulting in erosion of surface layers. Besides loss of nutrient rich top soil and/or formation of unproductive gullied and ravenous lands the large quantities of soil washed or flown away are deposited in tanks, reservoirs, streams and river beds and reduce their water holding capacity, resulting in heavy floods.

Overgrazing: India with just a fortieth of the total land area of the world supports more than half of its buffaloes, 15 percent of its cattle, 15 percent of its goats and 4 percent of its sheep. This large number of livestock is the source of fuel, power, nutrition and raw material for industries. But these animals are underfed and malnourished as the fodder needed is not enough. Only about 13 million hectares in the country are recorded as permanent grazing lands. This amount is sufficiently less in comparison to the demand. The result is over grazing on fallow, uncultivated and forest lands. The absence of ground vegetation causes soil erosion, gradual depletion of soil organisms and ultimately the land is transformed into wastelands.

Mining: Mining causes land pollution both directly and indirectly. There are two methods of mining such as open cast mining and underground mining.

(a) **Open-cast mining:** This method follows complete removal of top soil and other strata, called overburden, for excavation and lifting of material. The result is the destruction of the whole land area, with large void and scars and loss of productive area.

(b) **Underground mining:** In this method the mineral is directly mined by making access to it through tunnel. The roof of the underground passages is supported by timber and pillars of ore. When the mine is abandoned the timbers are removed and depillaring is done. This leads to subsidence of land, making the whole area a big depression and it becomes wasteland.

In both the mining operations the ore is deposited at site adjacent to the mine. It causes unwanted occupation of land. Further, the mining waste dumped on the land are washed out to the adjoining agricultural fields and pasture. The debris blocks drainage channels resulting in waterlogging. The waste material often hardens on drying turning the fields infertile. Much of the mining activity is carried out in forested area. Mining operation needs deforestation and the obvious result is land degradation followed by erosion. Unless proper measurers are taken, mining activities in hilly areas cause landslides.

The loss of agricultural land due to mining of building sand and brick clay is serious menace in India and other countries. Valuable agricultural lands have already been wasted in Mogra-Pandua belt of Hooghly district, West Bengal for mining of building sand. Use of agricultural land for brick fields is also universal. Bricks made of nearly 120 tonnes of soil are needed to build a modest house of five members. So for 156 million of urban population in India nearly 300 million tonnes of soil, mostly top soil, would have to be excavated.

Radioactive fallout: The explosion of a nuclear bomb releases nuclear elements which become attached to tiny particles of dust. Eventually, the contaminated dust falls on earth, often in rain or snow. These deadly products pollute soil to a great extent. It considerably reduces the productivity of the soil through eradication of microfauna and micro flora. It also affects the higher plants and animals including man.

Assessment of Environmental Impact on Soil Biota

The land is continuously being polluted resulting in significant depletion of soil fauna and flora. These biotic components actively participate in formation of healthy soil, their absence inhabits this process and ultimately changes the healthy land into wastelands. It is therefore, necessary to make an assessment of probable environmental changes and its impact on soil biota before and after the establishment of any developmental project.

In order to determine the coverage of EIA process it is necessary to clarify what is meant by 'significant impact on the environment'

Type of impact to be covered: For the purpose of EIA, the environment is usually given a broad, but not all-encompassing, definition, it includes:

(a) **Receiving environmental media:** Changes in the quantity of land available for different purposes and in the quality of land (*e.g.*, through changes in the quality of landscape, the propensity to soil erosion, the level of chemical residues in the soil).

(b) **Living receptors:** Changes in the damage levels to fauna and flora and natural ecosystems with consequential effects on species diversity and abundance.

Assessment methods: Although the assessment methods are numerous and diverse, for the most part they are not unique to the EIA process. They originate as tools of analysis developed within a wide range of disciplines. The major elements in the process are identification, measurement, interpretation and communication of impacts (Table 4). The measurement techniques vary, interpretations vary on the basis of their nature of impact, i.e. either adverse or beneficial. So a number of methods have been developed of which the ad-hock methods, network method, impact check-list and impact matrices are commonly used for assessment of impact on ecology and biology. The method is based on ecological survey with the following steps.

i) Analysis of previous physico-chemical data of land and soil biological components.
ii) Assessment of physical and chemical properties of the land.
iii) Assessment of all possible pollutants in the soil.
iv) Quantitative and qualitative assessment of biotic components in the soil.
v) Study on correlation between the soil biota and edaphic factors *viz.*, temperature, moisture, pH, salinity, porosity, water holding capacity, micro-organisms, vegetation, organic carbon, phosphate, nitrate, heavy metals and other organic and inorganic pollutants, etc.
vi) Assessment of biota in respect of their endemism and conservation measures already in operation.

Table 4

A Classification of Assessment Methods By Task	
Identification methods	to assist in identifying the project alternatives, project characteristics and environmental parameters to be investigated in the assessment.
Data assembly methods	to assist in describing the characteristics of the development and of the environment that may be affected.
Predictive methods	to predict the magnitude of the impacts which the development is likely to have on the environment.
Evaluation methods	to assess the significance of the impacts which the development will have on the environment.
Communication methods	to assist in consultation and public participation, and in expressing the findings of the study in the form suitable for decision-making purposes.
Management methods	to assist in managing the scope of the study, the preparation of the impact study, the efficient conduct of the consultation process, etc.
Decision-making methods	to assist decision-makers in assessing and understanding the significance of environmental impacts relative to other factors relevant to a decision on the proposed development.

Preparation of the EIA study: It is a mandatory requirement of any formal EIA system that an EIA study be prepared for submission as a written report (often called an Environmental Impact Statement or EIS) in support of the developer's application for authorization of his chosen project.

The structure of the written report should reflect the key environmental issues associated with the particular project under consideration and therefore there is no standardized format to which all EIA reports should closely adhere. However, in order to conform with the provisions of the EIA directive, it is likely that the report related to impact on soil biota need to cover the following items

(a) A description of the main features of the chosen project which may cause significant impacts on soil fauna and flora, including estimates of the residues and wastes it may create.

(b) A description of the base-line condition of those aspects under consideration.

(c) An assessment of the likely significant impacts of the chosen project on the aspects under study.

(d) A description of any ameliorating measures which are proposed (of which have already been incorporated into the project design) to reduce the potentially harmful effects of the project on the environment, particularly the soil fauna and flora.

(e) A non-technical summary of the total assessment.

Conclusion

The foregoing discussion indicates two approaches of which one emphasizes that the soil is a biological system with myriads of faunal elements responsible for maintaining the intricate bioeoclogical system in nature. The other approach advocates the fact that the soil is continuously being degraded due to adverse effects of pollutants generated from different developmental projects. Thus there is a continuous conflict between the developmental process and biological characteristics of soil. However, this could easily be minimized through judicious and rational utilization of land by means of various methods of which EIA is one.

The notification issued by the Ministry of Environment and Forests, Government of India in January, 1994 (as amended in May, 1994) makes EIA statutory for different identified developmental projects and related activities. For obtaining environmental clearance of the projects the Government, Public Sector undertakings and Private organizations are now approaching the Zoological Survey of India for long studies on faunal diversity and possible impact of environment on faunal resources in the project site. In these studies the scientists are paying special attention to soil fauna and many such studies have already been completed.

Suggested Readings

1. CHAUDHURI, A.B. 1992. Environmental Impact Assessment. *In:* Mine Environment and Management (An Indian Scenario), Ashish Publishing House, New Delhi, pp. 158-188.

2. SANYAL, A.K. 1989. Land pollution. *In:* Environmental Awareness and Wildlife Conservation (eds. A.K. Ghosh, J.K. Jonathan & P.P. Kulkarni), Zoological Survey of India, pp. 47-58.

ENVIRONMENTAL IMPACT ASSESSMENT ON WETLAND ECOSYSTEMS

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Introduction

India is a nation of extraordinary diversity, the second largest in Asia and the seventh largest and second populous country on Earth. It is the giant of the Indian subcontinent which comprises fully one third of Asia. India supports one-seventh of humanity and this population is continuing to increase at an astonishing rate. The demands of these 850 million people, the vast majority of whom, being agriculturists, are concentrated in the same areas as India's principal wetlands, place incredible pressure on the nation's natural resources; the survival of the sites depends upon the attitudes and awareness of these people.

Wetlands may be defined as a diverse assemblage of wet and watery habitats. It includes a wide range of inland, coastal and marine habitats which share a number of common features of both aquatic and terrestrial ecosystems: Even though the global attention is increasingly focused on the wetland ecosystems, there is yet no single, universally accepted definition of a wetland.

Definition of wetlands

Wetlands have been defined by more than fifty different ways to include a wide spectrum of habitats, The 1971 Convention defines wetland as

> "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas marine water the depth of which at low tide does not exceed six metres."

The above IUCN definition, however, fails to specify parameters in case of inland waters. To classify these inland water bodies the following definition of Cowardin *et al.* (1979) of US Fish and Wildlife Service is useful.

> "The wetlands are lands transitional between terrestrial and aquatic systems where water table is usually at or near the surface or the land is covered by shallow water"

According to US Fish and Wildlife Service, wetlands should have the following three attributes:

1. An area which is permanently or periodically inundated for at least seven successive days during growing season.
2. An area which supports hydrophytic vegetation at least for some part of the year.
3. An area which has predominantly hydric soils that are saturated for a sufficiently long period to become anaerobic (lacking in oxygen) in their upper layers.

Classification of Wetlands

There is a wide range of classification for wetlands. The classification made by Scott

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(1989), modified by Dugan (1990) and adopted as the Ramsar classification is presented below in Table 1:

Table 1

Wetland Classification		
1. Salt Water		
1.1 Marine	*1. Subtidal*	i) Permanent unvegetated shallow waters less than 6m depth at low tide including sea bays, straits.
		ii) Subtidal aquatic vegetation, including kelp beds, sea grasses, tropical marine meadows.
		iii) coral reefs
	2. Intertidal	i) Rocky marine shores, including cliffs and rocky shores.
		ii) Shores of mobile stones and shingle.
		iii) Intertidal mobile unvegetated mud, sand or salt flats.
		iv) Intertidal vegetated sediments, including salt marshes and mangroves, on sheltered coasts.
1.2 Estuarine	*1. Subtidal*	i) Estuarine waters; permanent waters of estuaries and estuarine systems of deltas.
	2. Intertidal	i) Intertidal mud, sand or salt flats, with limited vegetation.
		ii) Intertidal marshes, including salt-marshes, salt meadows, saltings, raised salt marshes, tidal brackish and freshwater marshes.
		iii) Intertidal forested wetlands, including mangrove swamp, nipa swamp, tidal freshwater swamp forest.
1.3 Lagoonar		i) Brackish to saline lagoons with one or more relatively narrow connections with the sea.
1.4 Salt lake		Permanent and seasonal, brackish, saline or alkaline lakes, flats and marshes.
2. Freshwater		
2.1 Riverine	*Perennial*	i) Permanent rivers and streams, including waterfalls.
		ii) Inland deltas.
	Temporary	i) Seasonal and irregular rivers and streams.
		ii) Riverine flood plains, including river flats, flooded river basins, seasonally flooded grassland.
2.2 Lascustrine	*Permanent*	i) Permanent freshwater lakes (>8 ha), including shores subject to seasonal or irregular inundation.
		ii) Permanent freshwater ponds (>8 ha).
	Seasonal	i) Seasonal freshwater lakes (>8 ha), including flood plain lakes.

Table 1 *(contd.)*

Wetland Classification		
2.3 Palustrine	*Emergent*	i) Permanent freshwater marshes and swamps on inorganic soil, with emergent vegetation whose bases lie below the water table for at least most of the growing season.
		ii) Permanent peat-forming freshwater swamps, including tropical upland valley swamps dominated by Papyrus or Typha.
		iii) Seasonal freshwater marshes on inorganic soil, including sloughs, potholes, seasonally flooded meadows, sedge marshes and dambos.
		iv) Peat lands, including acidophilous, ombrogenous, or soligenous mires covered by moss, herbs or dwarf shrub vegetation, and fens of all types.
		v) Alpine and polar wetlands including seasonally flooded meadows moistened by temporary waters from snowmelt.
		vi) Freshwater springs and oases with surrounding vegetation
		vii) Volcanic fumaroles continually moistened by emerging and condensing water vapour.
	Forested	i) Shrub swamps, including shrub-dominated freshwater marsh, shrub carr and thickets, on inorganic soils.
		ii) Freshwater swamp forest, including seasonally flooded forest, wooded swamps on inorganic soils.
		iii) Forested peat lands, including peat swamp forest.
3. Man-Made Wetlands		
3.1 Aquaculture/Mariculture		i) Aquaculture ponds, including fish ponds and shrimp ponds.
3.2 Agriculture		i) Ponds, including farm ponds, stock ponds, small tanks.
		ii) Irrigated land and irrigation channels, including rice fields, canals and ditches.
3.3 Salt Exploitation		i) Salt pans and salines.
3.4 Urban/Industrial		i) Excavations, including gravel pits, borrow pits and mining pools.
		Wastewater treatment areas, including sewage farms, settling ponds and oxidation basins.
3.5 Water-storage areas		i) Reservoirs holding water for irrigation and/or human consumption with a pattern of gradual, seasonal, draw down of water level.
		ii) Hydro-dams with regular fluctuations in water level on a weekly or monthly basis

Source: Dugan (1990)

The wetlands of India are frequently divided by region into eight basic categories:

1. the tanks and reservoirs of the Deccan plateau together with the lagoons and other remaining wetlands of the West coast of the peninsula;
2. the vast saline expanses of Rajasthan, Gujarat and Gulf of Kutch;
3. the freshwater lake and reservoirs from Gujarat eastwards through Rajasthan and Madhya Pradesh;
4. the deltaic wetlands and lagoons of India's east coast;
5. the marshes, jheels, terai swamps and charlands of the Gangetic Plain;
6. the flood plain of the Brahmaputra and the marshes and swamps in the hills of Northeast India and the Himalayan foothills;
7. the lakes and rivers of the montane (primarily Palaearctic) region of Kashmir and Ladakh;
8. the wetlands (primarily mangrove association) of India's island area.

Recent estimates of the total area of wetlands in India

Area under paddy cultivation		40,990,000 ha
Area suitable for fish culture		
(a) Freshwater	1,600,000 ha.	
(b) Brackish water	2,000,000 ha.	3,600,000 ha.
Area of captive fisheries		2,900,000 ha.
Mangroves		356,000 ha.
Estuaries		3,900,000 ha.
Man-made impoundments		3,000,000 ha.
Rivers including tributaries	28,000 km.	
Canals and irrigation channels	113,000 km.	
Total area of wetlands (excluding rivers)		58,286,000 ha.

Environmental Impact Assessment: A process which involves the systematic evaluation of all the significant effects and action is likely to have upon the environment before the decision to take the action is made. The process should also suggest mitigating measures if the proposed action is likely to have and adverse impact on the environment.

Wetland benefits: Commonly known in literature as function, uses, values and attributes, features, goods or services, they are defined as any of these terms which may have a value to people, wildlife, natural systems or natural processes (Claridge, 1991).

Assessment approach: The environmental impact assessment (EIA) study on wetlands involves multi-disciplinary expertise in identifying, evaluating and interpreting the potential impact. It will help in understanding the physical and ecological effects on social, cultural and aesthetic concerns. The purpose of such study is to evaluate the beneficial and adverse effect (Tables 2-4; *see pp. 274-276*) of the proposed development project on the wetland which could be integrated with economic analysis of the project costs and benefits. Thus, EIA study on wetland must include the following five elements:

1.	Existing environment	A description of the existing environment with special reference to aquatic life in the proposed project area.
2.	Environment impact	A description of the future impact on environment (wetland) as a result of the completion and use of the proposed project.
3.	Mitigating measures	A description of the measures that are to be implemented to reduce degradation of environment (wetland) associated with the proposed project.
4.	Alternative	A description of the changes in the design/technology, if any of the project that may be adopted to reduce degradation of environment (wetland) associated with the project.
5.	Growth-inducing aspect	A description of the growth inducing potential of the proposed project and the secondary impact on the environment (wetland) resulting from the induced growth.

A comprehensive study of these elements will help in choosing and environmentally acceptable course of action.

Scientific study: In ascertaining the environmental impact it is necessary to make a scientific study of the biotic communities with special reference to aquatic life and wildlife. A study of the water quality requirements for the survival/sustenance of aquatic life in the wetland is also needed. An inventory of all kinds of flora and fauna associated with the wetland has to be made during the course of impact assessment study. It is also essential to make thorough ecological, hydrological and limnological study of the wetland besides inventorisation of the flora and fauna existing/associated with the wetland. Such hydrological study should be done along with socio-economic survey of the site to collect data on the following aspects:

1.	Ecological data	Habitat type/Soil type Vegetation/Pollution problems, etc.
2.	Hydrological data	Temperature/Dissolved oxygen/ pH / Conductivity / Transparency /Suspended solids, etc.
3.	Limnological data	Plankton/Nekton/Benthos/Associated wildlife/Endemic and endangered species
4.	Piscicultural data	Economic species/Culturable species/Annual production, etc.
5.	Socio-economic data	Human settlement/Fishermen population/Forest produce/Economic dependency. etc.

Water quality requirements for aquatic life: Criteria for the quality of freshwater that will support a good fish fauna were presented by Ellis (1944). Subsequently, Doudoroff and Katz (1950, 1953) made an excellent review of the literature on toxicity of industrial wastes and their components on fish. However, the tentative guides for evaluating the quality of water for aquatic life as recommended by McKee and Wolf (1963) and compiled by McGauhey (1968) is presented in Table 5 *(see p. 277)*.

The factors deserving attention are: D.O., pH, temperature, salinity, crude oil and petroleum products, turbidity and colour, settleable/floating substances (e.g. pesticides, heavy metals and other toxicants), pathogenic bacteria and viruses and radioactivity.

Management aspects: The Environmental Management Plan (EMP) of wetland needs to cover the following aspects:

1. Safeguards and control measures preventing the adverse environmental impacts.
2. Monitoring and feed back mechanism on implementation of necessary safeguards (e.g. setting up on Environmental Management Cells).
3. Plan for rehabilitation of project oustees/fisherman community dependent on the wetlands.
4. Assessment of risk and plans for dealing with accidents/disasters, if any, i.e. Disaster Management Plan.
5. Effluent Treatment Plan/abatement of pollution.

