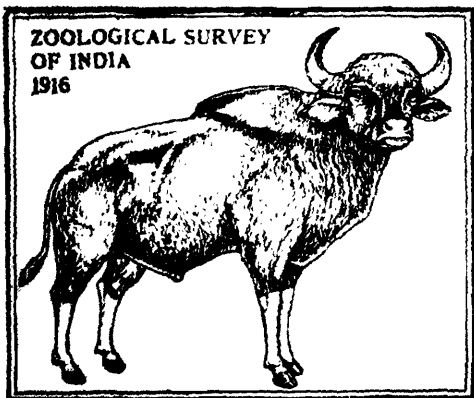


ZOOLOGIANA

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ENVIRONMENT AND HUMAN HEALTH

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Environment is the milieu of physical, biological and social circumstances through which man has lived during many thousands of years of his biological evolution. Hence, man has to survive or modify himself under multiple provocative forces which may help him to survive or endanger himself. Environment is, thus, in a continuous everchanging state. This is, however, very much different from human internal environment (milieu interior). In this a host of interrelating physiological agencies like hormones etc. play an important role in regulating the provocative forces of the environment in disrupting the normal state of health. In spite of all these beneficial interacting forces, human health had to suffer from maladjustment where in there is some alteration of living tissues, cells and components of cell which may jeopardize its survival in its environments. This may be described as altered state of Health or may be termed 'disease'.

The various environmental factors, which may act adversely on human health, may produce certain altered physiological responses on the host and are regarded as 'stimuli' These stimuli may be grouped broadly as—

- (a) Physical-chemical, or inorganic
- (b) Biological or organic
- (c) Socio-cultural.

A. Physical-chemical Environments :

A very wide range of factors—such as heat, cold, humidity, trace elements in food, water and in soil and the like—is involved as stimuli alone or in combination. It is difficult to isolate specific factor or factors. The effect of high heat, as in tropical countries, on the human body is largely related to depressed body functions, lower general vitality, and predisposition to disease. On the other hand, moderately cold conditions below 20°C increases the susceptibility to respiratory diseases. Thus, it is possible to predict that extremes of heat and cold are definitely harmful.

Studies from Netherlands indicate the relationships between the frequency of respiratory diseases such as asthma and bronchitis, and certain phases of weather. Although allergens could be important factor in certain cases of asthma, certain steep drop in atmospheric pressure with or without influx of cold weather could also act as a major triggering agent or stimuli.

Death from coronary disease in middle and high latitude is observed to be highest in colder months and lowest in warm months. This would only indicate the influence of metereological stimuli on anatomical state of blood vessels, activity of sympathetic stimuli and physiochemical state of the blood.

Various manifestations of rheumatic disorders are well known to be associated with dampness and sudden changes of temperature.

Deficiencies in trace elements in food might be associated with certain diseases. Deficiency of iodine in water and food in the terrai region of the Himalayas is associated with goitre. Deficiency of fluorine in water gives rise to dental carries while excess of fluorine leads to crippling arthritis.

Pollution of domestic water supplies come from two ways—(i) Chemical pollution in the industrialised countries where effluent from the industries, domestic sewage and from firms who use large amount of pesticides in fertilizers is voided in rivers or lakes and (ii) Microbial pollution from man and animals using water for bathing and using it in their cycle of ingestion and excretion. Diseases, like cholera, dysentery, poliomyelitis, infectious hepatitis, measles, and large number of virus infections occur from water contamination while role of water in transmission of pasific diseases is welknown.

B. Biological environment :

In addition to the above bacteria, protozoa and viruses, which are responsible for a large number of diseases in man, there are also large number of bacteria and parasites living within man permanently without causing any structural change or functional disturbance. They are in a state of mutual tolerance. They are called commensals. The state of existence is known as commensalism.