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Table 2

Wetland Values

	Estuaries (without mangroves)	Mangroves	Open coasts	Floodplains	Freshwater marshes	Lakes	Peatlands	Swamp forest
Functions								
1. Groundwater recharge	○	○	○	■	■	■	●	●
2. Groundwater discharge	●	●	●	●	■	●	●	■
3. Flood control	●	■	○	■	■	■	●	■
4. Shoreline stabilisation/erosion control	●	■	●	●	■	○	○	○
5. Sediment/toxicant retention	●	■	●	■	■	■	■	■
6. Nutrient retention	●	■	●	■	■	●	■	■
7. Biomass export	●	■	●	■	●	●	○	●
8. Storm protection/windbreak	●	■	●	○	○	○	○	●
9. Micro-climate stabilization	○	●	○	●	●	●	○	●
10. Water Transport	●	●	○	●	○	●	○	○
11. Recreation/Tourism	●	●	■	●	●	●	●	●
Products								
1. Forest resources	○	■	○	●	○	○	○	■
2. Wildlife resources	■	●	●	■	■	●	●	●
3. Fisheries	■	■	●	■	■	■	○	●
4. Forage resources	■	■	●	■	■	■	○	●
5. Agricultural resources	○	○	○	■	●	●	●	○
6. Water supply	○	○	○	●	●	■	●	●
Attributes								
1. Biological diversity	■	●	●	■	●	■	●	●
2. Uniqueness to culture/heritage	●	●	●	●	●	●	●	●

Key: ○ = Absent or exceptional; ● = present;
■ = common and important value of that wetland type.

Source: Dugan (1990)

Table 3

Information for a Wetland Inventory

A wetland inventory should seek to collect at least the following information for each site.

1. The name of the site.
2. Geographical co-ordinates and the general location of the site.
3. The area of the wetland in hectares.
4. The altitude of the wetland in metres above sea-level.
5. The biogeographical province in which the wetland is situated.
6. A reference to the types of wetland habitat present.
7. A general description of the site
8. A brief note on the local climatic conditions.
9. A description of the principal aquatic vegetation.
10. Details of the ownership of the wetland and the ownership of surrounding areas
11. Details of any protected areas established at or around the wetland
12. Details of any proposals for the conservation of the wetland.
13. Details of any principal forms of land use and human activities at the wetland and in surrounding areas.
14. Available information on proposed changes in land use and development plans which might affect the ecological character of the wetland.
15. Details of existing and possible future threats to the wetland and its wildlife.
16. Value of the wetland for fisheries production
17. The importance of the wetland for wildlife including aquatic mammals
18. Information on any plant species or communities for which the wetland is particularly important.
19. A review of major research activities completed and ongoing and information on any existing facilities for research and education.
20. References to published literature and unpublished reports relevant to the site.
21. Names of individuals and institutions providing information on the site.

Source: Scott (1989)

Table 4

The Causes of Wetland Loss

	Estuaries	Open coasts	Flood plains	Freshwater marshes	Lakes	Peatlands	Swamp forest
Human Actions							
Direct							
Drainage for agriculture, forestry, and mosquito control	■	■	■	■	●	■	■
Dredging and stream channelization for navigation and flood protection.	■	○	○	●	○	○	○
Filling for solid waste disposal roads, and commercial, residential and industrial development	■	■	■	■	●	○	○
Conversion of aquaculture/mariculture	■	●	●	●	●	○	○
Construction of dykes, dams, levees, and seawalls for flood control, water supply, irrigation and storm protection.	■	■	■	■	●	○	○
Discharges of pesticides, herbicides, nutrients from domestic sewage and agricultural runoff, and sediment.	■	■	■	■	■	○	○
Mining of wetland soils for peat, coal, gravel, phosphate and other materials.	●	●	●	○	■	■	■
Groundwater abstraction	○	○	●	■	○	○	○
Indirect							
Sediment diversion by dams, deep channels and other structures.	■	■	■	■	○	○	○
Hydrological alterations by canals, roads, and other structures.	■	■	■	■	■	○	○
Subsidence due to extraction of groundwater, oil, gas and other minerals.	■	■	●	■	■	○	○
Natural Causes							
Subsidence	●	●	○	○	●	●	●
Sea-level rise	■	■	○	○	○	○	■
Drought	■	■	■	■	●	●	●
Hurricanes and other storms	■	■	○	○	○	●	●
Erosion	■	■	●	○	○	●	○
Biotic effects	○	○	■	■	■	○	○

Key : ○ = Absent or exceptional; ● = present, but not a major cause of loss;
■ = common and important cause of wetland degradation and loss.
Source: Dugan (1990)

Table 5
Tentative Guides for Evaluating the Quality of Water for Aquatic Life

Determination	* Threshold concentration	
	Freshwater	Saltwater
Total dissolved solids (TDS), mg/l	2000+	
Electrical conductivity, micromhos/cm @ 25°C	3000+	
Temperature, maximum	34	34
Maximum for salmonoid fish	23	23
Range of pH	6.5-8.5	6.5-9.0
Dissolved Oxygen (DO), Minimum mg/l	5.0**	5.0**
Flotable oil and grease, mg/l	0	0+
Emulsified oil grease, mg/l	10+	10+
Detergent, ABS, mg/l	2.0	2.0
Ammonia (free), mg/l	0.5+	
Arsenic, mg/l	1.0+	1.0+
Barium, mg/l	5.0+	
Cadmium, mg/l	0.01+	
Carbon dioxide (free), mg/l	1.0	
Chlorine (free) mg/l	0.02	
Chromium, hexavalent, mg/l	0.05+	0.05+
Copper, mg/l	0.02+	0.02+
Cyanide, mg/l	0.02+	0.02+
Fluoride, mg/l	1.5+	1.5+
Lead, mg/l	0.1+	0.1+
Mercury, mg/l	0.01+	0.01+
Nickel, mg/l	0.05+	0.0
Phenolic compounds as phenol, mg/l	1.0	
Silver mg/l	0.01	0.01
Sulphide, dissolved, mg/l	0.5+	0.5+
Zinc, mg/l	0.1	

(Source: McKee and Wolf (1963) and compiled by McGauhey (1968))

* Threshold concentration is value that might normally not be deleterious to fish life. Waters that do not exceed these values should be suitable habitats for mixed flora and fauna.

\+ Values not to exceed more than 20% of any 20 consecutive samples, not in any 3 consecutive samples. Other values should never be exceeded. Frequency sampling should be specified.

** Dissolved oxygen concentrations should not fall below 5.0 mg/l more than 20% of the time and never below 2.0 mg/l (Note: Recent data indicate also that rate of change of oxygen tension is an important factor, and that diurnal changes in D.O. may in sewage polluted water render the value of 5.0 of questionable merit).

VEGETATION AND WILDLIFE IMPACT ANALYSIS

S.C.SANTRA*

Introduction

Vegetation and wildlife are important features of the environment, and they present special problems in environmental assessment. Living things are adapted to their setting. They are organised into natural groupings (communities) with mutual dependence among their members, and they show various responses and sensitivities to outside influences.

Environmental impacts vary in their directness, intensity and duration depending upon both the nature of the action and of the biotic community. Developmental projects and activities usually produce adverse biological consequences of two types, direct or indirect and of varying duration, short term or long term. 'Direct impacts' are those that destroy, displace, or in some way adversely affect plants and animals. Examples are logging, clearing for agriculture, land grading, channelization, and hunting. " Indirect impacts" are those that destroy or disrupt habitats, ecosystems, or other physical or biological factors upon which a species depends. Examples are livestock grazing, altering water table or drainage, eliminating nesting or resting sites, breaking food chains or webs upon which an organism depends, using biocides, introducing species, dumping pollutants upon the air or water ways, causing noise, and blocking animals movement. 'Short term impacts' on nature relate to the immediate and direct environmental changes that occur at the inception of a project or action, but end or are corrected soon after the completion of the project or termination of the action. 'Long term impacts' on nature result either major, direct environmental change or chronic perturbations resulting from the operational phase of a completed project (Fig. 1, on page 292).

The full consequence of many impacts on organisms may not be obvious, but the long term impact may be more profound in the life of the organism than is evident. As an illustration Table 1, presents typical human-induced environmental impacts (both adverse and beneficial) on biota.

Table 1

Typical impact of Activities on Biota

Activities	Type of impact on biota	Adverse	Beneficial
Clearing	Creates new environment	x	x
	Creates conditions suitable for rodent outbreaks	x	
	Habitat destruction	x	
	Loss of shelter and food	x	
	Loss of native plants and animals	x	
	Reduced species diversity	x	

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Table 1 *(contd.)*

Typical Impact of Activities on Biota			
Activities	**Type of impact on biota**	**Adverse**	**Beneficial**
Agriculture	Encourages a few species	x	x
	Habitat destruction	x	
	Loss of native plants and animals	x	
	Increase in weed species	x	
Dams and Reservoirs	Creates shoreline ecosystem		x
	Potential increase in species types	x	x
	Habitat destruction	x	
	Loss of native plants and animals	x	
Power plant construction and operation	Alteration of breeding and feeding activities by noise pollution	x	
	Changes in form of aquatic life due to heating of adjacent waters	x	x
	Potential loss of wildlife due to radiation effects	x	
Discharges of pollutants into water bodies	Disturbance of wet land habitat	x	
	Loss of native plants and animals	x	
	Reduced species diversity	x	
	Potential for species extinction	x	
	Loss of fisheries	x	
Air pollution	Potential crop damage	x	
	Loss of timber and natural foliage	x	
Resource exploration and development	Habitat destruction	x	
	Wildlife disturbance	x	
Industrial, commercial & residential development	Enhances site for weedy species of plants and animals	x	
	Habitat destruction	x	
	Loss of native plants and animals	x	
	Increased edge effect in the form of hedgerows, windbreaks, road-sides and embankment		x
Offshore drilling	Habitat destruction	x	
	Potential hazard to inter tidal organisms and birds from oils spills and leaks	x	
Fish, hunting and trapping	Keeps population size below carrying capacity of the site		x
	Eliminates old and infirm individuals		x
	Creates nature imbalance	x	

Table 1 *(contd.)*

Typical impact of Activities on Biota			
Activities	**Type of impact on biota**	**Adverse**	**Beneficial**
Landfills	Favours scavenger species	x	x
	Habitat destruction and destruction	x	
	Loss of native plants and animals	x	
Wild life management	Favour selected species	x	x
	Enhances habitat		x
	Hinders non managed species	x	
Conservation and restoration	Increases numbers of natives plants and animals		x
	Increases species diversity	x	
	Restores balanced ecosystem	x	
Draining and filling	Habitat destruction	x	
	Loss of native plants and animals	x	
	Reduced species diversity	x	

Impact Analysis Methodology

The evaluation of impact of a developmental project or man made activities on biota is very complex. Most of the information, has to be transferred into qualitative ways. A number of suitable sample recording in the field (Table 2).

Table 2: Sample Field Form Used in Biotic Assessments

1. Name of project .... Date ....

2. Type of project ....

3. Prepared for ....

4. Investigator ....

5. Reconnaissance: Record key features on plot map or sketch to show location.

   A Physical features
   1. Geography ....
   2. Geology and soils ....
   3. Climate ....
   4. Water ....
   5. Other ....

   B Vegetation

1. Plant communities — dominant plants.............................. ....
2. Unique vegetative features..

C Fauna

1. Animal populations — dominant animal...
   Mammals ....
   Bird ....
   Amphibians ....
   Fish...
   Insect ....
   Other invertebrates ....
2. Uniaue wildlife ....

D.Uniqne habitats for:	Important plant species	Important an mal species	Important wildlife productivity	Visual, historic and/or aesthetic values

Condition of unique habitats:	Disturbed to pristine	Fragile to durable	Recovery potential and speed

F. Special relationships

1. Vegetation to substrate ....
2. Animal to substrate..
3. Plant to animal..
4. Animal to plant ....
5. Animal to animal ....
6. Others..

G. Aquatic habitat

1. Present condition ....

2. Visual, historic, and/or aesthetic features ....
3. Sport, commercial, recreational, or educational values ....
4. Rare or endangered species ....

6. *Are there any unique wildlife features?*
This question should call attention to any intrinsic or extrinsic wildlife features such as:
   a. Rare or endangered species
   b. Species of high visual, historic, or aesthetic appeal
   c. Threats posed by animal species (for example, poisonous, large carnivores, disease carriers).
7. *What natural habitats are present?*
This question focuses attention on natural assemblages of plants and animals in relation to specific physical factors. It leads to further questions such as:
   a. Are any of the habitats suitable for special, important, or rare or endangered species? (For example, rocky cliffs for nesting, gravel beds for spawning, marshy area for shelter, prairie grassland for breeding.)
   b. Are any of the habitats important in wildlife productivity? (For example, sport, fish and wildlife, spectators, commercial, educational.)
8. *What is the disturbance level?*
This question is basic in assessing not only the existing environment but also its response potential to various perturbations. The well-trained biologist uses such clues as the presence of weedy species, successional species, lack of young climax species, and the response of indicator species to various kinds of impacts to assess both the durability of a natural community and the level of disturbance. Further questions may be asked:
   a. Is the area or site pristine or relatively undisturbed by people or natural forces?
   b. Is the community or habitat fragile or durable?
   c. What is the recovery potential?
   (1) Area of low vegetative recovery potential may be due to such site factors as soil compaction, erosion, low soil fertility, low rainfall, lack of seed, and severe climate.
   (2) Area of high vegetative recovery potential possess deep and rich soil, good seed source, and moderate climate.
9. *Are there any special relationships?*
This question gets to the heart of the ecology of the area; that is, it goes beyond naming the biotic components of the area by pointing out the interdependencies that exist between organisms and between organisms and other environmental factors. Example are the interdependencies between:
   a. Vegetation and substrate — tallus slope, dune, chemical composition
   b. Animal and substrate — burrowing animals

c. Plants and animals — pollination, shelter, food
d. Animal and plants — herbivore
e. Animal and animals — parasite

10. *Are sonic conditions a problem to the wildlife?*
This question addresses the problem of people and their machines producing noises sufficient to disturb or display certain wildlife species. This factor needs to be assessed.

Both plant and animal population survey provides a number of important clues to the impact assessment practices. Plants may be assessed in several descriptive ways – a species list or by quantitative measures (i.e., determination of density, frequency and cover etc.). However animal survey mostly made by species lists and species population determination. The approach of computing different values are given in the Table 3.

Species diversity indices were measured by different methods (Table 4), which indicate the quality of biological environment. For instance disturbed, polluted or degraded natural communities – such as vacant lots and polluted or channeled streams – usually have low species diversity indices, whereas mature and intact communities such as natural woods, forests and natural streams often have high diversity indices.

Table 3: Computation methodology of various computative data

The approach to computing importance values is as follows:

$$Density = \frac{Number\ of\ species\ A^{*}}{Area\ sampled}$$

* *Species 'A' represents any species being considered*

$$Relative\ density = \left(\frac{density\ of\ species\ A}{total\ density\ of\ all\ species}\right) \times 100$$

$$Dominance = \frac{Total\ cover\ or\ basal\ area\ of\ species\ A}{Area\ sampled}$$

$$Relative\ dominance = \left(\frac{Dominance\ for\ species\ A}{Total\ dominance\ for\ all\ species}\right) \times 100$$

$$Frequency = \frac{Number\ of\ plots\ in\ which\ Species\ 'A'\ occurs}{Total\ number\ of\ plots\ sampled}$$

$$Relative\ Frequency = \left(\frac{Frequency\ value\ for\ Species\ 'A'}{Total\ of\ frequency\ values\ for\ all\ species}\right) \times 100$$

$$Importance\ value\ (\%) = \frac{(Relative\ density + Relative\ dominance + Relative\ frequency)}{3}$$

Table 4: Determination methods of biological indices

Simpson's index:

$$D = \frac{N(N-1)}{\sum n(n-1)}$$

where D = Diversity index
N = Total number of individuals of all species
n = Number of individuals of a species

Shannon Weaver's Index:

$$D = -\Sigma \pi \log \varepsilon \, \pi$$

where D = Diversity Index,
π = ni/N (ni = number of individuals in species i)
N = Total number of individuals in the sample

Log 2 may be used in place of log ε to calculate 'D' in order to get the average information context per individual.

Kothe's species deficit index:

$$\text{Species deficit index} = \frac{A_1 - A_x}{A_1} \times 100$$

where A_1 = Number of species at the unpolluted site;
A_x = Number of species at the polluted site

Odum's species index:

$$\textit{Index value} = \frac{\textit{Total number of species encountered in the sample}}{\textit{Total number of individuals of all the species}}$$

The evaluator must assess not only both of these causes of biotic change but also the kind and extent of the biotic changes. Table 5 summarises these assessment considerations for selected terrestrial and aquatic projects that create unique impacts needing special attention.

On the whole, it is the biologists' responsibility to state clearly all possible impacts of the proposed project or action on the plants, animals, biotic habitats and ecosystems on and near the project site. It is through the biologist's eyes that the lay person sees the biological and ecological significance of impacts and possible synergistic and cascading effects in the habitats and ecosystems directly and indirectly involved with the project or action. Disruption of cycle in nature, both biotic and abiotic, must be discussed in the light of short-term and long-term stability of natural ecosystems. The assessment of possible biotic impacts must explain how and why they are significant biologically.

In assessing the biotic environment, the biologist must consider viable alternatives to the proposed project that would reduce or eliminate negative impact on the biota. Alternatives are derived in part, therefore, from the anticipated environmental impacts described earlier. Generally, the more severe the anticipated impacts on the biota, the greater is the necessity for viable alternatives to the project. Negative impacts might be accepted as or mitigated without the necessity of project alternatives.

Table 5

Impact Assessment Consideration in Selected Terrestrial and Aquatic Projects

Projects	Projects activities	Potential impacts to be assessed
Expansion and construction of new airports	Construction phase	1. Vegetation destroyed or disturbed 2. Wildlife habitat reduced and broken up. 3. Wildlife destroyed or displayed. 4. Migration routes for wildlife disrupted or destroyed. 5. Nesting, mating, and other wildlife behaviour patterns disrupted or destroyed.
	Operation phase	1. Bird and wildlife migration disrupted 2. Wildlife displaced. 3. Animal behaviour disrupted by noise and activities.
Construction of new highways	Construction phase	1. Vegetation destroyed or disturbed 2. Wildlife habitat reduced and broken up. 3. Wildlife displaced. 4. Migration routes for wildlife disrupted or destroyed.
	Operation phase	1. Bird and wildlife migration disrupted 2. Wildlife displaced. 3. Road kills. 4. Animal behaviour disrupted by noise and traffic activities.
Construction of nuclear power plants	Construction phase	1. Normal project impacts to vegetation and wildlife due to construction.
	Operation phase (potential problems such as radiation leakage, air pollution, water pollution, contaminated forage)	1. Radiation damage to vegetation and wildlife resulting from direct radiation exposure or radioactive materials.

Table 5 *(contd.)*

Impact Assessment Consideration in Selected Terrestrial and Aquatic Projects		
Projects	**Projects activities**	**Potential impacts to be assessed**
Construction of new oil pipelines	Construction phase	1. Vegetation destroyed 2. Wildlife killed or displaced. 3. Migration routes disrupted or destroyed if pipeline is large and above ground.
	Operation phase	1. Destruction or disruption of plants and animals from maintenance activities. 2. Destruction of vegetation and wildlife from pipeline rupture and leakage.
Transfer and transport of crude oil	Loading and unloading Tankers and barges; Drilling platforms/ Tankers' mishaps	1. Killing of intertidal and shore biota. 2. Killing of some open-water biota. 3. Killing and damage of marine and shore waterfowl.
Strip mining of coal and minerals	Operation phase	1. Vegetation destroyed 2. Small animals destroyed. 3. Wildlife displaced. 4. Wildlife habitats destroyed. 5. Migration routes destroyed or disrupted. 6. Breeding grounds destroyed. 7. Wildlife ranges divided. 8. Isolation of animals with small home ranges.
	Reclamation phase	1. Soil erosion. 2. Regeneration potential of vegetation. 3. Loss of native forage. 4. Effects of air and water pollution on plants and animals. 5. Human impact of plant and animal life.
Construction of dams and reser-voirs	Preparing dam site and clearing for reservoir	*Terrestrial habitat* 1. Vegetation destroyed 2. Small animals destroyed. 3. Wildlife displaced.

Table 5 *(contd.)*

Impact Assessment Consideration in Selected Terrestrial and Aquatic Projects		
Projects	**Projects activities**	**Potential impacts to be assessed**
Construction of dams and reservoirs *(contd.)*	Preparing dam site and clearing for reservoir *(contd.)*	4. Wildlife habitats destroyed. 5. Migration routes destroyed or disrupted. 6. Breeding grounds destroyed. 7. Wildlife ranges divided. 8. Isolation of animals with small home ranges. 9. Suitability of remaining habitats.
	Impoundment of water	*Aquatic habitat* 1. Physical properties of impounded water. 2. Changes in aquatic species composition and number. 3. Changes in bottom versus sediment dwellers. 4. Fish stocking practices.
	Changes in impounded water level	*"Edge" Habitat and Draw down Zone* 1. (Invasion of new plant species and plant communities. 2. Increased habitat diversity. 3. Invasion of new animal species. 4. Human impact on biota.
	Downstream water discharge	*Aquatic Habitat* 1. Physical properties of water. 2. Changes in aquatic species composition and number. 3. Alteration of stream and riparian habitats. 4. Migration and spawning of fish disrupted. 5. Reduction of fish sizes.
Channelization of streams and rivers	Straighten channel and line banks and bottoms	*Aquatic Habitat* 1. Physical properties of the water. 2. Changes in aquatic species composition and number.

Table 5 *(contd.)*

Impact Assessment Consideration in Selected Terrestrial and Aquatic Projects		
Projects	**Projects activities**	**Potential impacts to be assessed**
Channelization of streams and rivers *(contd.)*	Straighten channel and line banks and bottoms *(contd.)*	3. Changes in bottom dwellers. 4. Fisheries destroyed. 5. Fish sizes decrease. 6. Aquatic animals without suitable habitat or food supply. *Terrestrial habitat* 1. Vegetation destroyed or disturbed 2. Wildlife habitat reduced and broken up. 3. Wildlife destroyed or displayed. 4. Migration routes for wildlife disrupted or destroyed. 5. Breeding feeding grounds destroyed.
Dredging harbours and coastal marshes	Opening harbours and channels for boat and barge traffic	1. Physical properties of the water. 2. Disruption or destruction of bottom sediment organisms. 3. Wildlife habitat disrupted or destroyed. 4. Wildlife breeding feeding grounds disrupted or destroyed. 5. Broken life-cycle and chains

In addition, a considerable degree of study has been conducted on the effect of air pollutants on wildlife in recent years (Table 6). Pollutants from the industrial developmental activities have direct bearing on wildlife health. In addition we now turn from wholesale habitat change to the consequences of anthropogenic changes in terrestrial ecosystems for individual species. Large scale habitat destruction will lead to local elimination of plant species and of animals which are dependent upon those plants. Even if small reserves of the habitat are left undisturbed, some loss of species diversity will occur — the small area can support only a relatively small population, at least of large species. These smaller populations are more vulnerable to extinction as a result of random environmental fluctuation smaller populations also have a lower genetic diversity, so the may be less well equipped to respond to rare events such as climatic fluctuation or infections decreases.

The biotic assessment also include measures that will reduce project impacts on the biota. These mitigations are based on a knowledge of the natural communities and habitats involved. Species and ecosystems vary not only in their structural nature but also in their abilities to undergo alternations and impacts. For this reason, mitigating measures need to be site specific and realistic. Various developments and activities will and must occur, but the purpose of mitigating measures to insure that the resulting impacts on nature will be kept to a minimum.

Table 6: Recent Incidents Involving the Adverse Effects of Air Pollutants on Wildlife

Date	Location	Species	Pollutant(s)	Effects
1963	South Africa	Baboons and rats	Asbestos	Respiratory lesions
1965	Czechoslovakia	Small birds	Fluoride	Declining populations
1967	Canada	White tail deer	Fluoride	Fluorosis
1968	Czechoslovakia	House sparrows	Fluoride	Biological concentration
1969	Czechoslovakia	Red and roe deer	Arsenic	Sickness and death
1970	USA	House sparrows	Photochemical oxidant smog or particulates	Respiratory lesions
1971	Canada	Passerine birds	Hydrogen sulfate	Death of hundreds of birds
1971	Czechoslovakia	Hares	Sulfur dioxide and fly ash	Hypocalcaemia and hypoproteinesis
1973	Japan	Sparrows	Cadmium	Death of birds
1973	USA	Bighorn sheep	Oxidants	Blindness in herd
1974	USA	Voles	Lead	Biological concentration
1975	Japan	Larks	Urban air pollution	Reduced populations
1975	England	Sparrow hawks and song thrushes	Cadmium	Food chain accumulation
1975	USA	Small mammals	Oxidants	Reduced populations
1975	USA	Mule and white-tail deer	Fluoride	Fluorosis
1976	USA	Black-tail deer	Fluoride	Fluorosis
1977	Czechoslovakia	House martins	Sulfur dioxide particulates fluoride, and nitrogen oxides	Reduced nesting
1977	England	Wood mice and voles	Mercury	Biological concentration
1978	Canada	Black and mallard ducks	Copper and nickel	Biological concentration
1979	USA	Black-tail deer	Fluoride	Browse contamination
1979	USA	Deer mice	Ozone	Genetic changes in sensitivity to ozone

Table 6 *(contd.)*

Date	Location	Species	Pollutant(s)	Effects
1979	Czechoslovakia	Hares	Sulfur dioxide, fly ash	Decrease in comeal proteins
1980	England	Tawny owls, badgers	Cadmium	Biological concentration
1982	USA	Rats	Lead	Biological concentration
1982	London	Pigeons	Lead	Biological concentration
1982	Canada	Ruffed grouse	Copper, nickel, iron	Biological concentration
1982	USA	Deer	Fluoride	Fluorosis
1983	Poland	Roe deer	Cadmium, lead, nickel, chromium, iron copper, zinc, manganese, magnesium	Decline in antler quality
1984	Wales	Foxes	Fluoride	Biological concentration
1984	USA	Owls, bats, songbirds, mice	Hydrogen sulfide	Death
1984	Czechoslovakia	Ducks	Trace metals	Biological concentration
1984	Czechoslovakia	House martins	Sulfur dioxide, fly ash	Decline in nesting with increased emissions
1986	Czechoslovakia	Pheasants and hares	Mercury, lead, cadmium	Bioconcentration
1986	Finland	Night-flying moths	Radioactivity	Bioconcentration
1987	Poland	Invertebrates, including arthropods	Sulfur dioxide	Densities inversely related to pollution
1987	USA	Passerine birds	Sulfur dioxide	Death approximately 3,000 birds
1987	Sweden	29 species of birds and animals	Radiocaesium	Bioconcentration
1988	Poland	Roe deer	Lead, cadmium, copper, manganese, iron	Bioconcentration in tissues

Table 6 *(contd.)*

Date	Location	Species	Pollutant(s)	Effects
1988	Sweden	Red fox	Metals (cadmium, mercury, lead, copper, zinc, chromium, manganese, nickel)	Interuterine losses negatively correlated with pollution source
1988	England	Otters	Radiocaesium	Bioconcentration
1988	England	Roe deer	Radiocaesium	Bioconcentration
1989	Germany	Magpie	Metals, including zinc and cadmium	Bioconcentration in feathers
1989	Czechoslovakia	Birds	Sulfur dioxide, fly ash	Reduced bird species and density in relation to habitat damage
1989	Canada	Caribou	Cadmium	Bioconcentration
1989	Sweden	Moose	Radiocaesium	Bioconcentration
1990	Italy	House mice	Radiocaesium	Increased mutagenicity from pre-Chernobyl conditions

Source: modified from Newman 1980.

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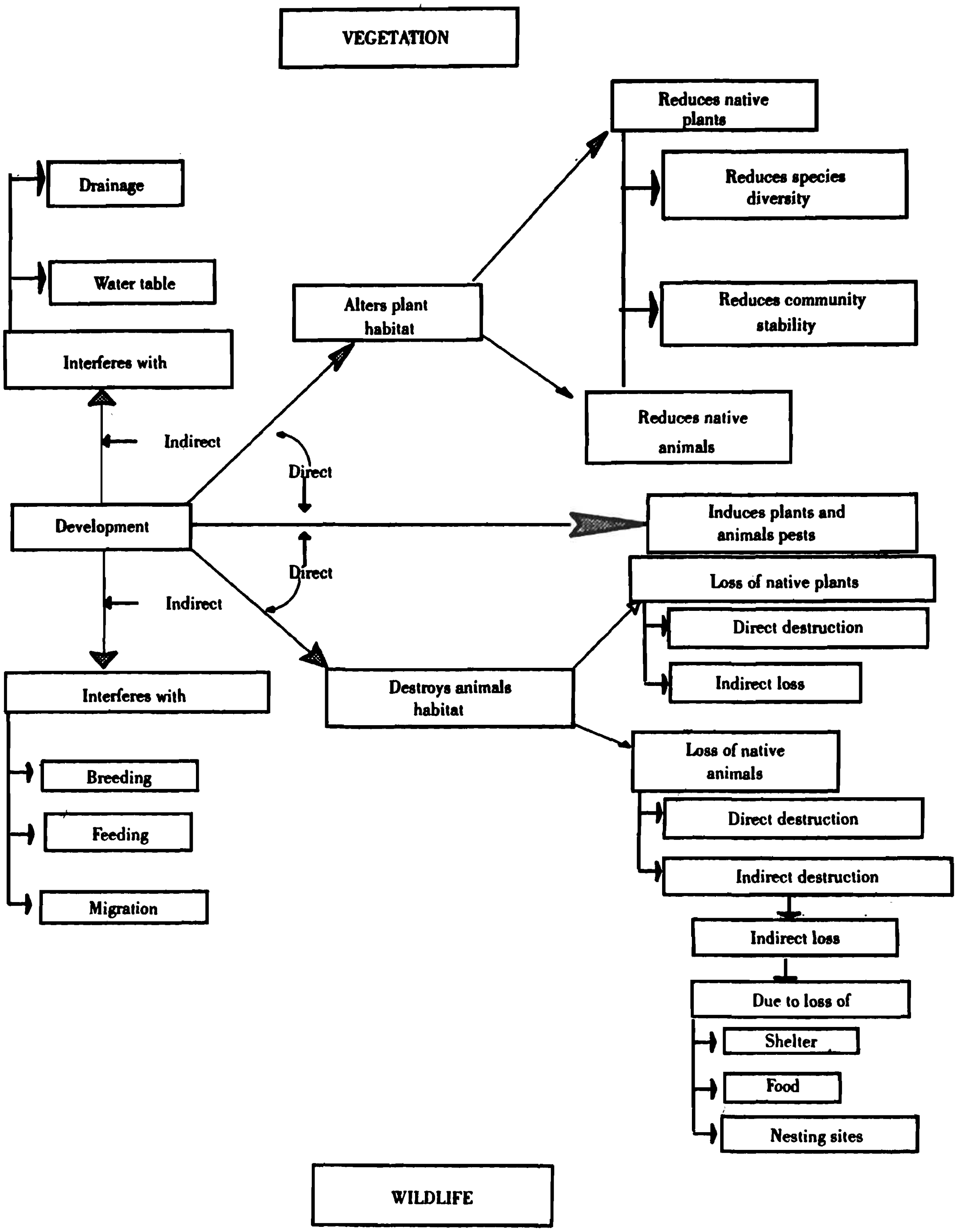

Fig. 1. Impact of development on Vegetation and Wildlife.

ENVIRONMENTAL MANAGEMENT PLAN — A CASE STUDY RECLAMATION OF COAL MINE AREA BY REVEGETATION

S.C.SANTRA*

Introduction

Mining for coal, underground and open cast both require removal of huge quantities of carbonaceous materials, clay stone, sand stones and other rock materials to reach the coal seams. Those extracted rock materials, together with upper crust of soil in the case, particularly, of open cast mines, are dumped in and around the mining sites. The procedure of dumping of different kinds of rock and soil separately, though desirable, is hardly practised and as a result in most of the cases mixed dumps are created.

The dumps as such create environmental problems of different kinds. These are (i) rendering the land of occupation unproductive; (ii) changing the aesthetics of the landscape; (iii) erosion by rain water causing siltation and pollution of nearby water courses; (iv) dispersion of fines by air currents causing particulate air pollution and (v) instability of the dumped material which is dangerous to the work-force and other local inhabitants.

The simple solution to the problems of waste dumps is not to allow them to occur. But this is not always possible except where they are recycled. The other possibility is to put them to some remedial measures and productive use or to reclaim them. Amongst the various measures of reclamation, the biological one provides the best means to achieve rapid visual integration, surface stabilisation and reduction of air and water pollution. Moreover, a wide variety of land use possibilities can be planned by this method at an acceptable cost.

Usually there are two approaches to re-vegetation work on the waste dumps (Down & Stokes, 1977). The first one is the 'ecological approach' whereby the existing substrate conditions are accentuated and searches are made for tolerant species in the natural vegetation on these dumps. Study of succession gives clues to pioneers and these may be used in re-vegetation practices. The procedure is less likely to yield rapid results. The second approach enabling quick results is to alter the physical and chemical conditions of the substrate for plantation of selected species. The latter approach, though commonly followed has its limitations because of maintenance of amendments which otherwise can deteriorate. A self-perpetuating, relatively maintenance-free vegetation cover probably requires a marriage of both the practices.

Problems

Down & Stokes (1977) have enumerated the main environmental factors inhibiting plant growth on such dumps and these are instability, spontaneous combustion, unworkable steep slopes, high level of toxic elements, wind erosion, low nutrient status, sheet and gully erosion and absence of soil micro-organisms and soil fauna. Other less

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inhibitory factors include inhibitory water regime, compaction and cementation, excessive stoniness and absence of fine soil-forming material and broken, uneven surface.

Instability results from steep slopes of the dumps, effect of gravity on loose stony materials, wetting and drying of bare surfaces and wind and water erosion. Instability apart from causing danger to the local populace and work men, may severely damage the vegetation of any sort by tearing and uprooting the plants. Few of the mines care to re-grade the dumps particularly in the Jharia coal field. Coupled with instability other factors like green slopes, sheet and gully erosion, compaction, etc. are related as cause and effect and these need physical reclamation by engineers. This kind of work necessitates predetermination of future land use pattern and itself precedes biological reclamation. However, there is a need to differentiate between biological reclamation by vegetation growth and afforestation which has duly been stressed by Banerjee (1989).

Natural vegetation that comes up on such dumps expresses the prevailing soil and climatic conditions (Down & Stokes, 1977). The succession of natural vegetation on coal-mine dumps is different from that occurring in abandoned fields, because the dumps provide anthropogenic ecotopes and the succession one sees is primary in nature (Motorina *et al,* 1971). The succession is a result of autecological properties of the participating species and of both biotic and abiotic conditions. Bradshaw & Chadwick (1980) have recommended the following parameters of the natural vegetation as important. These are: (a) degree of vegetational cover; (b) number of colonising species; (c) habital composition; (d) depth and extent of rooting of the species; (e) plant vigour and (f) deficiency or toxicity symptoms in the plants. These parameters help in site assessment as: (a) absence or sparseness of vegetation can indicate toxicity, nutrient deficiency or physical constraints; (b) a rich floristic diversity can indicate suitability of the site; (c) general appearance or vigour of the colonisers indicate site suitability; (d) depth and extent of rooting indicate moisture status and (e) occurrence of indicator species specifies a particular kind of substrate.

Progress of natural vegetation on coal mine spoils is usually very slow and patchy. Stability and particle size are important than slope angle (Brierley, 1956). Usually pioneers invade the dumps from boundaries and margins of the dumps and they favour insects of gravel, sand and soil horizons. Analogues of screes preferred by the pioneers are provided by rocks and boulders on slopes. Thus species establishment and success can be related to micro site preferences (Prach, 1987; Brierley, 1956).