A change of temperature, humidity or some other upsetting factors can favour a little to barely subsisting form of bacterial life and change the dominance among competitors of bacterial population in the environment. This may lead to flourishing of a silghtly different bacterium in a newer environment. These may become pathogen and may produce disease. This

would only indicate that the causative organism of disease or a pathogen has its own ecology and specific environmental requirements. Thus, disease in a given locality is the result of a combination of geographical circumstances which bring together disease agent, vector, intermediate host, reservoir, and man at the most optimum situation. In understanding the cause, geographical location and control of an infectious disease, it is essential to have the knowledge of ecological and environmental relationships. In the developed countries through enlightened environmental changes, health, legislation, health education and therapeutic advance, this has largely been controlled.

C. Socio-cultural Environment

This is essentially created by man in their way to better living facilities. This can be considered under (a) habitat, (b) economy and (c) society.

(a) *Habitat*—Pollution of habitat with particulate matter, gases and host of other contaminants coming from motor vehicles, manufacturing industry, power plants, refused disposal etc. in the main causes of diseases like chronic bronchitis, lung cancer, emphysema and asbestosis.

Other sources of atmospheric pollution are smoke from burning coal for household purposes, gases, smoking and from household sprays. Use of nuclear energy as an alternative source of energy derived from natural resources could be another cause of insidious contaminant of radioactive radiation.

Fertilizer and agricultural pesticides pass on their trace elements characteristics to soils and hence to crops growing in the soils. Such crops enter the food chain of man and of livestock.

Synthetic detergents are powerful deoxygenator and are highly lethal to fish and reduce the efficiency of filters in the sewage and, thus, interfere with the quality of the effluent produced. These are few examples.

(b) *Economy*—State of health of every country is depended on its economic growth. The latter is dependent on the industrialisation, which has got both favourable and unfavourable effects. The favourable effects on health are influence of improvements in water supply, sewage disposal, housing, diet, education, hygiene and living standards. But hazards from industry unless taken care of are numerous (*vide supra*). Chronic inhalation of certain dusts eventually leads to the development of various pathological lesions in lung which goes by the generic name, 'pneumoconiosis'

(c) *Society*—Associated with urban living there are many aspects of

the activities imposed upon individuals, which act to disturb the homeostasis, impose a load on adaptable mechanisms and likely to be manifested chronically in reduction of human fitness. This disturbance may act on physiological, biochemical and psychological level since this very environment is quite different and very new which prevailed throughout most of human evolution.

The health of human beings is being determined not by heredity but by the conditions under which they live. The natural environment is under constant interference by man. Some of such changes are very obvious while others are imperceptible and insidious. Some may be good, some are harmful and others are catastrophic. It is, thus, unwise to interfere with the environment without, at the same time, striving to determine the real and lasting effects of such actions on the health of man. It reminds us the warning of Winston Churchill "It would be a tragedy if the sunrise of technology were to be the sunset of mankind."

THE ENVIRONMENTAL CRISIS

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Man has been consistently exploiting our living environment and his failure to successfully control it has been a source of increasing concern. It is but naked truth that with our air becoming increasingly unfit to breathe, our waters unfit to drink and with increasing levels of toxic substances becoming accumulated in all conceivable media threatening several hundreds of plants and animals with extinction, man is slowly but surely trying to realise the gravity of the situation. Nature is undoubtedly superior to human wiles and fancies and any attempt to interfere with nature will end up in catastrophic results. The basic principle, as such is the interdependence of organisms in relation to their physical and biological environment.

Looking at the evolutionary history of man, three basic features appear outstanding *viz.*, the evolution of cultural patterns, the development of agriculture and animal husbandry and industrial and medical revolution. In trying to achieve his own ends in all these activities he has degraded the environment, though of course the benefits cannot be underestimated. At the same time it cannot also be denied that such benefits have been at the cost of the environment. The population explosion necessarily demands increased production through proper utilisation of natural resources. From about 2 billion people in the thirteen of this century, we have a little over 5 billion at present and it is predicted that by the turn of the century the population would be about 8 billion or almost double the present population, in just about 20 years. The growth rate has been tremendous, from 0.3% in 1950, 2.1% in 1970 and perhaps over 3.5% by the turn of the century. This doubling of populations will naturally mean doubling of food production, water resources, housing, medical facilities, transport and so on. Recent studies indicate that there are about 7.86 billion acres potentially suitable for agriculture on this earth and about half of this *viz.*, the richest, has already been utilized. It is the lack of farsighted vision in considering long term implication of technical aids and concentrating initially only for a temporary increase of production and over exploitation of available resources that have

landed us in such an inescapable situation. The industrial revolution has no doubt increased the output of material for human use, but to compete with the explosive population rate we have to look for increasing energy resources and in meeting both energy demands as well as production, man has very badly contaminated the environment, resulting in atmospheric, soil and water pollution.