The succession is noted on coal mine spoils is that of initial colonisation by a grass-herb community in 2-3 years time and most of the plants are annuals. Though no time-correlated changes in the succession is possible to forecast, plants of the perennial type follow the annuals and then the woody ones. Absence of trees in the first 10-15 years was noted by Hall (1957) though sparseness of vegetation with a very low cover even in 26 years' time may not be unusual. In the succession when the stage of perennials with tap roots is reached, the success of vegetation is enhanced because these can utilise the water efficiently that is condensed mostly at a depth of 30 cm. It is worthwhile to mention that cover that has been referred earlier is never uniform all over the dump. This is because of the mosaic nature of the substrate due to dumping of various kinds of rock materials etc. together.

Succession is also influenced by the following changes in the substrate with time. It has been observed that there is an increase in the bulk density and decrease in the soil porosity in the surface layer (0-5 cm depth) with time. pH is reported to change from basic or neutral to acidic in time (Hall, 1975). For colonisation to occur seed source in the locality is necessary. The dumps being anthropogenic ecotopes do not possess original seed reserve. Propagules from the nearly vegetation reach the sites through wind or animals. Reproduction by both seed and vegetative spread in later stages are the main stay for the increase in cover.

Nutrient deficiency, particularly low nitrogen content is a common aspect in all derelict land including coal mine spoils (Jefferies *et al.*, 1981). Absence of soil humus on such locations is also of common occurrence, and the organic matter is mostly added naturally by the dying and decaying plants of previous growth. But decomposition is hampered by the general lack of soil micro flora. Soil micro flora is responsible for adding humus by decomposing the organic matter and cycling or trace elements or in other words the help in soil development (Lawrey, 1977). Some of the soil fungi form an association with roots to form mycorrhizas. Mycorrhizas are important in seedling establishment and effective nutrient utilization in otherwise poor nutrient conditions (Mosse & Haymann, 1971). Inoculation with endomycorrhyza favour significant growth increments of plants on coal mine spoils (Aldon, 1978).

Adaptation of various kinds help some of the plants more. Of these, the adaptation for C4 photosynthetic pathways, particularly in the pioneers is important. C4 taxa possess higher efficiency of nutrient utilisation in nutrient poor microsites in hot dry climates. The ruderal or exploitive strategies in growth forms is the pioneers have been noted by Ramakrishnan (1986) and such traits are established in tolerance of sun in seedling stage, pre-monsoon growth, rapid growth of principal axis and renewal of leaves. Seedlings with persistent paracotyledons are succesful at the initial open grounds. Allelopathic interaction is also one factor that enables one plant to spread at the expense of another.

Thus, with the limitations mentioned here, success or sustenance of vegetation occur on coal mine dumps. Any kind of reclamation of by plant growth needs the pre-assessment of these limitation.

Case Study: The Chasnala Experience

There is little data on the above mentioned aspects from Indian coal mines, and particularly of the natural vegetation on coal mine wastes. Mukherjee *et al* (1991) have made some initial work in this regard in respect of coal mines in Dhanbad.

The Chasnala mine is the captive coal mine for IISCO's Burnpur Works. It covers a total area of 362.02 hectares and is bounded on the south by the river Damodar, on the north by the Dhanbad-Sindri Road, on the east by the perennial stream Domochani Jore and on the west by the railway line to Sudamdih. The underground mining started at the very beginning of this century but it has been stopped since the disaster in 1976, pending renovation. In the meantime, open cast operations have started in the seams 13 and 14. The total area available for dumping of overburden is about 224 hectares. There has been an attempt in dumping different kinds of overburden material separately: alluvium is dumped on the northern perimeter of the quarry as well as an embankment along the Damodar, stony materials are dumped as mounds of 10-15 metres high on the north-west corner of the quarry and another on the north cast corner. The mounds are steep-sided with ridges, plateaux and hollows. Chiefly clay stones and sand stones, ranging in size from huge boulders to broken lumps of 1 sq. cm. to particle size of sand, along with filling of sand constitute these dumps, and are about 12 years old. Disturbance by human beings and pets is not infrequent. Besides the overburdens, Chasnala Mines also produce rejects from its washery and they are dumped as landfills along the Damodar behind the water treatment plant. The rejects are gritty, ranging in size from 3 cm sq. to 2 mm sq.

The mineralological components, physico-chemical properties of waste dumps were examined and data presented in Tables 1 and 3. Climatically, the area is warm humid zone with moderate annual rainfall (Table 2). Quite a good number of plant species appear to colonise on dumps (Table 4). On the whole, the occurrence of 82 plant species indicates the potentiality of these dumps for plant growth. Apart from heterogeneity of dumps with various kinds of rocks, deficiencies of nutrients especially nitrogen, poor water holding capacity, and alkaline pH are notable in the wastes. The colonisers are mainly anemochorous and thus presence of suitable plant types in the neighbourhood is important. In the initial stages of succession, a preponderance of herbaceous plants (green – herbs) in notable and presence of woody plants (trees, shrub and climbers), though in small quantity, indicates their prospect of growth. The micro-climatic situations are necessary. The open hardened surfaces are seen with patchy growth of herb-grass community and the woody species are seen growing on slopes or amongst boulders. Probably these sites offer suitable sites for lodging and germination of diaspores and primary shelter from sun or protection from grazers. The experiment on germination behaviour of some colonisers indicate that the best pH regime for this is between 6.5-8.5 and thus pH of waters is not limiting. The chief limiting factors for plant growth are noted in Table 5.

Table 1

Summary of Wastes of Chasnala Coal Mines, IISCO, Dhanbad

	Type of waste	Mineral constituents	Method of Disposal	Nature of Problem
i)	Overburdens of open cast mines (alluvium, rocks-sand, clay stones, sand stones etc.)	Alumina, Silica, Ferric-oxide, Chloride of N, K & Mg, Sulphides of Mg & Ca, Aluminium-borosilicates, Aluminium-silicates, Ferrous sulphide.	Chiefly tipped as wastes in surface dumps, occasionally as land fills or road construction.	Surface instability, emission of wind blown dust; land slips due to steep slopes; washoffs.
ii)	Washery rejects			

Table 2

Climatic data of Chasnala

Rainfall (mm)			Temperature (°C)		Humidity (%)	
Maximum	Minimum	Monthly average	Maximum	Minimum	Maximum	Minimum
738.80 (Aug'86)	2.80 (Mar'85)	157.69	35.62	12.50	96	14

Table 3

Physical & Chemical Characteristics of Wastes				
Characteristic		Sites		
		O.B. Dump	Aluminium Dump	Washery Rejects
1.	Colour	Greyish-black	Grey	Black
2.	pH	8.2	8.3	7.8
3.	Conductivity (10^2 micro ohms)	1.30	1.50	3.25
4.	Total nitrogen (%)	0.01	0.30	0.01
5.	Organic carbon	0.36	0.46	5.81
6.	Total phosphorous (%)	0.50	0.02	0.50
7.	Total potassium (%)	0.20	0.50	0.40
8.	Exchangeable calcium (mgm/gm)	2.4	1.2	4.40
9.	Exchangeable magnesium (mgm/gm)	0.7	0.2	0.7
10.	Water holding capacity (%)	22.56	40.90	25.90
11.	Sand (%)	60	50	n.d.
12.	Silt (%)	25	15	n.d.
13.	Clay (%)	10	32	n.d.

Table 4

Habit and Dispersal types of natural colonisers						
Habitats	Total No. of plants	Habit		Dispersal types		
		Herbaceous	Woody	Anemo-chorous	Zoo-chorous	Others
OB–	55	44	11	36	10	9
AD–	65	54	11	43	9	13
WR–	25	21	4	16	4	15

OB – Overburden dump; AD – Alluvial dump; WR – Washery reject dump.

Table 5

Limiting factors for plant growth of coal mine wastes

Factors	Response
Instability	+
Spontaneous combustion	++
Unworkable steep slopes	++
Inhibitory water regime	+
Level of toxic elements	-
Compaction and cementation	+
Surface temperature	+
Wind erosion	++
Low nutrient	++
Excessive stoniness and absence of soils	+
Sheet & Gully erosion	++
Absence of soil micro-organisms and soil fauna	++

Inhibitory factors very marked (++), present (+) and negligible or absent (–).

Thus coal mine waste dumps are viewed as spatio-temporary if probabilities of their reuse in back filling is envisaged. The area had agricultural use and any planning of reclamation should consider that factor as the probable land use after mining is completed. The coal: overburden ratio of the overburden can be used to fill the words created by open cast mining. It is needless to mention that filling up the voids conjointly with mining is economical but this can not be done presently in the area for reasons of mining technicalities.

The immediate need is therefore to stabilise the dumps against land slides and erosion and also to bring about an aesthetic change in the general scenario. Drawing of some economic benefit from the dumps can also be planned and plants yielding fuel, fodder or fruit can be tried to this end. For this suitable earth work may be necessary initially and then amelioration in respect of plant nutrients. A selection of plants made from those growing naturally in suggested and these are *Dalbergia sissoo, Pongamia glabra, Ailanthes excelsa, Azadirachta indica, Alstonia scholaris, Bombax ceiba, Adine cordifolia and. Sterculia urens*. For said amelioration, growth of a grass-legume mixture *(Echinocloa colonum, Cynodon dactylon, Crotalaria* sp., *Desmodium* sp. and *Indigofera* sp.) is required and this can be done by broadcasting of seeds in the rainy season.

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USE OF REMOTE SENSING IN LAND USE AND LAND COVER MAPPING.

P CHAKRAVARTI*

Introduction

An Environmental Impact Assessment (EIA) of any envisaged project, basically involves a study of the impacts which the various activities pertaining to that project will have on a given set of environmental attributes. Among these environmental attributes "Land Cover" is of primary importance, since by definition – "Land cover describes the vegetal and artificial covering of the land surface and forms a significant attribute of land or terrain" (Barley, 1961). On the other hand, the term "Land Use" has been defined as "Human activity associated with a specific piece of land" (Lillesand, 1987). Thus, for a proper assessment of the impact of any project activity on the surrounding lands, a thorough knowledge of both land use and land cover is essential. Data on land use and land cover are also indispensable for the formulation of an "Environmental Management Plan" (EMP). For drawing up an effective EMP, precise information on the prevailing land use and land cover is essential, so that those parcels of land which are of vital importance for the sustenance and well being of the local flora, fauna and human populations, can be saved to the extent possible from the damaging impacts of project activities. It is because of these reasons that the Department of Environment, Govt. of India, has made the study of the land use and land cover mandatory for an EIA or EMP.

"Remote sensing" may be defined as the science and art of obtaining information about an object, area, or phenomenon through the analysis of physical data acquired from a distance by a device that is not in contact with the object, area or phenomenon, under investigation. The process of reading a book may be cited as a common example of remote sensing. The eyes act as "sensors" that respond to the light reflected from the pages of the book. The "data" acquired by the eyes are impulses corresponding to the amount of light reflected from the dark and white areas on the page. These data are analysed or interpreted in the brain and explain the dark areas on the pages as a collection of letters forming words. In the next step, the sentences formed by the words are recognized and finally the information conveyed by the sentences is obtained through interpretation.

In the present context the term "Remote sensing" has been used to describe the remote sensing techniques, involving the use of electro-magnetic energy sensors that are currently being operated from aircraft and satellites to assist in mapping of earth's surface. These sensors acquire data by recording the intensity and nature of the electro-magnetic energy (sunlight) reflected by various features on the earth's surface. Subsequently, these data products are analysed and interpreted to provide information about the terrain under investigation.

The present write-up describes in brief the possible utilisation of remotely sensed data products like air photographs and satellite imagery currently available in India, for

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preparing Land use and Land cover maps on suitable scales, in connection with EIA studies.

Basic Concepts of Remote Sensing

The general processes and elements involved in Remote Sensing (RS) of earth's surface are schematically illustrated in Fig. 1. The two basic processes involved are: 1) data acquisition and 2) data analysis. The basic elements of the data acquisition process, are: a) energy source, b) propagation of energy through atmosphere, c) energy interaction with earth surface, features, d) retransmission of energy through atmosphere, e) airborne and/or space-borne sensors, and f) generation of sensor data in pictorial or digital form.

The data analysis process involves: a) collection of ground data to assist interpretation, b) interpretation of pictorial data through visual means, c) interpretation of digital data with the help of a computer and d) preparation of maps from interpreted data.

A brief discussion of these elements, as relevant to the present topic, is given in the following paragraphs.

The Sun is the primary source of energy used in most of the RS system. The electromagnetic (EM) spectrum of the sunlight extends in wavelength from 0.3 to about 1 million µm (micrometre), as has been depicted in Fig. 2. The "visible" portion of this spectrum is extremely small, since the human eye can record EM energy only from 0.4 to 0.7 µm. The colour "blue" is ascribed to the range of 0.4 to 0.5 µm, "green" to 0.5 to 0.6 µm, and "red", 0.6 to 0.7 µm. Ultraviolet energy adjoins the blue end of the visible portion of the spectrum. Adjoining the red end of the near-IR (from 0.7 to 1:3 µm), mid-IR (from 1:3 to 3.0 µm) and thermal-IR (beyond 3 µm). The part of the EM spectrum, characterized by wavelengths ranging from 1mm to 1m, is known as microwaves. Most common RS systems operate in one or several of the visible, IR or microwave parts of the EM spectrum.

The solar energy (Fig. 3a) used for RS studies, has to travel through the earth's atmosphere, once from the sun to the earth and again, after reflection, from the earth's surface to the sensor mounted either on aircraft or satellite. The water vapour, carbon dioxide and ozone present in the atmosphere absorb or scatter some parts of this energy in specific wavelength bands, and prevent their transmission. Hence, these particular wavelengths cannot be utilized for RS purposes. On the other hand, some parts of the EM spectrum are not absorbed or scattered by the atmosphere and are freely transmitted. These regions of the spectrum are called "atmospheric windows" (Fig. 3b). Remote sensing data acquisition is limited to these "windows" only, as the transmission of both incident and reflective solar energy is maximum in these ranges. Different types of sensors used in RS operations, and having sensitivity corresponding to these "windows", are shown in Fig. 3c.

The radiation from the sun, after falling on the earth's surface, is either reflected, absorbed and/or transmitted. The proportion of the energy reflected, absorbed or transmitted, varies for different features on the earth's surface, depending on their material type and condition. These differences are detected by the airborne or space-

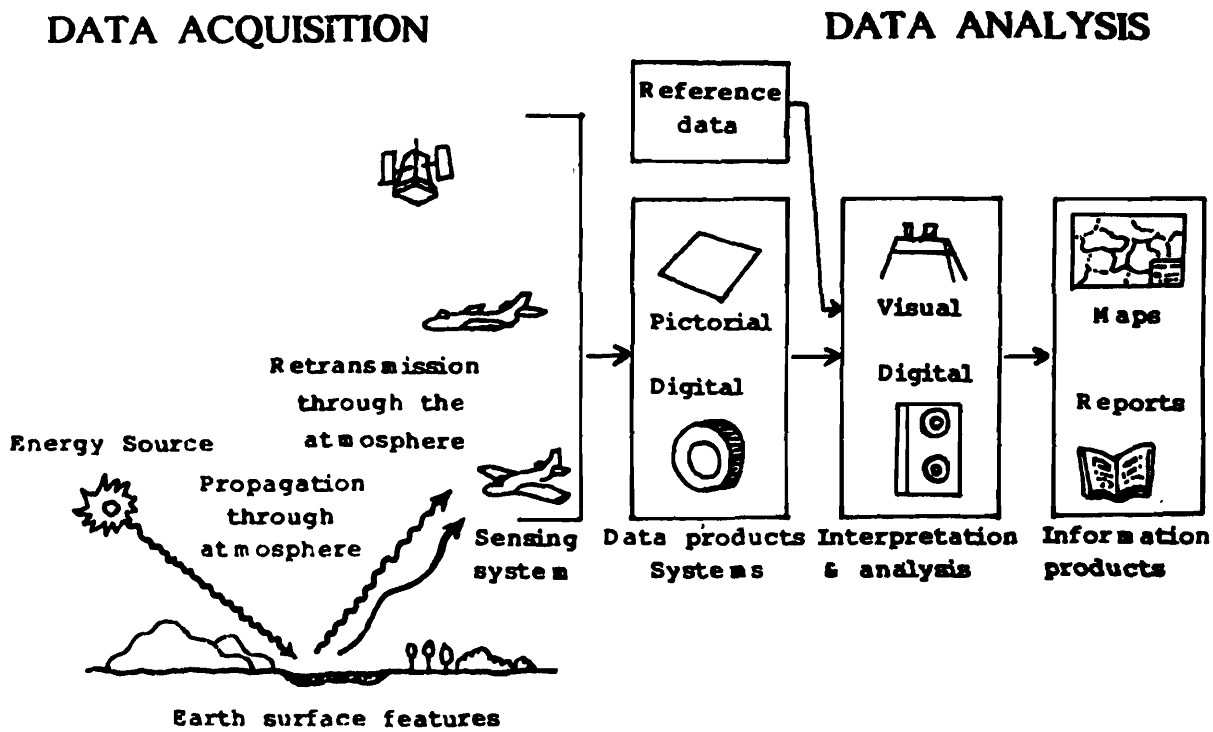

Fig. 1. Electromagnetic Remote Sensing of Earth.

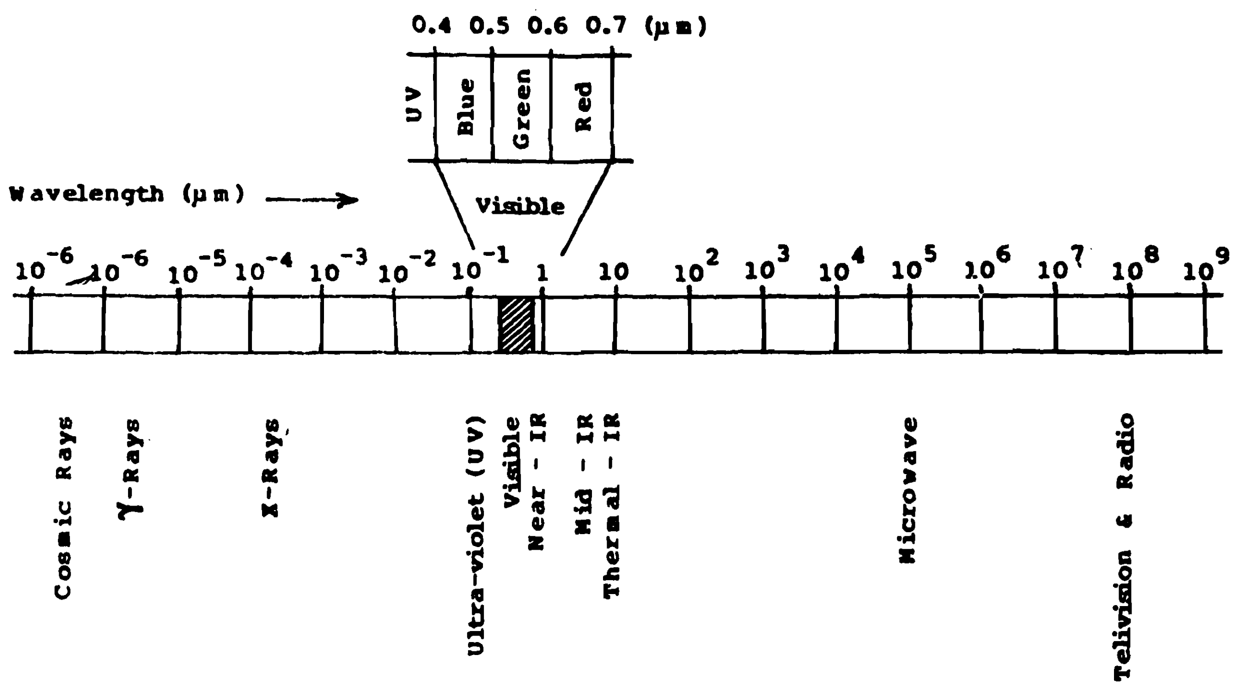

Fig. 2. Electromagnetic Spectrum.

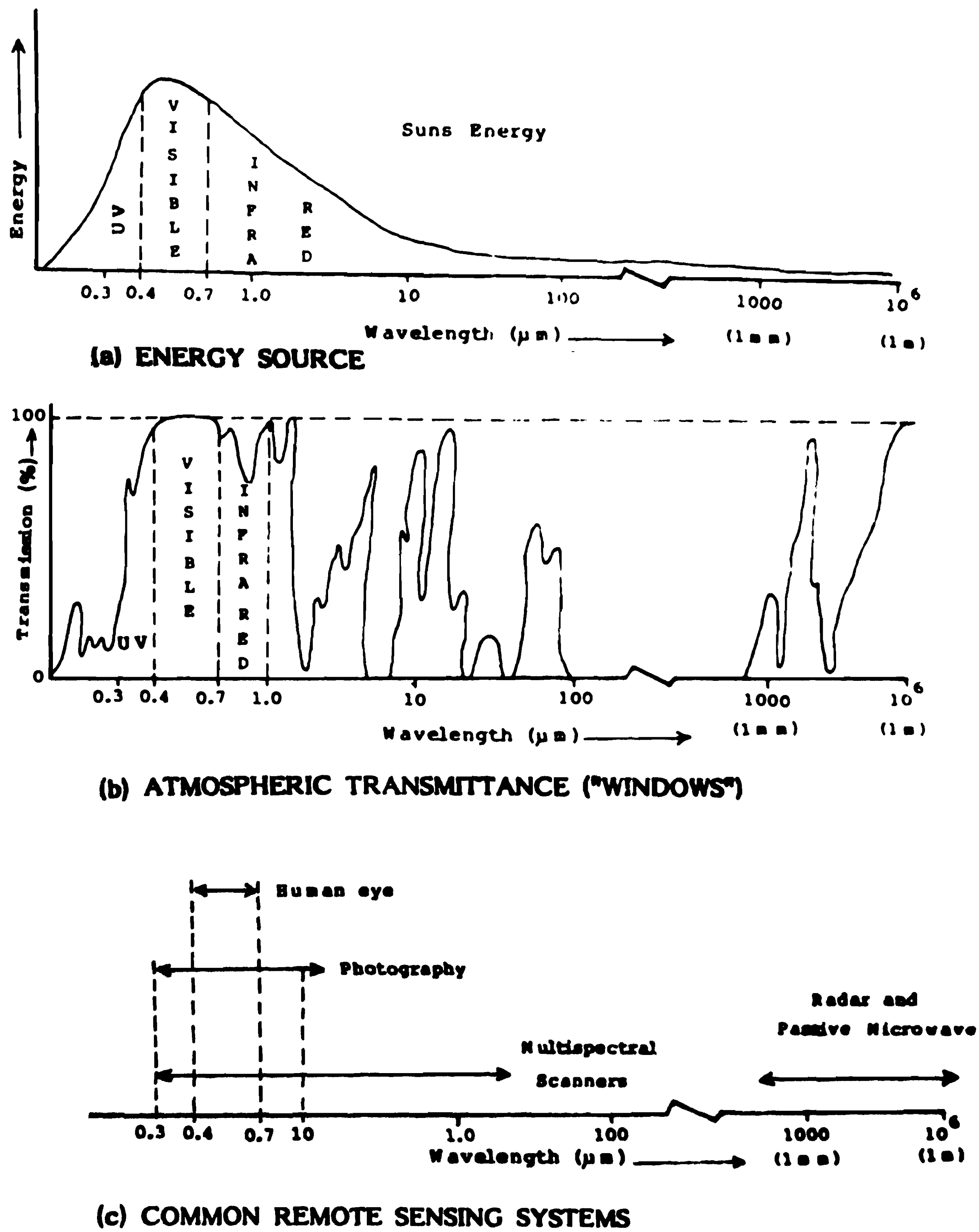

Fig. 3. Spectral Characteristics of: (a) Energy Source; (b) Atmospheric Effects; (c) Sensing Systems

borne sensors and permit us to distinguish between different features on a remotely sensed image. Moreover, for a particular type of terrain feature, the proportion of reflected, absorbed and transmitted energy varies with different wavelengths of the incident energy. Thus, two features of same type may be indistinguishable in one spectral range, but may appear to be very different in another spectral range. Because most of the RS systems operate in the wavelength regions in which reflected energy predominates, the reflectance properties of earth's features are very important. A graph of spectral reflectance of an object as a function of wavelength is termed as a "spectral reflectance curve" Such curves for vegetation, soil and water are given in Fig. 4. It is apparent from the figure, that although water and vegetation might reflect nearly equally in visible wavelengths, yet these features are clearly separable in near–IR wavelengths.

The sensors used in RS operations are of two types — a) Photographic and b) non-photographic (multi-spectral scanners). The photographic systems record the reflected solar energy from earth's surface in the 0.38 to 1.10 μm range (visible and near–IR) on photographic film housed in camera mounted on an aircraft. On development of the exposed film and printing on photographic paper, aerial photographs are produced.

The non-photographic sensors, also called multi-spectral scanner (MSS) can record energy over a wide spectral range (0.30 to 14.00 μm and 1mm to 1m). Such sensors can be operated both from aircraft and satellite. MSS are indispensable for satellite borne RS–system, as these are designed to transmit the digitized recorded data by telemetry to the data receiving stations on earth. A generalized satellite-borne MSS system (Fig.5) consists of:

a) Optical head with scanning mechanism.
b) Radiation defracting element to split the received reflected solar radiation coming from a single ground resolution element (GRE) into the required number of spectral band.
c) Electronic detectors, corresponding to each spectral band.
d) Recorder for storing digitized output from detectors.

Unlike aerial camera, which photographs the required part of the terrain at a time, the MSS system scans the ground, line by line, perpendicular to the direction of flight of platform (aircraft/satellite). The scanning rate is so adjusted with respect to the velocity of the platform, that succeeding scan lines are just adjacent to each other. Along the scan lines, the MSS system views only a small area of the ground at a particular instant of time. This is called instantaneous field of view (IFOB). The area on the ground corresponding to the IFOB is called the ground resolution element (GRE) or "Pixel" At a particular instant, the output signal of the scanner depends upon the net amount of radiation received from all types of terrain features lying within the GRE. Hence, finer features which fall within the GRE cannot be resolved or detected. Thus, the efficiency/sensitivity of a MSS system depends upon the smallness of the size of its GRE.

The GRE and spectral range of the 3 satellite borne MSS systems, whose data are available in India, are given in Table 1.

Table 1

Satellite System	Pixel size	Spectral Range (μm)						
		Band 1	Band 2	Band 3	Band 4	Band 5	Band 6	Band 7
1. LANDSAT-4 & 5	79m× 79m	0.5–0.6	0.6–0.7	0.7–0.8	0.8–1.1	x	x	x
2. LANDSAT-TM	30m × 30m	0.45–0.52	0.52–0.66	0.63–0.69	0.76–0.90	1.55–1.75	10.4–12.5	0.8–2.35
3. INDIAN REMOTE SENSING SATELLITE								
a) LISS-I	72m × 72m	0.45–0.52	0.52–0.59	0.62–0.68	0.77–0.86	x	x	x
b) LISS-II	36m × 36m	36m × 36m	36m × 36m	36m × 36m	36m × 36m	x	x	x
c) SPOT-1	10m × 10m	0.51–0.73	x	x	x	x	x	x
d) SPOT-2	20m × 20m	0.50–0.59	0.61–0.68	0.79–0.89	x	x	x	x

Note: TM — Thematic Mapper: SPOT — System Pour L'Observation de la Terre (French satellite)

Remote Sensing Data Products Suitable For Land Use and Land Cover Mapping

Air photographs: Aerial photography is one of the most common, versatile and economical form of remote sensing. Air photographs, when viewed under a stereoscope, affords a 3-dimensional terrain model which considerably aids in their interpretation. Successive air photographs have an overlap of 60% and stereo-viewing is possible only for the overlap area. The ground area covered by air photographs of different scale is given in Table 2.

Table 2

Photo-scale	Ground area covered by single photo	Effective ground area covered by a stereo-pair for stereoscopic viewing
1:60,000	13.8km x 13.8km	114.264 sq. km
1:25,000	5.8km x 5.8km	19.837 sq. km
1:10,000	2.3km x 2.3km	3.174 sq. km

The planimetric accuracy of air photographs, as are generally available to the indentor is rather low. However, with special rectification and adequate ground reference data, highly accurate and contoured topographic maps can be generated from air photographs. For preparing detailed Land use and Land cover maps; 1:10,000 scale air

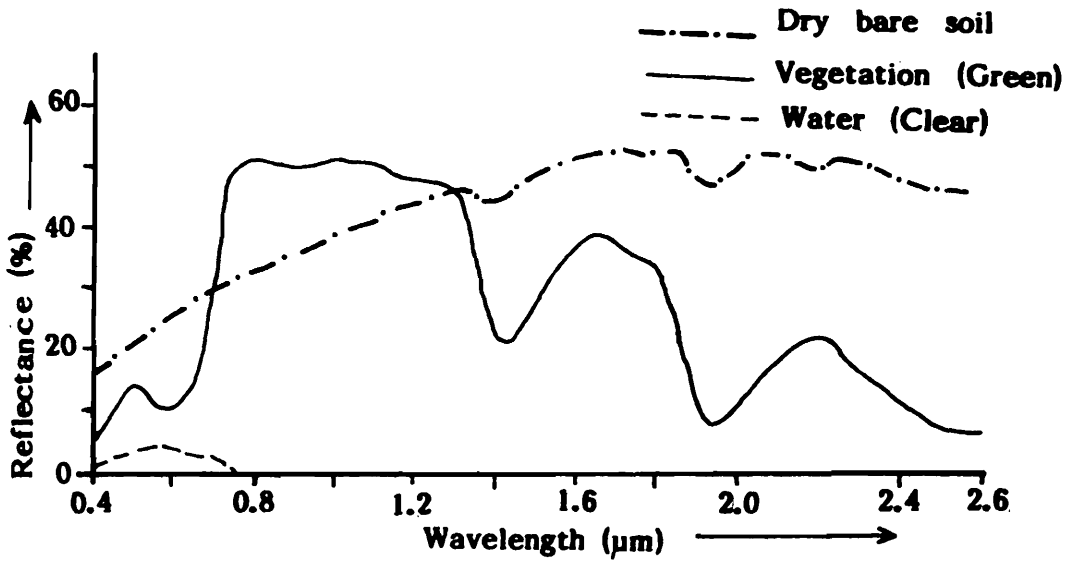

Fig. 4. Typical Spectral Reflectance Curves for Soil, Vegetation and Water.

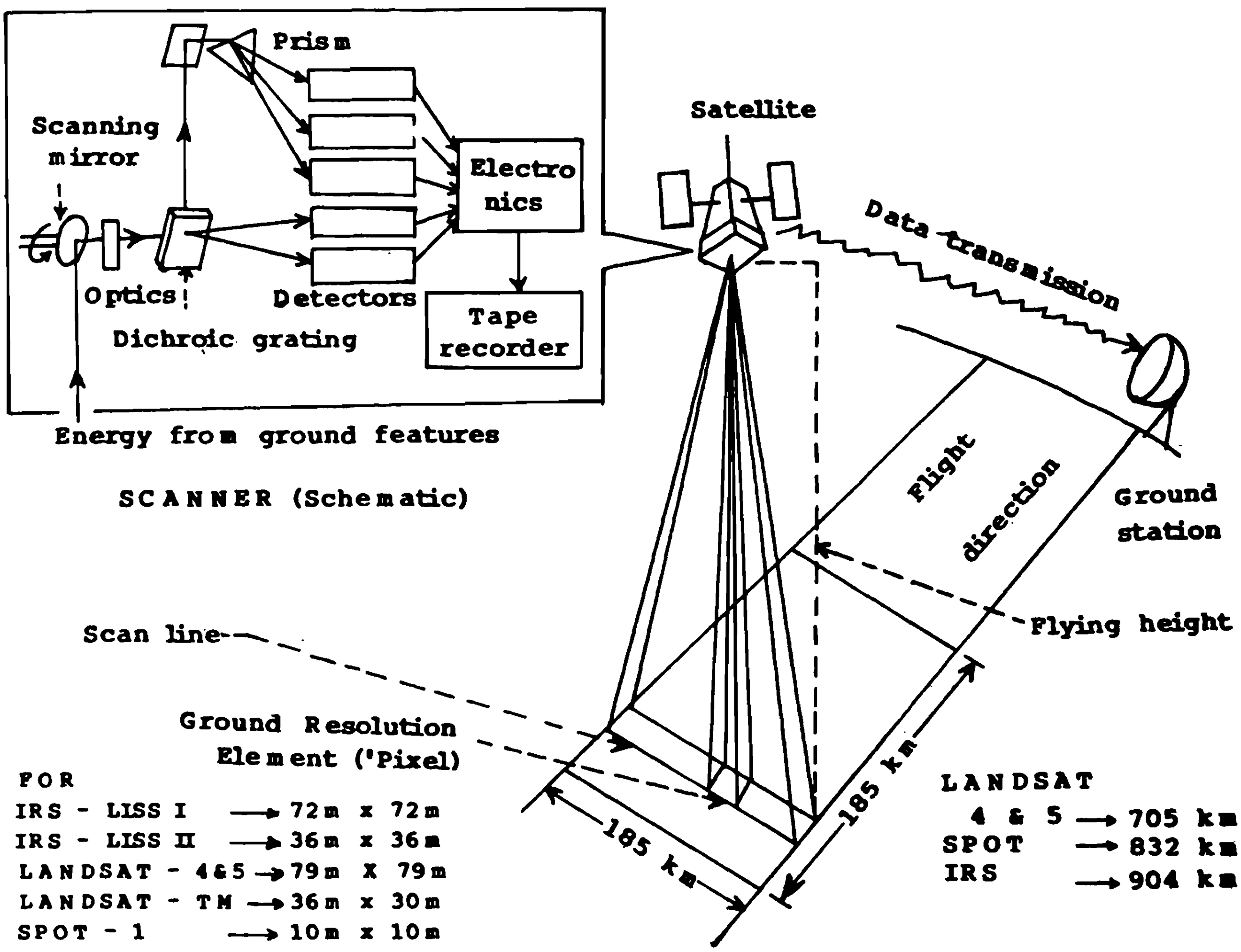

Fig. 5. Satellite-borne Multispectral Scanner System.

photographs, and for semi-detailed maps, 1:25,000 or 1:60,000 scale air photographs are found to be highly useful. Aerial photography in India is controlled and coordinated by Survey of India, having its headquarters at Dehra Dun (U.P). Aerial photographs, irrespective of their scale, are considered as classified documents and can be procured from Survey of India, only after obtaining a clearance from the Ministry of Defence.

Satellite imagery: Satellite imageries do not permit 3-dimensional viewing, but have a very high degree of planimetric accuracy. Satellite imagery should be considered as a complementary, interpretative tool, instead of a replacement of air photographs, for Land use and Land cover mapping. The most suitable form of imagery for this purpose is False Colour Composite (FCC) on 1:50,000 scale paper prints. The FCC are generated from MSS data obtained from LANDSAT (MSS & TM), IRS (LISS-I & II) and SPOT satellites, by printing data of 3 spectral bands (Ref. Table 1), in registration, on to colour film. Generally Band-1 data is printed in blue, Band-2 data is printed in green and Band-4 data is printed in red. The result is a "false colour" composite imagery, in which the blue images result from objects reflecting energy in the green spectral band, green images result from objects reflecting energy in the red spectral band and red images result from objects reflecting energy in near-IR spectral band. Satellite imageries are not considered as classified documents and can be freely procured from Data Centre of National Remote Sensing Agency, located at Hyderabad (A.P.). The price list of "Geo-coded" FCC paper prints on 1:50,000 scale is given in Table 3. A single FCC covers an area of nearly 700 sq. km on ground and corresponds to the standard 15'× 15' Survey of India topo sheet on 1:50,000 scale of the same geographic location.

Table 3

	Satellite	Data produced	Scale	Price (Rs)
1.	Indian Remote Sensing Satellite	False Colour Composite (1000mm paper print)	1:50,000	2,300
2.	LANDSAT Thematic Mapper	False Colour Composite (1000mm paper print)	1:50,000	8,300
3.	SPOT Multi-spectral Linear Array (MLA) data	False Colour Composite (1000mm paper print)	1:50,000	6,700

Note: Price as on 31.3.1993.