Talking about air pollution, it may be mentioned that the continued expansion of industries, new technological developments, increasing use of automobiles to cope up with population growth especially in urban areas, have resulted in considerable contamination of the atmosphere. Clean atmosphere contain 20.94 per cent of Oxygen and the presence of dust, smoke, fumes, fog etc. mostly from industrial establishments, tend to decrease the oxygen content. Several environmental pollutants like carbon monoxide, sulphur dioxide, sulphuric acid, hydrogen sulphide, oxides of nitrogen, ammonia, ozone, hydrogen fluoride etc. as well as the multitude of insecticides, herbicides, rodenticides, fungicides, acaricides, to mention but a few, have badly contaminated the environment. Gaseous pollutants in the air occur through combustion of fuels and chemical industrial activities such as petroleum refining etc. Burning of coal and other fuels result in varying quantities of sulphur dioxide and it is estimated that a power station burning 5,000 tons of coal per day would be releasing 150 to 200 tons of sulphur dioxide per day. Sulphur dioxide in gaseous or in the form of sulphuric acid mist, cause acute irritation of the skin, eyes and upper respiratory tract causing chronic bronchitis. It also enter the leaves of plants through their stomata causing serious injury to leaf tissues. Oxides of nitrogen are produced by combustion of organic matter and the principal source are from exhausts of automobiles, furnace stalks. During the day time increased oxides of nitrogen are formed from automobiles, resulting in what has been called the photochemical smog. A complicated series of reactions result in ozone and highly irritating substances called peroxyacyl nitrate, producing acute burning of eyes. Ozone causes inflammation of lungs and bronchioles become fibrotic preventing normal respiration. Carbon monoxide is also produced during the combustion process and automobile exhausts form 80% of the carbon monoxide source, besides blast furnaces, petroleum refineries, coal mines etc. Hydrogen sulphide also results from petroleum refineries, coke oven plants, viscose rayon plants, sewage treatment plants, tanneries and so on, while hydrocarbons and chlorine also occur. Several hundreds and thousands of tons of fine dust like particles or aerosols become suspended in the atmosphere sufficient to alter the amount of sunlight reaching the earth's surface. This naturally tends to decrease photosynthesis, resulting in an increase of carbon dioxide. The global decrease in photosynthesis would impoverish man's total environment through loss of food resources for all

organisms. Two diverse view points have often been expressed (a) the noxious gases from the exhausts of more than 2-3 hundred million automobiles in the world to day, as well as from millions of factories, add to the number of particles which remain airborne for a long time, resulting in the change in the reflectivity of the earth's atmosphere, starting an irreversible cycle towards on ice age, (b) through the use of power plants—both nuclear and non-nuclear waste heat becomes accumulated and in the course of time this may alter the temperature of the atmosphere by 2-3°C sufficient to melt the polar ice. Added to these, the introduction of the supersonic aircraft which can operate at speeds greater than sound, only in the stratosphere, may further contribute to this cooling effect as a result of the production of long lasting clouds in the stratosphere.

The problem of water pollution is as old as life itself and pollutants from rivers and estuaries as well as the sea have their impact not only on the aquatic resources, but also considerable impact on human health. The effects of pollutants in rivers include (a) alteration of temperature, (b) suspended impurities, (c) oil films and detergents, (d) increase in organic products, (e) discharge of poisons chemicals and biological consequences such as growth of sewage fungi and destruction of fish are concomitant changes following alteration of physico-chemical status of these waters. The discharge of warm waters, from power plants into streams and rivers have adverse physiological effects on the fauna and cause a redistribution of faunal and floral communities, not to mention the changes effected in the reproductive efficiencies of the animals. The impact of technology on riverine systems cannot be underestimated. Let us examine the impact of sewage effluents and other organic residues in river and lake systems, particularly such discharge products emanating from manure heaps, from cattle yards, slaughter houses, tanning yards, dairies, textile manufacturing and fish meal processing units and so on. Natural riverine system has 10 ppm by weight of oxygen depending upon temperature, salinity and photosynthetic activity. The most important biological effect arises from the breakdown of organic matter in polluted rivers by bacteria, fungi and Protozoa into CO_2 , H_2O and ammonia and the latter is further oxidized to nitrite and nitrate. But if the demand for dissolved oxygen is greater, only a partial breakdown occurs pollution is high resulting in disastrous consequences, particularly with bacterial breakdown of sulphates releasing hydrogen sulphide. Naturally therefore polluted water tends to be deoxygenated and being able to support fewer faunal elements. To cite an example, calculation from the oxygen demand created by the manufacture of a ton of strawboard correspond to the sewage output of 1700 persons and it could deoxygenate 17 million litres of oxygen saturated water daily. Polychlorinated biphenyls (PCB) are exceedingly poisonous compounds used as ingredients in lubricants, waxes, adhesives etc. and PCB contamination

is indirect through leakage from transformers and it is estimated that over 4,500 tons of PCB are lost all over the world through such leakage. Fish are the best indicators of PCB pollution with average levels of 1.87—35.29 ppm.

Marine pollution has also resulted in serious consequences to marine life at all levels and hence to man. Very recently Japan was in the grip of a peculiar disease, "The Minimata disease" which thousands of young men, women and children born with limbs twisted and brains damaged due to methyl mercury poisoning of fish as a result of release of mercury through industrial wastes into the sea. Elevated levels of methyl mercury occurring as a result of industrial discharge one met with mammals, birds and fish and transfer up the food chain is a logical mechanism. Contamination of the environment with mercury has been on the increase and the use of elemental mercury in caustic-chlorine industries and of mercurial compounds as seed dressings and subsequent discharge of waters to water bodies create widespread environmental problems. Oil pollution in the sea has caused considerable damaging effects on marine life and birds swimming and diving in search of food became fouled with oil penetrating their feathers and displacing the air which normally aids buoyancy and makes them incapable of flying, resulting in their death. Where oil pollution is severe, the activity and growth of oysters, clams, mussels and other shell fish are affected seriously and animals in the intertidal zone are most affected. The recent Torrey Canyon disaster of 1967 with 120,000 tons of crude oil of which wrecked off the British coast caused by high mortality of littoral marine life and sea linds and completely upset shore fisheries.

It would now be worthwhile examining the impact of green revolution in terms of environmental quality, particularly due to the introduction of mechanized farming and uncontrolled use of insecticides. In other words the industrialisation of agriculture has also brought in its wake several environmental hazards. To make the soil more productive tons of artificial fertilizers like ammonium phosphate, ammonium nitrate, ammonium sulphate, urea, superphosphate etc. are used and this tends to pollute rivers and lake and irrigation of poorly drained land may cause waterlogging of soil resulting in their accumulation. Doubling of crop yield is achieved only by 5-10 fold increase of pesticides. To give an e.g., to achieve a 34% increase in world food production from 1951—1966, agriculturists increased yearly expenditure on tractors by 63%, annual investment in nitrate fertilizers by 146% and annual use of pesticides by 300%. No doubt, the chemical revolution in insect pest control provided an effective pesticide umbrella to the crop, from which high yielding varieties were selected. But then, it was soon realised that once it is withdrawn, pest infestation reaches such a high level

that yield is reduced. The result was the consistent and indiscriminate use of pesticides, destroying natural agents in biological control and resulting in many insects developing resistance to these insecticides. DDT has been the most indiscriminately used insecticide and too late in the day it was discovered that being fat soluble, it is susceptible to biological magnification as it ascends up the food chain and leaving considerable residues in every form of aquatic life—plankton, small fish, large fish, birds mammals and even in mother's milk. The wide variety of pesticides continuously used, whether they be organo-phosphorus compounds or chlorinated hydrocarbons or systemic insecticides have so saturated the atmosphere that irreparable damage has been caused to a wide range of animal life and indirectly to man. Besides the biological magnification referred to earlier, insecticidal residues are persistent in the soil for years, even to the extent of preventing nitrogen fixation, not to mention of the disappearance of soil fauna (except for a few like *Collembola*), so important in the building up of productive soils. The most toxic chemical ever made by man in TCDD a herbicide, 1/28 ounce of which has the potential of killing 5 million guinea pigs and 2,225,000 gallons were used in defoliation in recent years.