Preparation of Land Use and Land Cover Map Using Remote Sensing Techniques

As per the directives of the Department of Environment, the land use studies, in connection with the preparation of EIA and EMP for proposed, as well as existing projects are to be carried out in two different categories – a detailed study in the Core Zone and a semi-detailed study in the Buffer Zone.

Core-Zone: This zone covers the entire area of the actual project site and varies in size from project to project. The land use data generated are presented as a table, indicating the percentage of the Core Zone occupied by each land use and land cover class. The spatial distribution of such classes are depicted on a large scale map (preferably 1:10,000 scale).

Buffer Zone: This zone covers a circular area (314 sq. km) surrounding the proposed/existing project site, having a radius of 10 km, measured from the central point of the Core Zone. The land use and land cover data are presented as a table, indicating the percentage of the Buffer–Zone, occupied by each land use and land cover class. Their spatial distribution is depicted on a 1:50,000 scale map.

The land use and land cover studies in the Core Zone help to identify and to some extent quantify the immediate impact of the various anticipated project activities that might lead to permanent changes in the existing land use pattern in the areas lying within the project site. It also helps in the formulation of the mitigative measures to be incorporated in the Environmental Management Plan (EMP). For example, the impact of the envisaged project would be "severe" if the land to be occupied by it belongs to such land use classes, as forest land, fertile agricultural land, residential land or any other land use category that supports and sustains the local eco–system, including human population. The impact of the same activities would be much less "severe" if the project is located in waste land. Thus, it is apparent that land use studies are essential not only for the preparation of EIA/EMP documents, but also for initial siting of the project, so that its adverse impact on the existing land use pattern can be minimised.

Land use studies in the Buffer Zone of the envisaged project, bring to light the possible changes in the land use pattern over a much larger area that might be induced due to large scale influx of outside people, enhanced economic and constructional activities and opening of ancillary industries. Such studies also help to locate suitable land for compensatory afforestation and resettlement of persons displaced from their home, due to the project.

Land use and Land cover Map: Preparation of Land use map, based on RS Techniques, starts with the preparation of Land cover map, from the data interpreted from air photographs and FCC. Subsequently, each land cover class is studied in the field of determine the actual use to which it is put by the local people, and a Land use map is generated. In case detailed field work is not possible due to terrain constraints, the map is designated as a Land use and Land cover map. The various land use classes and sub–classes that can be mapped by these techniques are given in Table 4.

Preparation of Land use and Land cover Maps: The preparation of land use and land cover map of the generally small core areas of most of the projects can be done by ground surveys, using telescopic alidade with plane table or microptic theodolite. But similar survey techniques can not be utilized, because of time and cost constraints, in case of Buffer Zone mapping in general and Core Zone mapping of large project sites like, open cast coal mines. Cadastral Survey Maps (16"= 1 mile scale) or "Mouja Maps", with suitable changes in the index, can be utilized for preparing land use and land cover maps of Core Zones. But the large scale of such maps does not permit their use in the preparation of land use and land cover maps of the Buffer Zone, as the resultant map will be too large for handling.

Table 4

	Land use classes		Sub–classes	
1.	Agricultural land	a)	Irrigated	Mono crop Multi crop
2.	Agricultural land formed due to shifting cultivation		Non-irrigated	Mono crop Multi crop
3.	Forest land	a)	Dense forest	
		b)	Moderately dense forest	
		c)	Open forest	
4.	Forest land (degraded)			
5.	Forest plantation land			
6.	Grove land including orchard			
7.	Scrub land	a)	Dense scrub	
		b)	Moderately dense scrub	
		c)	Open scrub	
8.	Waste land	a)	Cultivable	Pasture
		b)	Non–cultivable	Sandy waste Stony waste Gullied waste
9.	Mining land	a)	Surface installations	
		b)	Open cast quarries	
		c)	Dumps	
10.	Industrial land	a)	Surface installations	
		b)	Waste dumps	
11.	Residential land	a)	Urban – Cities, towns, industrial colonies, mining colonies, commercial, recreational	
		b)	Rural	Village
12.	Communication/transportation corridors	a)	Roads	Metalled unmetalled
		b)	Railway line	
		c)	Electric transmission lines	
13.	Surface water bodies	a)	Rivers	Major Minor
		b)	Reservoirs (man made)	
		c)	Lakes	
		d)	Tanks/Ponds	

In view of these constraints, a method has been developed for preparation of land use and land cover maps, of both Core and Buffer Zones, based primarily on the interpretation of air photographs, and space imagery, followed by selective ground checks. This method has been effectively utilized for the preparation of such maps for 3 coal mines in Raniganj Coal field, 19 iron ore mines in Orissa and Jhamarkotra phosphate mines in Rajasthan.

Data Product Required: a) Air photographs on 1:10,000 and 1:60,000 scales; b) latest available False Colour Composites (FCC) of LANDSAT or IRS Space imagery on 1:50,000 scale – preferably one of post–monsoon period and one of summer period.

Equipment required: a) Pocket stereoscope, b) Mirror stereoscope with binoculars, c) Optical pantograph and d) Digital planimeter.

Methodology: The air photographs are studies under the mirror stereoscope and interpreted data are traced on a transparent plastic film, while the photos are in stereo fusion. With the help of the optical pantograph, the interpreted data are transferred from the film to the plotting base. The land use and land cover map of the Core Zone is prepared from 1:10,000 scale photographs and the photo–interpreted data are plotted on contoured site map of 1:10,000 scale or any available map of sufficiently large scale. In case such maps are not available, uncontoured maps on photo–scale are generated from the air photographs, after subjecting the interpreted data to certain photogrammetric methods for scale corrections. Similar maps for the Buffer Zone prepared on the basis of data interpreted and mapped from 1:25,000 or 1:16,000 scale air photographs. These data are transferred either visually or by optical pantograph to the corresponding, Survey of India, Topographic Sheets on 1:50,000 scale. If the available air photographs are out dated, the interpreted data are suitably updated with the data interpreted from space imagery (FCC). The photo–interpreted land use and land cover maps are taken to the field and subjected to ground verification. Generally, the Core Zone maps, because of their small ground coverage, are thoroughly checked while the Buffer Zone maps are checked at a few critical points selected on the basis of their accessibility. The areas occupied by the different land use and land cover, classes are measured from the maps with the help of digital planimeters. In this connection, it may be mentioned that application of digital enhancement techniques, such as band rationing, contrast stretching and principal co-ordinate transformation, applied to the Computer Compatible Tape (CCT) data from the Indian Remote Sensing Satellite, has yielded highly encouraging results in connection with the land use and land cover studies and their mapping, carried out in iron-ore mining areas of Orissa, on an experimental basis, under the sponsorship of TISCO.

Time Scale: On the basis of the experience gained from the land use and land cover mapping projects completed so far, the time required for the different steps can be generalised, and these have been tabulated below:

a)	Scale of air photo used.	1:10,000	1:60,000
b)	Area covered by one stereopaired photograph.	3.174 sq. km	114.264 sq. km

c)	Time required to interpret one stereopaired photograph.	8 interpreter hours	5 interpreter hours
d)	Time required for ground checking.	18 man-hours	60 man-hours

Note: The time required to interpret and ground checking is likely to increase for hilly terrain and areas of complex/diverse land use.

Results

From 1:10,000 scale air photographs used for the mapping of Core Zone it has been possible to demarcate 13 major land use and land cover classes and 49 sub-classes. Out of these, 10 major classes and 23 sub-classes could be demarcated from 1:25,000 and 1:60,000 scale air photograph used for the mapping of the Buffer Zone. From 1:50,000 scale FCC imagery only 8 major classes and 13 sub-classes could be demarcated. However, it should be kept in mind, that all of these land use and land cover classes did not occur in a single area, but is a cumulative total of data obtained from all the lahd use mapping projects undertaken so far.

From these figures, the data-yielding capacity of the FCC imagery might appear to be limited, but multi-data FCC imageries are excellent tools for differentiating between mono-crop and multiple crop agricultural land and classifying Forests into density classes. But these density classes are qualitative and refer to the crown density. It does not refer to the quantified density classes worked out on the basis of number of trees of a particular specification, occurring within a unit area.

In case forest land occurs within the Core Zone of a proposed/existing project, apart from depicting such forest land in the land use maps, its administrative status (Reserve forest, protected forest, 'Khesra' forest, Village forest etc.) is to be clearly mentioned in the EIA/EMP. This is mandatory, as the conversion of such land for mining or any other purpose will attract the attention of the Forest Conservation Act and a detailed administrative procedure will have to be followed, for getting a clearance from appropriate authorities. Moreover, a land which has been recorded as a forest land in the land record, may not have any forest growth at present and detection of such lands is not possible through remote sensing techniques. Hence, detailed field work coupled with collection of data from the local land record/forest office is necessary, for supplementing the land use and land cover map.

Suggested Readings

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REMOTE SENSING APPLICATION IN MONITORING COASTAL LANDFORMS AND ECO-SYSTEM

PARTHASARTHI CHAKRABORTY*

Introduction

The coastal zone is rich in biodiversity. The mangroves, reefs, intertidal and wetlands are vital breeding, nursery and feeding areas for the majority of marine species. On the other hand, the coastal zone being the interface between land and sea, is constantly shaped by varied interaction of fluvial, marine (both tides and waves) and aeolian processes. The geomorphic and geological set up in these areas largely depends on the interplay between Clastic sediments introduced from one direction by the rivers of variable magnitude and the strength of the wave/tide energy which acts in the opposite direction. In response to that a good understanding between the changeable landform features and related land use/land cover is very essential for maintaining the natural eco-system, to the extent possible, of the coastal zones, especially when the natural set up is being largely threatened by various anthroposgenic activities starting from checking the upland fluvial discharge, reclamation of coastal low lands and wet lands, destruction of mangrove forests and coral reefs etc.

Such change detection studies require continuous monitoring of the coastal landform features and the land cover/land use pattern. In this respect utilisation of the aerospace data not only provides a wealth of subject specific information to the users community in a cost effective manner (considering both time and economic aspects) but also quality is much more improved than the traditional means of approaches. It is now being an established fact that the remote sensing application is very suitable for one time inventories and surveys as well as for continuous monitoring in time and space of natural resources and human activities.

Remote Sensing

Remote Sensing is the science or technology to collect thematic and geometric information of an object without having any physical contact with the object. in the present context, the term Remote Sensing is restricted to identify various objects on the earth's surface using visible (0.4 to 0.7µm), infrared (0.7 to 0.5µm), thermal infrared (8 to 14µm) and microwave (0.1 to 30 cm) regions of solar radiation (EMR) which is reflected, emitted or scattered by the objects depending on its physical and chemical properties. The remote sensing techniques are classified into tow types depending on the source of energy which illuminate the object under study viz. i) passive remote sensing and ii) active remote sensing. In passive remote sensing system, the naturally radiated or reflected energy from the earth's surface features is measured by the sensors operating in different spectral bands onboard the airborne/space-borne platforms. An active remote sensing system supplies its own source of energy to illuminate the objects and measures the reflected energy returned to the system.

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System Overview: The essential pre-requisites for collection of remote sensing data are:

A. Platform

B. Sensor

PLATFORM	**Ground borne**		
	Airborne	1.	High altitude (>15 km from earth's surface)
		2.	Low altitude (<15 km from earth's surface)
	Space-borne	1.	High altitude (36,000 km above – geo-stationary, e.g. INSAT)
		2.	Low altitude (700-900 km above – Sun-synchronous e.g., Earth Resources satellite, e.g., IRS, SPOT, LANDSAT, ERS-1)
SENSOR	**Image forming**		
	Non-image forming		

We are more concerned about the image-forming sensors.

IMAGE FORMING SENSOR	Active (e.g., microwave radar) Passive (e.g., Photographic camera, Television camera, optical scanners, – normally in the atmospheric windows)

These sensors are being used in airborne or space-borne platforms to assist in mapping, monitoring of earth resources. In case of airborne survey we are getting direct photographs of the earth's surface with overlapping portions (minimum 30% forward overlap). Two photographs with such overlapped portions are called 'stereo-pairs' or 'stereo-mats' and are used under stereoscope for getting 3D vision.

The aerial photographs (black & white) are available in different scales ranging from 1:60,000 to 1:10,000. The scale of A.P. depends on the flying height of the aircraft and focal length of the camera used.

$$S = H/f$$

where S = scale of the photographs,
H = flying height and
f = focal length/ principal distance of the lens.

In general, three types of aerial photography are used for various purposes:

a) Vertical Photography;

b) Orthophotos and

c) Oblique photography, comprising:

   i) High angle

   ii) Low angle

In India, Survey of India is the controlling authority for air photos.

The satellite data is available in digital form based on 'greyvalue variations' (DN values ranging from 0-255) and is supplied on CCT's (Computer Compatible Tapes). The satellite images or hard copy are prepared in the laboratory using CCT data. In general, the scales of data products vary from 1:1 million to 1:50,000. The receiving station for satellite information is at Sadnagar, Hyderabad. The National Remote Sensing Agency, (NRSA), Dept. of Space, Govt. of India is the authority for satellite data.

Hard copy imageries are available in Panchromatic (B/W) mode as well as in False Colour Composite (FCC) mode. The CCT's are also used directly in the Digital image processing system. The imagery of different type of earth observing satellites available in India are IRS, LANDSAT, SPOT (both in B/W and FCC), ERS-1 (B/W) and CCT's.

Based on the tone, texture, pattern, shape/orientation etc. the different features are identified in aerospace data products by the interpreter.

In recent decades, with the advancement of the scientific and technologic world, the aerospace data products especially the space-based earth observation system (i.e., satellites) provides more "operational" information due to its repetitive cycles which varies from 4 days in case of NOAA to 26 days in SPOT. The LANDSAT series of satellites have a repeat period ranging between 16 to 18 days whereas, in case of IRS it is 22 days. Presently, in Indian context we are having IRS-1A and IRS-1'B with 11 days repeat period as a whole. Unlike other satellites which have a fixed repetitive cycle, the ERS-1 satellite is manoeuvred to revisit the same place after 3, 35 and 176 days to meet the various application requirements. The resolution of the satellites also varies from one to the other (Table 1, on following page).

Basically, the information delivered by the operational earth observing satellites is used by two user communities viz.:

Scientific users: whose role is to develop and maintain the knowledge base which is scientific and technologic foundation of the entire system.

Operational users or thematic users: who participate in the economy directly and whose output has direct economic value e.g. earth scientists, engineers, planners are customers who can utilise the thematic information extracted from the RS data.

RS Data in Coastal Zone Study

In the present day scenario, in comparison to the Survey of India (SOI) toposheets, photo-mosaics and/or up-to-date geocoded satellite data products of similar scale (i.e. 1:50,000) provide more quantifiable information about the morphology, morpho-arrangement, morpho-genesis and constituent materials of the different landform units as well as the existing land cover/land use pattern at a glance to the users (Table 2).

In coastal zone/esturarine areas the common landforms/mapping units are:

a) marine cliffs and notch zones,
b) marine wave cut platforms,
c) beaches, beach ridges/runnels, spits and tombole bars,
d) coastal dunes (active, inactive or dormant),
e) vegetated/non-vegetated tidal sandy/mud flats,
f) marine terraces/flood plains,

g) coral reefs/reef flats/reef caps/uplifted reefs,
h) ramparts and cays,
i) lagoons,
j) fluvio-deltaic flats.

Table 1

Different Earth Observing Satellites		
	Launched on	**Resolution**
NASA (U.S.A.)		
ERTS—1	July 1972	**79 Mts**
ERTS—2 (Renamed as LANDSAT-2)	January 1975	**79 Mts**
LANDSAT-3 (New Generation Satellite)	March 1978	**79 Mts**
LANDSAT-4	July 1982	79 Mts
LANDSAT-5	March 1984 TM (7 Septral bands)	79 Mts 30 Mts
LANDSAT-6 Failure		
FRENCH SATELLITE		
Spot - 1	February 1986	Pan 10 Mts. MLA 20 Mts.
Spot - 2	January 1990	Pan 10 Mts. MLA 20 Mts.
EUROPEAN SATELLITE (Microwave Remote Sensing)		
ERS- 1	July 1991	SAR 25 Mts.
INDIAN SATELLITES		
Experimental Satellites:		
Bhaskara- I	June 1979	
Bhaskara- II	November 1981	
Operational Satellites:		
IRS- 1A	March 1988	LISS-I 72.5 MTS.
IRS- 1B	August 1991	LISS-II 36.25 MTS.
IRS- 1C	Tentative Launch in 1994 - 1995.	PAN 10 MTS. LISS-III 2.3 MTS. (5 days repeat cycle for PAN) (24 days repeat cycle for LISS-III)