Considerable efforts are now being made the world over to protect wild life and many endangered species of animals. It is well known that wildlife affects man and his interests in many ways and his policy towards animals is influenced by their relationships to him. Environmental pollution has had profound effects on wild life and one particular element fluorine, requires special mention, because of the toxicity of this element in large doses. Fluorine occurs in the smoke of brickworks surrounded by agricultural land. Iron and aluminium industries are also a source. After deposition it is concentrated by green plants and grasses (2000 ppm) and if eaten by wild animals or livestock, serious effects occur. Bone abnormalities and dental deterioration result, followed by lameness and general loss of conditions. Seed dressings of mercury have affected birds killing several of them, and mercury seems to have accumulated in hawks, owls, and predatory birds. Numerous pheasants and partridges have been affected and organochlorine pesticides, particularly dieldrin seed dressings have been responsible for mass killing of birds and peregrine falcons have also been much affected. In general eggs fail to hatch, breeding is prevented, and in many cases though eggs are laid, they do not develop. Even behavioural effects such as non incubation of eggs result and in extreme cases eggs are broken by parent birds.

Man's thoughtless action in interfering with nature without considering the overall effects, relates to the numerous hydroelectric projects, which while directed towards the welfare of the human population ends up in long term

disadvantages and no example could be better than the Aswan Dam over the Nile in Egypt. Far reaching ecological effects associated with the Nile and consequent human hardships have outweighed its benefit, with considerable effects on agriculture, fisheries and on public health. The trapping of nutrients in the lake has resulted in the utilisation of fertilizers at a high cost to compensate the lost natural fertility. The problem of loss of ground water due to reversed flow due to hydrostatic pressure and evaporation from the lake, has resulted in the loss of water meant for irrigation and power generation. One of the most detrimental effects is the high incidence of schistosomiasis due to the optimum habitat for the snails in the numerous irrigation channels which offer an excellent breeding ground. Increase in oncocerciasis is also on record.

We in India are equally concerned about the impact of the numerous hydroelectric projects, and it is only in recent years that we have become conscious of their environmental impact and there has been no greater controversy over the initiation of such projects as the Silent Valley project of Kerala. Already huge projects like the Iddukki and Kudremukh projects have brought in their wake doubts regarding their effects on the fauna and flora of these areas. It is very essential to have guidelines prepared for the protection of ecosystems so that the future generations may not be committed for ignoring the sanctity of these ecosystems.

The increased utilisations of nuclear power plants has another potential hazard, namely the accumulation of radioactive wastes, which are by-products of energy production and which are estimated to exceed one thousand billion curies. Some of these nuclear wastes are mostly in the form of krypton gas and tritium. It is not difficult to anticipate their impact on living organisms and to man himself, who lives in eternal fear of the increasing deterioration of his environment.

It would be useful to ponder over the order of things to come, if we are to overlook the sanctity of the environment and continue to release all kinds of toxic substances which would pose a continuing threat to life itself. In the words of Rachel Carson, The "control of Nature is a phrase conceived in arrogance, born of the Neanderthal age of biology and philosophy, when it was supposed that nature exists for the convenience of man. As crude a weapon as the cave man's club, the chemical barrage has been hurled against the fabric of life—a falsie on the one hand delicate and destructible, on the other miraculously tough and resilient and capable of striking in unexpected ways".

ENVIRONMENT AND WILD LIFE

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All living resources are invariably linked in one form or other with the habitat in which they live. The environment that govern these bio-organisms thus, are of three categories (i) physical (ii) chemical and (iii) biological. It is the Law of Nature that any tampering of any of these factors would ultimately result in unforeseen damage to the ecosystem as a whole and its inhabitants. One such example is the Wild life of our country, the rich heritage and value of which is being realised only in recent years. In this paper the impact of a multipurpose hydel project in the Tehri Garhwal area of U.P. on the Wild Life and other biomass is outlined.