Table 2

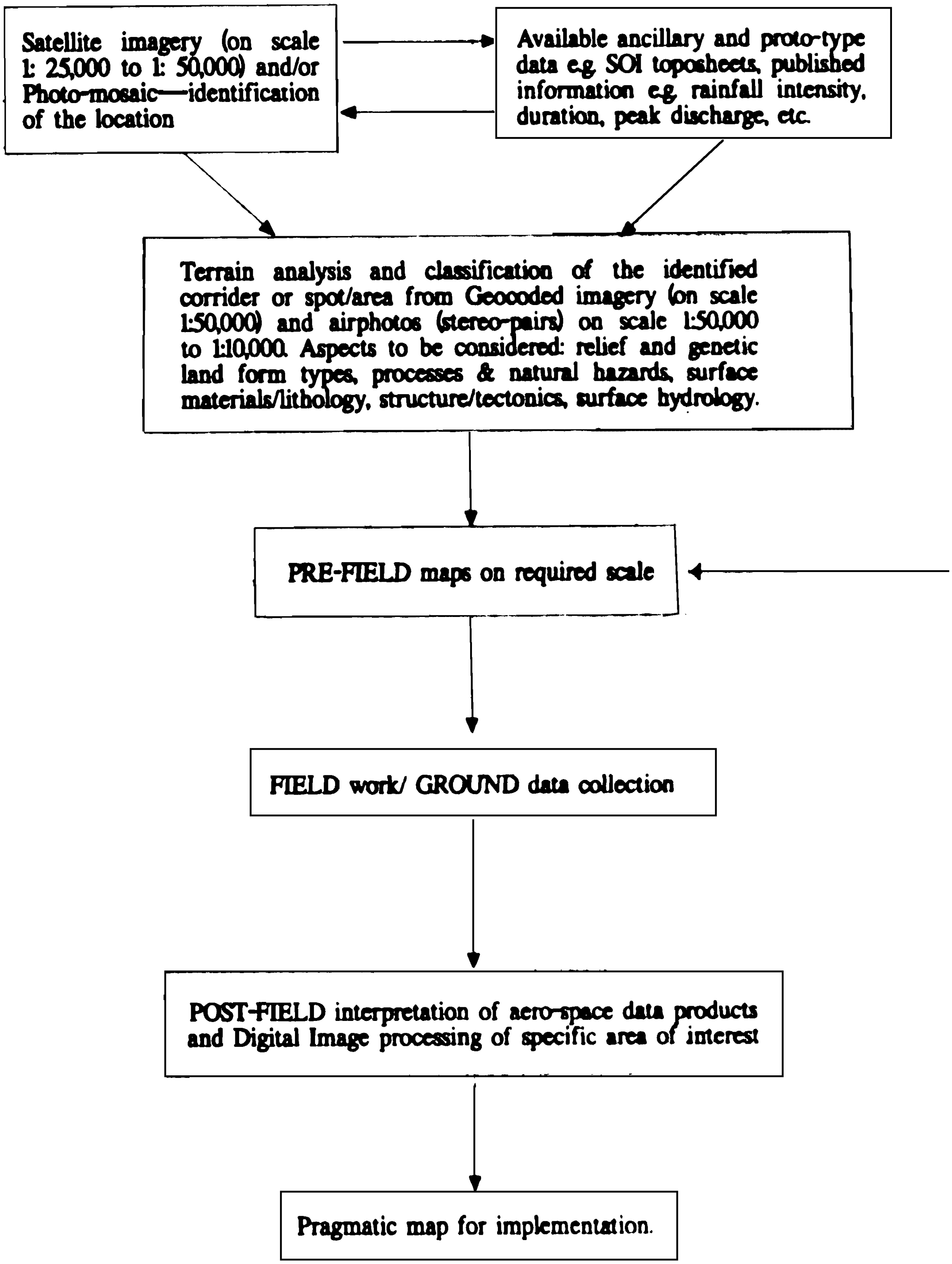
APPLICATION OF RS DATA

- ★ Landuse Land cover mapping
  - Forest Land
  - Agricultural Land
  - Built-up Land
  - Waste Land
  - Wet Land
- ★ Crop inventory and crop yielding forecasting
- ★ Applied Geomorphological Studies
  - Drought monitoring Desertification
  - Food monitoring (both fluvial & coastal)
  - Soil erosion
  - Landslide monitoring
- ★ Geotechnical Investigation
  - Dam/Reservoir site selection
  - Highway/Railway route selection
- ★ Groundwater targetting
- ★ Geology & Mineral Resources
- ★ Urban Planning
- ★ District/Watershed level Planning
- ★ Marine fishing

↑ Environmental Impact Assessment

Table 5

MULTI-PHASE APPROACH IN USE OF RS DATA



In response to the repetitive coverage, multi-seasonal or time-critical satellite imagery could be use to monitor the spatial variation of the aforesaid landform units/mapping units, the fluctuation of the inundated area of the tidal flats or the nature of the tidal creeks through seasons. Change detection in the mangrove forest boundary or deforested patches could also easily be identified in the RS data products as the broad leaf, healthy mangroves have their very characteristic reflection pattern. It may be mentioned here that the range of scales for surveying and or resolution of the RS data are also to be subject specific i.e., varies with the nature of the project undertaken. For instance, monitoring of the shore line changes requires more resolution than those needed in study of general landform features. In view of that a 'zooming-in' or multiphase approach is suggested starting from use of geocodes imagery/aerial photographs (on scale 1: 50,000) to air photos or digitally enhanced imagery (on scale 1:25,000/20,000/10,000) with subsequent field checks (Table 3).

Conclusion

Remote sensing data provides spatial, spectral and temporal information of any object on the earth surface. We can make good use of this information by extracting purpose-oriented data (both visual as well as digital methods) for preparation of pre-field maps. But the users capabilities to make good use of the information obtained is an important factor. The intelligence, capacity and experience of an interpreter or as a whole the 'absorption capacity' and 'application capacity' of an interpreter plays an important role in identifying the various features discussed above. In response to that substantial amount of field check on ground data collection is all the time preferable in finalizing the maps.

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NOISE LEVEL: MEASUREMENT & STANDARDS

A. K. SAHA*

Introduction

Noise is proportional to the pressure exerted on the ears by sound waves. The unit of sound pressure level is called *decibel*, which is based on a logarithmic scale, $20 \log_{10} \frac{P_1}{P_0}$; where P0 is the pressure at the threshold of hearing, *e.g.*, $2 \times 10^{-5} N/m^2$ (or .0002 dynes/cm^2). This may be compared with normal atmospheric pressure of 106 dynes/cm^2

Thus if the pressure of a sound is 200 N/m^2 (or 2000 dynes/cm^2), then sound pressure level (SPL)

$$= 20 \log_{10} \frac{200}{2 \times 10^{-5}} = 20 \log_{10} 10^7 = 20 \times 7 = 140 \text{ dB}$$

Note: SPL at threshold of hearing is zero dB.

Sound intensity is proportional to the square of sound pressure

$$I \alpha p^2$$

$$\frac{I_1}{I_0} = (P_1 / P_0)^2, \text{ so dB} = 10 \log (P_1 P_0)^2 \; 10 \log I_1 / I_0$$

where the ref. Pressure, $P_0 = 2 \times 10^{-5} N/m^2$
$I_0 = 10^{-12}$ Watt/m^2

Sound level meter

The sound level meter used for the measurement of sound pressure levels consists of a microphone amplifier and a meter. The microphone converts the sound pressure waves into electrical voltage which operates the meter. But no single meter could indicate such a large range as 30 dB to 120 dB or more. To overcome this, amplification is altered as required in steps of 10 dB, and the meter records the difference between the amplifier settings and the sound pressure level.

Now audible sound waves vibrate at rates varying from 16 cycles/sec. to 8000 cycles sec. (Hertz). This entire range of frequencies is classified into Octaves or bands with centre frequencies as follows: 16, 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000 Hz. Many Sound Level meters are connected to electrical filters which select particular frequencies of the sound. In some instruments, the pressure level is recorded on charts or tape.

Instead of measuring SPL on a linear scale, most meters have A and B scales, in which the response varies with frequency, as shown in Table 1. Readings on the A scale, dB(A),

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correspond most closely to the response of the human ear. As response of the ear is dependent on frequency, readings of SPL on a linear scale can be misleading.

Table 1

A, B and C weightings			
Frequency (Hz)	**Curve A (dB)**	**Curve B (dB)**	**Curve C (dB)**
16	-56.7	-28.5	-8.5
31.5	-39.4	-17.1	-3.0
63	-26.2	-9.3	-0.8
125	-16.1	-4.2	-0.2
250	-8.6	-1.3	0
500	-3.2	-0.3	0
1000	0	0	0
2000	1.2	-0.1	-0.2
4000	1.0	-0.7	-0.8
8000	-1.1	-2.9	-3.0
16000	-6.6	-8.4	-8.5

Thus a 30 Hz note of sound pressure level 70 dB would indicate 70–40 = 30 dB(A) or 70–17 = 53 dB(B) or 70–3 = 67dB(C). The C-scale is taken to be linear for most practical purposes.

Knowing the dB values for the different octaves, it is possible to calculate the total sound pressure level. But this cannot be done arithmetically, because the dB scales are logarithmic. For this purpose, a curve or nomogram is used.

Example: Calculate the sound pressure level in dB(A) with the following analysis:

Centre frequency (Hz)	31.5	63	125	250	500	1000	2000	4000
SPL, dB(A)	20	33	48	62	62	65	45	40

The dB(A) values in each octave are added in pairs, as follows:

Frequency (Hz)	Level dB(A)	Sum dB(A)	Sum dB(A)	Sum dB(A)
31.5	20			
		33.2		
63	33			
			62.2	
125	48			
		62.2		
250	60			
				68.1
500	62			
		66.8		
1000	65			
			66.8	
2000	45			
		46.2		
4000	40			

Calibration of sound level meters: This is usually done using a pistonphone which fits over the microphone of the sound level meter. The pistonphone produces a note of 250Hz at 124dB; inside the pistonphone a small motor operates a cam, producing the sound by sinusoidal movement of two small pistons. This method is also convenient as a standard source of sound.

Environmental Effects of Noise

Environmental impact of noise can have several effects varying from hearing loss to annoyance. Specifically, sufficiently loud noise may–

a) damage hearing or health.

b) interfere with work tasks.

c) interfere with speech communication.

d) affect inter-room privacy.

e) interfere with sleep.

f) cause annoyance and in many cases raise blood pressure.

Noise sensitivity of certain land uses is as follows:

Very sensitive	Educational facilities, hospitals, wildlife sanctuaries.
Sensitive	Residential buildings, dormitories, resort hotels.

Moderately sensitive	Research institutions, Restaurants, Professional Offices.
Insensitive	Agriculture, mining and metal extraction, natural open space, motor vehicle transport, auto parking, market places, etc.

Damage risk criteria have been developed in the USA, so as to reduce hearing loss, as follows:

Table 2

Maximum allowable per day (hrs.)	Noise level (dBA)
16	85
8	90
6	92
4	95
3	97
2	100
1	105
½	110
¼ or less	115

D.O.En. in India has prescribed the following maximum permissible noise exposure levels (in dBA). Actually this is the same as in the UK.

90	8 hrs
93	4 hrs
96	2 hrs
99	1 hr
102	½ hr
105	¼ hr
108	7.5 minutes

Acceptable outdoor noises: [IS 4954, (1968)]

Location	dBA Noise level range	
	Day	Night
Rural	25 - 35	20 - 30
Residential (urban)	35 - 45	30 - 40
Urban (mixed)	40 - 50	35 - 45
Urban (commercial)	45 - 55	35 - 45
Industrial	50 - 60	45 - 55

Some other countries have slightly higher levels for urban residential areas–

Country	Noise level	
	Day	Night
India	35 - 45	30 - 40
Sweden	55	45
Germany	60	45
Switzerland	60	50
U.K.	55	45

Outdoor Sound Propagation

Outdoor propagation of sound is influenced by–

(a) weather, i.e. local micrometeorology; interaction of humidity and temperature; atmospheric turbulence, wind direction and velocity on sound propagation has been studied and can be quite complex;

(b) presence of topographic barriers;

(c) presence of tree barriers;

(d) presence of building barriers;

(e) sound attenuation by rain, snow or fog.

In an EIA study, outdoor sound attention is studied by simultaneous recording of SPL at different distances and in different directions from the proposed noise generator by a loud siren placed at that site. This experiment has to be done in different seasons of the year. Measures have to be taken to increase noise attenuation if the expected noise is excessive particularly in residential colonies. One effective method is the creation of appropriately located green belts. Another effective method is to build high walls or earthen structures close to the noise source.

EIS for Noise

Typical noise assessments in the EIS should include comparisons of existing and anticipated noise levels with the criteria established by Govt. agencies. A typical EIS should have the following subheads:

1. Existing Noise

   (a) Describe existing noise levels.

      1) Measurement results.

      2) Modelling results.

   (b) Determine current noise regulations.

   (c) Assess the existing noise environment.

2. Noise Impact
   (a) Determine the potential noise sources associated with the project.
      1) Motor vehicle noise.
      2) Airport and aircraft noise.
      3) Train noise.
      4) Stationary noise sources.
   (b) Describe the noise characteristics of the project.
      1) Through comparison with an existing similar project.
      2) Through acoustic modelling of the noise sources associated with the project.
   (c) Determine the noise sensitivity of surrounding land uses as well as the noise sensitivity of the project.
   (d) Assess impact of the project on surrounding land uses.
3. Develop mitigation measures for potential impact.
4. Discuss noise consideration of alternatives to the project.

Broad Guidelines for Planners of Town and Industrial Sites

Location of Aerodromes: New aerodromes should be located sufficiently away from the city (at least 15 km away) and a boundary area of 6-8 km square should be set apart for the aerodrome, so that residential accommodation may come up only beyond that area. When planning the routes for flying into and out of an airport, it is necessary to avoid flying over towns of thick populations.

Layout of Rail and Road Traffic: The rail tracks, highways and arterial roads should preferably be routed away from the residential area and commercial areas. However, if due to other considerations, a railhead or line has to be located in or near a residential area, certain precautions to abate the noise shall have to be taken. One method for reducing noise from rail tracks is to keep the track below ground level (at a depth of 3-3.5m and walls sloping at 45° to the vertical. By this device the track noise is appreciably reduced, though the engine and whistle noise is not much reduced. Use of a solid barrier between the rail track and the residential or commercial area would help in the attenuation of noise. If R be the distance between source of noise and the barrier, and D that between barrier and the receiving position, and H the height of the barrier, the noise reduction may be calculated from the formula–

Reduction (dB) = $10 \log_{10}(20 H^2/\lambda R)$,where λ is the wavelength of sound.

A relatively less expensive method is to plant trees and hedges on either side of the track or road – however, such foliage barrier has to be wide and should consist of densely planted trees with broad leaves.

Location of Industrial Areas: Industries emitting loud noises, even if they are small, have to be located away from residential areas, while large industries could be allowed to stay close to such areas if their noise potential is low. In any case, really heavy and noisy industries like ship-building, locomotive workshops, steel and coach factories, etc., should be located in specially reserved areas as far away from residential areas as possible, with wide and dense greenbelts around them to cut off noise and also air pollution to a large extent. Geomorphologic considerations should also be considered in locating sites of heavy noise-generating industries. Ideally, a ridge or high-ground should separate the industrial sites from the residential areas – an attempt in this direction was made in the case of Rourkela Steel Plant. However, in the case of Durgapur, geomorphology was not considered during planning with some disastrous consequences.

In cases where the noise level exceeds the permissible limit, the planner has the following alternatives to consider:

a) To re-allocate the area for a zone where higher noise-levels are permissible. Thus from the noise point of view, the residential areas could be downgraded to commercial areas, which in turn could be earmarked as industrial areas,

or

b) To take protective measures in and around the residential pockets within commercial/industrial areas by having green belts, hedges, better surfacing of roads /streets, etc.

Some case studies

A. Study of noise at Traffic intersections in Calcutta city: Noise levels at four traffic intersections in Calcutta were measured by CSME in February 1984 at various bands of frequencies, ranging from 31.5Hz to 16,000Hz. The recordings were taken at several corners of the traffic intersections. The decibel values for the different bandwidths were re-computed into dB(A) scale and the summarised results are given in Table 3.

Table 3

Mean Noise level values (in dBA scale) at four traffic intersections in Calcutta

Place	Date	Time	Mean Noise level (dBA)
B.B.D. Bagh (NE Corner)	2.2.84	10.30 hrs.	84.4
		17.15 - 18.15 hrs.	80.4
Esplanade-SN Banerjee Rd crossing	3.2.84	10.40 - 11.40 hrs	82.1
		12.45 hrs.	75.0
		17.15 - 18.15 hrs.	83.8
Park Street-Chowringhee Crossing	6.2.84	11.25 - 12.00 hrs.	78.8
		12.10 hrs.	81.0
		16.50 hrs.	77.6
		17.30 - 18.30 hrs.	77.6
Gariahat Road Junction	9.2.84	17.40 hrs.	80.1
		18.15 - 18.30 hrs.	81.2
		18.40 - 18.55 hrs.	82.4

Thus the noise level is in the hazardous category (above 80dBA), though not in the dangerous category (above 90dBA). This must be causing hearing loss to people who have to stay at, or close to the traffic intersections for long hours, viz., traffic police and roadside stall workers. One alarming feature of the results of this survey is that though major sound is in the range of 1000-4000 Hz range, at some places even 8000 Hz sound reaches as much as 80dBA. It is known that hearing damage is caused as much by high-frequency noise (>4000 Hz) as by low-frequency noise (≤500 Hz). Electric horns are mostly responsible for high-frequency noise and should be banned.

B. Noise levels in the Iron ore mining areas of Keonjhar district, Orissa. Noise levels in 19 ore mines (most of them in working condition) were studied in 1988-89 at various noise sources, viz., (a) Blast hole drill, (b) Shovel, (c) Dumper, (d) Loader, (e) Bulldozer, (f) Primary crusher, (g) Secondary crusher, (h) Ore washing plants, (i) Loading bin, (j) Central workshop, etc., and also at the townships which are located close to the respective mines. Readings at each station were taken in 4 cardinal directions and average 2/3 times a day, each reading being an average of 3 observations.

Objectionable noise levels of 90dB and above for an exposure time of 8 hours have been recorded at places at the mechanised mines at Daitari and Joda (East). Noise levels in the operator's position of blast hole drill, shovels, dumpers, loaders and bulldozers range from 92 to 102dBA. Primary/secondary crushers, apron feeders and vibrating screens emit noise ranging between 90 and 99dBA. At some of the mines, operators of crushers, air compressors and jack-hammers are subjected to noise levels of 95, 100 and 110dBA, respectively. Such high levels of noise should not normally be permitted and very good quality ear-muffs should be provided to the workers.

Suggested Readings

1. VESTRE, V.E. and WOOTEN, D.C.: Noise Impact Analysis.

2. SMITH, B.J., PETERS, R.J. and OWEN, S. 1982. Acoustics and Noise Control. Largmous (London), 236 pp.

3. Indian Standards Institution: Recommendations for Noise Abatement in Town Planning. IS:4954-1968.

ENVIRONMENTAL LAWS: REGULATORY INSTRUMENTS FOR ENVIRONMENTAL PROTECTION

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Environmental Protection: A Pressing Issue

The Issue: Nothing has underlined the common dilemma of mankind so starkly real as environmental pollution problems now unfolding all over the World. Signs of stress on the natural environment are everywhere today, reported daily in the press and other media. The life-support systems of our earthly habitat (only known live-planet) are being threatened by increasing pollution crisis. The crisis knows no political or geographical boundaries and affects every one – theist and atheist, rich and poor, male and female, old and young, born or unborn, black and white. Environmental degradation or more specifically speaking, environmental pollution is not a technical problem, and the fault lies not in Science and Technology as such. It is the effects of damage caused by man's reckless plundering of nature and the natural resources, for rapid development or, in contradiction, due to perpetuating under-development in major part of this World forcing poverty, malnutrition, unhygienic/insanitary living conditions and diseases. In India, specially after the post-independence period. The country has been passing through a phase of ever increasing population growth, rapid industrialization and urbanisation mainly triggered for rapid economic development and self-reliance – mostly without any devised policy or planning, in the lack of the needed prudence and foresight about the possible impacts on quality of the environment. Even though the environmental degradation problems are yet not so acute as they manifested in the industrially advance affluent countries, they have started showing up in their characteristics ugly facets here and there, now and then. It is now being realized that immediate and urgent steps are necessary for restoration/development and conservation of quality of the country's environment.

Required Management Approach: Good environmental management must rely on some basic prerequisites. First, a sound economic policy must be established, whereby common environmental goals are in compliance with the country's environmental characteristics and the prevailing administrative system, enabling to focus attention on the advantages of a specific system of environmental protection. Furthermore, a fair and competent authority must be established, to exercise the regulatory powers, during applications for effluent/emission permits, and also to supervise and control the polluting activities. In this regard, the initiative must be taken on the governmental level, with the help of the non-governmental organisations representing public interest, to ensure restoration/ protection of the environment – through assigning requisite authorities/ responsibilities – so as to promote appropriate site-specific applications of the accepted approach. Such authority/activities can necessitate:

- gaining and giving information through research and monitoring programmes
- regulatory measures through enforcement of laws.

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Environmental Legislation

Regulatory instruments: Since the beginning of mandated environmental protection, the legal framework has been largely restrictive. Regulations of various kinds, e.g., for pollutant purification and process and infrastructural changes, implemented by an expanding machinery, have been introduced to limit and repair damage caused by environmental pollution. These regulations have helped to reduce pollution, but not been able to fully address the sources of many problems.

Over the last two decades, many countries have used a variety of policy instruments to protect the environment, in many cases/based on *environmental quality guidelines*. Environmental laws are the regulatory instruments or institutional measures having "the objective of influencing the environmental performance of polluters by regulating processes or products used, by prohibiting or limiting pollution discharge, and/or restricting activities to certain time and areas" Regulatory instruments are know to perform relatively well in regard to institutional compatibility, administrative feasibility and environmental effectiveness, but not as well in terms of economic efficiency, cost-effectiveness and enforcement. However, fear was expressed in some quarters that regulatory instruments (or environmental laws) could inhibit technical changes and innovations with decreased productivity and economic growth. But such fears proved to be unfounded. Instead, it was found that in order to support the overall innovations and technological advances (including that for pollution control), regulatory system should:

— stipulate performance standards, without specifying the process or technology to be used:
— establish reasonable deadlines and time-tables for compliance with performance standards;
— use economic instruments in a supplementary role to build into the market an incentive for innovation;
— encourage consultation with business to help identify the most vulnerable/effective parts in the production cycle at which to tackle the environmental problems under consideration;
— review the requirements of environmental regulations so that contradictory technological requirements may be eliminated, wherever possible, and
— encourage dissemination of technical information, technical advice about methods of pollution control and strengthen financial sources for innovations.

Clean Technology: The use of *clean technologies* to replace traditional "end-of-pipe" pollution treatment has been relatively limited, mainly due both to market and regulatory failures, because of:

— relatively small existing market for clean technologies;
— poor availability of appropriate clean technologies in some areas;
— higher initial costs. even where subsequent operating costs may be lower;
— additional risks and uncertainties perceived to flow from the newer technologies;
— lack of support (or even obstruction) for development of clean technologies from manufacturers of anti-pollution equipment, and

— encouragement of continued use of "end-of-pipe" treatment systems due to ill-suited regulations.

Implementational Weak Points: Enforcement of environmental policies with regard to regulatory concerns has often been found to be a weak point in their implementation. A number of suggestions have been made to overcome these problems. Examples are:

— to introduce clean enforcement mechanisms at every stage in the environmental management cycle;
— to rationalise and simplify regulations, where possible, as well as permit/consent procedure;
— to strengthen compliance monitoring, including self monitoring procedures;
— to encourage the use of environmental auditing;
— to enhance cooperation with business in the rule making process;
— to make controls and sanctions for non-compliance more stringent by imposing tougher fines and penalties;
— to simplify legal and administrative procedures for applying such sanctions;
— to support regulations with economic instruments to increase the financial incentives for compliance;
— to improve information and publicity aimed at polluters in respect to control requirements and pollution abatement technologies, and aimed at the public in respect to effluent discharges and penalties for non-compliance.

However, through re-allocation and re-development of existing resources for enforcement and implementation, regulatory instruments may be used more effectively. Anyway, considerable scope exists for achieving cost and time savings in the formulation of regulatory instruments.

Environmental Legislation – International Overview: Environmental Legislation differs from country to country, due to social, economic and cultural patterns, the history of environmental protection, and the existing state of the environment. However, some general and common features exist that have been used as guiding principles in setting up an environmental policy and associated regulatory instruments. These are briefly highlighted below with reference to the programmes adopted by some major countries of the world:

(a) The European Community (EC): The environmental legislation rests on three basic principles:

— to support preventive environmental measures;
— to adopt a precautionary principles;
— to stimulate international cooperation.

The overall environmental policy focuses on those areas where combined efforts of the Member States to safeguard the environment make it easier to accomplish the goals, collectively rather than with separated programmes. The environmental legislative, so called Directives, (consisting over one hundred legislative texts), sets out minimum requirements to be achieved by all Member States. However, it is possible for an individual State/Country to introduce or maintain more stringent regulations provided that the principles of free trade are not violated. The environmental management in the EC countries follows specific and well planned 'Five-Year-Programmes' with due attention to priority areas, The Fifth programme (1993-97) is now in operation.

(b) The United States of America (USA): Environmental Laws and Ordinances are principal components of the United States system of environmental legislation. The Environmental Protection Agency (EPA) acts as a combined Environmental Protection Board and Ministry of the Environment. Its main functions are to supervise the compliance of environmental laws. Environmental legislation exists on both a federal and state levels. The state laws often encompass specific local problems, or strengthening of federal laws. But different states cannot enforce environmental policies that mitigate or make an exception to the federal laws. There are 10 such principal Acts now in the USA.

(c) The former Soviet Union (Commonwealth of Independent States): In the former Soviet Union, a number of environmental laws and ordinance have been enacted. The different laws encompass:

- environmental protection;
- areas of high priority for nature conservation;
- rational land-use, and
- use of nuclear energy and inherent safety aspects.

The different ordinances focus on:

- registration of industries with specific environmentally hazardous processes and products;
- liability with regard to organisational and private compensation for environmental damage;
- charging industries with specific environmentally hazardous technologies;
- openness with regard to public information about the state of pollution and the occurrence of ecological catastrophes, if they occur; and
- the establishment of general circulation through domestic newspapers covering environmental issues.

The responsibility for compliance with existing legislation rests with a State Committee for Environment and the Rational Use of Natural Resources. Environmental legislation is being referred and made more stringent (in terms of permitted pollution emissions), and being adjusted to international conventions.

(d) The People's Republic of China: Chinese environmental legislation is mainly in the form of general guidelines. It is not very specific with regard to setting national permitted emission levels. However, some emission levels have been established in cooperation with the International Standards Organization (ISO). Regionally-adapted emission levels can be set by local authorities, and can be more stringent than the general levels, as well as in regard to the classifying and protective of certain areas of specific ecological values. However, Central Authorities rule in those areas of special national concern and exempt them from regulations on environmental protection, e.g., nature reserves, historical sites, tourist attraction, etc.

A system of charges has been implemented, under which a polluter has to pay a specified fine to the Provisional Environmental Authority if exceeding the prescribed emission level. However, the main portion of the fine goes back to the polluter, to be used in environmental protection measures, which must be made within a certain time period.

The existing environmental legislation comprises various components. These include the Environmental Protection Law, the Marine Environmental Protection Law, the Law concerning Protection Control of Water Pollution, Regulations for strengthening Environmental control in Townships and Neighbouring Enterprises, Prevention and Control of Coal-Smoke Pollution, and Provisional Measures for Examining Environmental Protection Standards of Industrial Enterprises.

(e) Japan: The Basic Law of Environmental Pollution (BLEP) was enacted in 1967 to which certain amendment and corrections have been made with the passage of time. With regard to its application, BLEP encompasses seven principal areas for environmental management - air pollution, water pollution, soil pollution, noise vibration, ground depressions and disturbing odours. The BLEP establishes Government authorities for setting environmental standards; one for Environmental Quality Standards (EQS) and one for Emission Standards (ES). These authorities are responsible for the state of the environment and the control of pollutant emissions respectively. The emission standards are regulated by various laws corresponding to the seven principal areas of concern mentioned above with the following general objectives:

- EQS represents a long-term policy aiming at successive improvements in the state of the environment.
- EQS operates both in areas where pollutant emission are to be reduced, as well as in areas to be used as reference sites, to maintain an acceptable environmental quality.
- ES is a means to achieve or maintain the environmental quality attained by the EQS, and should be practised on emissions to air or water bodies from specific plants and work-places.

The regulation of environmental pollution is carried out through legislation, ordinances or specific agreements on pollution control with industries and municipalities. The Air and Water Pollution Control Acts are important components of this environmental legislation. They are also the main tools used by prefectural governments in establishing their environmental policies, the Prefectural Ordinances on Environmental Pollution Control (POEPC), which generally is more stringent than the National Standards. Agreements on Environmental Pollution Control (AEPC) between the local government and major industries in the prefectural areas have proved to the most stringent ones, with regard to effective environment protection.

Environmental Legislation In India

Hindsight: Living in harmony with nature has been the trait of Indian civilisation since the ancient Vedic period. The sages, through their hymns, have inculcated in our mind a sense of kinship with nature in all its manifestations - both biotic and abiotic. Throughout the country one may find edicts carved on rocks, pillars and monuments which are reminders of man's integral relationship, as a part of nature, with other animals, plants forests and other natural endowments and his duty to preserve them. But with ups and downs of the history, marked mostly by eras of invasions and colonialisation during the medieval through recent periods, there has been an ever-widening gape in the development of infrastructure and other productivity which could satisfy the basic needs of a rapidly growing population causing thereby widespread poverty and steady multi-faceted degradation of the environment. The initial post-independence period is also characterized by disorderly growth, unplanned industrial development and urbanisation which resulted in and brought to the fore the environmental degradation problem in staggering dimensions.

However, like in almost all civilised countries, provisions were made in different laws (rather in a piece-meal way) to safeguard the environment, which were found practically ineffective in preventing environmental pollution. Provided in Table 1 is a selective list of environment-related legislation.

Table 1 : Selective List of Environment-Related Legislation

Central Enactments

1. **Water Pollution**
   1. The River Boards Act
   2. The Merchant Shipping (Amendment) Act, 1970
2. **Air Pollution**
   1. The Indian Boilers Act
   2. The Mines and Minerals (Regulation and Development) Act, 1923
   3. The Factories Act, 1948
   4. The Industries (Development and Regulation) Act, 1951
3. **Radiation**
   1. The Atomic Energy Act, 1962
   2. The Radiation Protection Rules, 1971
4. **Pesticides**
   1. The Poison Act, 1919
   2. The Factories Act, 1948
   3. The Insecticides Act, 1968
5. **Others**
   1. The Indian Fisheries Act, 1897
   2. The Indian Forest Act, 1927
   3. The Prevention of Food Adulteration Act, 1954
   4. The Ancient Monuments and Archaeological Sites and Remains Act, 1958
   5. The Wild Life (Protection) Act, 1972
   6. The Urban Land (Ceiling and Regulation) Act, 1976

State Enactments

1. **Water Pollution**
   1. The Orissa River Pollution Prevention Act, 1953.
   2. The Maharashtra Prevention of Water Pollution Act, 1969
2. **Smoke Control**
   1. The Bengal Smoke Nuisance Act, 1905
   2. The Bombay Smoke Nuisance Act, 1912
   3. The Gujarat Smoke Nuisance Act, 1963
3. **Pest Control**
   1. The Mysore Destructive Insects and Pests Act, 1917
   2. The Andhra Pradesh Agricultural Pests and Diseases Act, 1919
   3. The Assam Agricultural Pests and Diseases Act, 1905
   4. The U.P. Agricultural Diseases and Pests Act, 1954
   5. The Kerala Agricultural Disease and Pests Act, 1958
4. **Land Utilisation and Land Improvement**
   1. The Bihar Waste Land (Reclamation, Cultivation and Improvement) Act, 1946
   2. The Andhra Pradesh Improvement Schemes Act, 1949
   3. The Acquisition of Land for Flood Control and Prevention of Erosion Act, 1955
   4. The Delhi Restriction of Uses of Land Act, 1964

Awakening for Environmental Protection – New Legislation: The problem of increasing environmental pollution and degradation was brought to a sharp focus of global attention in United Nation Stockholm Conference on 'Human Environment', held during June 5-16, 1972. Instance started showing up of the increasing and spreading pollution of water, air and land along with speedy degradation of the productive capacity and species, loss of woodlands, range-lands and agriculture soils, caused by indiscriminate and uncontrolled dumping/discharge of all kinds of waste materials, deforestation, overstocking of pastures, over-harvesting of croplands and over-exploitation of fragile and other marginal lands – which in turn leads to erosion, soil degradation, lowering of water tables, food-shortage and despoliation of natural water-shed. Wanton use or abuse of nature either in quest of material prosperity or in perpetuating poverty must have its back-lash to the detriment of human survival.

However, India is the first country which has made provisions for the protection and improvement of environment in its constitution. In the 42nd Amendment to the Constitution (in 1976) – Article 48-A was inserted which enjoins the State to make endeavour for protection and improvement and or safeguarding the forest and wild-life in the country. By the same amendment, provision was made in Article 51-A (g) stipulating that it shall be the fundamental duty of every citizen of India "to protect and improve the natural environment including forests, lakes, rivers and wild-life and to have compassion for living creatures" In pursuance of its policy to protect the environment, the Government of India enacted a number of Pollution Control Acts and brought out the Corresponding rules and notifications thereunder to restore and maintain/protect the countries environment. A list of the above Acts, rules and notifications is provided below in Table 2. Pollution Control Boards/Agencies have been established at the Central, State and Union Territory levels with the tasks of implementation of these legislation acting as the regulatory agencies in areas of respective jurisdiction.

Table 2 : Pollution Control Acts, Rules and Notifications

I Water:

1. The Water (Prevention And Control of Pollution) Acts, 1974, as amended up to 1988.
2. The Water (Prevention And Control of Pollution) Rules, 1975
3. The Water (Prevention And Control of Pollution) (Procedure of Transaction of Business) Rules, 1975
4. The Water (Prevention And Control of Pollution) Second Amendment Rules, 1976
5. The Water (Prevention And Control of Pollution) Cess Act, 1977, as amended by Amendment Act, 1991
6. The Water (Prevention And Control of Pollution) Cess Rules, 1978
7. The Water (Prevention And Control of Pollution) Amended Rules, 1989

II Air:

1. The Air (Prevention And Control of Pollution) Act, 1981, as amended by Amendment Act, 1987
2. The Air (Prevention And Control of Pollution) Rules, 1982
3. The Air (Prevention And Control of Pollution) (Union Territories) Rules, 1983
4. The Air (Prevention And Control of Pollution) Amendment Rules, 1988

III Environment:

1. The Environment (Protection) Act, 1986
2. The Environment (Protection) Rules, 1986
3. The Environment (Protection) Amendment Rules, 1987
4. The Environment (Protection) Third Amendment Rule, 1987
5. Notifications on 'Emission Standards' and Guidelines for Location of Industries, mining operations, etc. for various Areas

IV. Public Liability:

1. The Public Liability Insurance Act, 1991
2. The Public Liability Insurance Rules, 1991

V. Notifications

1. Hazardous Waste (Management & Handling) Rules, 1989
2. Manufacture, Storage and Import of Hazardous Chemical Rules, 1989

3. Manufacture, Use, Import, Export and Storage of Hazardous Micro-Organisms, Genetically Engineered Organisms or Cell Rules, 1989
4. Guidelines for seeking Environmental clearance.

Harmonisation of Environmental Policies and Legislation: In recent years, it has become obvious to many governments that they are no longer in full control of the condition of the environment in their own countries. Decisions taken in neighbouring countries can be equally important to improving the environment within their boundaries than decisions taken in the home country. Many countries are prepared to participate more actively in international environment work, and to influence international opinion as a result of this realisation. Governmental bodies, environmental organisations and industries around the world must take note of their respective responsibilities to help achieve a better environment, even though there might exist different opinions about the pace, means and time needed to complete these tasks.

International agreements can lead to substantial environmental improvement of current regional and global problems. The work of politicians in this arena is of special importance. But it is also of great importance to emphasise the need for new institutional approaches to environmental protection and international cooperation. One such example is introducing environmental issues into already existing trade negotiating systems such as the 'General Agreement on Tariffs and Trade', (GATT). With this approach, international environmental work will be given even greater opportunities to accelerate.

If demands for sustainable economic development are to be fulfilled, it is extremely important to overcome problems with existing difference in laws and rules between various countries. Therefore, the coming years must be used efficiently to further reduce environmental impacts by establishing nearly as identical environmental impact regulations as possible between neighbouring countries. If successful, the risk that the environmentally-hazardous processes will be transferred to countries with less stringent rules will be minimised.

During this process of harmonisation, however, it is extremely important to carefully consider environmental regulations and costs in different countries. Creating unbalanced environmental legislation between countries might maintain or even enlarge Technical Barriers to Trade (TBT) in the short term, even though ambition to improve the environmental is well motivated over the longer time perspective. If the harmonisation of international environmental rules fails, foreign trade might be negatively affective, thereby threatening the build-up of resources needed for future preventive environmental degradation measures.

It is of vital importance to influence international opinion and cooperation. Those developed countries, which are considered to be comparatively active in the field of environmental protection can, to some extent, should come forward and serve as "models" in international negotiations. However, they can only be referenced as good examples if they can manage both economic and environmental issues.

Suggested Reading

1. ANON. 1992. Pollution Control Acts, Rules and Notifications issued thereunder. Central Pollution Control Board, New Delhi 110 032, p. 501 [Pollution Control Series PCL/2/1992 (vol. I)]