Monitoring studies carried out for three years from 1976-1979 by a team of scientists from the Zoological Survey of India headed by the author have revealed a number of endemic species being adversely affected by this drastic change in their habitat (Fig. 1).

Among the mammals, the Cheetal (*Axis axis*), the Hog Deer (*Axis porcinus*), the Indian elephant (*Elephas maximus*) and the Indian Porcupine (*Hystrix indica*) are affected the most.

De and Spillett (1966) reported 600 heads of Cheetal in that section of Savanah type grass land or the 'Chaud' near Dhikala which was going to escape inundation. In 1977 when the monitoring studies were taken up a maximum of 324 cheetal were observed although this time another few square kilometre of the Chaud were still above water. As this remaining area went underwater during the rains (July-Sept.) the number of cheetal in Dhikala Chaud started rising. On account of the population pressure in the Chaud (app. 10 sq. kms) some herds started spilling out of the area. Some of the animals were seen in the adjacent ridges upto an height of 3000 ft (Lamba and Tak 1977), where they had never been observed before. In March 1978 the Cheetal population at Dhikala Chaud reached a record number of 627 heads. Thereafter there was a gradual decrease in their numbers, presumably on account of dispersal triggered off by over population. In March 1979

the number fell to 418, perhaps still much more than the maximum carrying capacity of the area. But the most distressing fact that the monitoring brought to light was the sharp fall in the female : fawn ratio (birth rate) of the Cheetal population in the Dhikala Chaud. In 1976-77 fawning season (Nov.-Feb.) the birth rate was recorded as 22.2 fawn to every 100 females. In 1977-78 it fell to 11.8% and in 1978-79 it reached an all time low of 4.1%. A fall in the birth rate of mammals under conditions of stress and strain is a well known fact. The sharp fall of birth rate from 21.2 to 3.8 in three years times is indicative of the stress conditions felt by this population.

The Hog Deer (*Axis porcinus*) which is closely related to Cheetal and shares the same feeding grounds with them at Dhikala Chaud has also exhibited a sudden increase in numbers in the Chaud. By nature this deer is timid and always yields ground to its more aggressive relation the Cheetal. In March 1978 their number in Dhikala Chaud rose to almost three times their population of 19 heads in March 1977. Later, during the rainy season of 1978 some were observed in Paterpani Chaud, across the central ridge, where they had not been observed in 1977. It is presumed that under growing population pressure and the threat of dominant Cheetal herds some of them were pushed over the ridge.

The Indian Elephant (*Elephas maximus*) is yet another mammal affected by this change of habitat. Till about 6 years back (1974-75) herds of elephants moved during the rain from Nepal Terai, across the rivers Kosi, Ramganga and Ganga right upto the Shiwalik forests of Asarori near Dehra Dun. On their way some of them crossed Ramganga at a point near Dhikala. Most of the elephants that resided in the park also left the park during rains to avoid the vicious blood sucking Horse fly that swarm the valley in rainy season. They too made use of this crossing point. In 1976 this crossing point was submerged by the creeping reservoir. The earth near the water line being soft, the banks became too soft for the elephants to tread. As a result the elephant herds which had gathered in Dhikala Chaud and vicinity to cross over were trapped in in the Park during the rainy season of 1977. Each fullgrown elephant consumes about 220 kg of green leaves and grasses daily and it destroys at least 4 to 6 times that much vegetation while feeding in the forest. A tree may be felled but only a part of it may be eaten before felling the next one. Somewhere during the course of their evolution the elephants adopted the 'Survival factor' if not staying in an area for long. Confronted with the blockade of 1977 and presumably also to get relief from the blood-sucking Diptera, the trapped elephant herds did some thing they had not been observed to do in the living memory. They moved into the driest part of the Park near Bijrani across the ridge and remained there till winter of 1977-78. In 1978 some

M.A.B. PROJECT N.R.S. ZOOLOGICAL SURVEY OF INDIA, DEHRA DUN

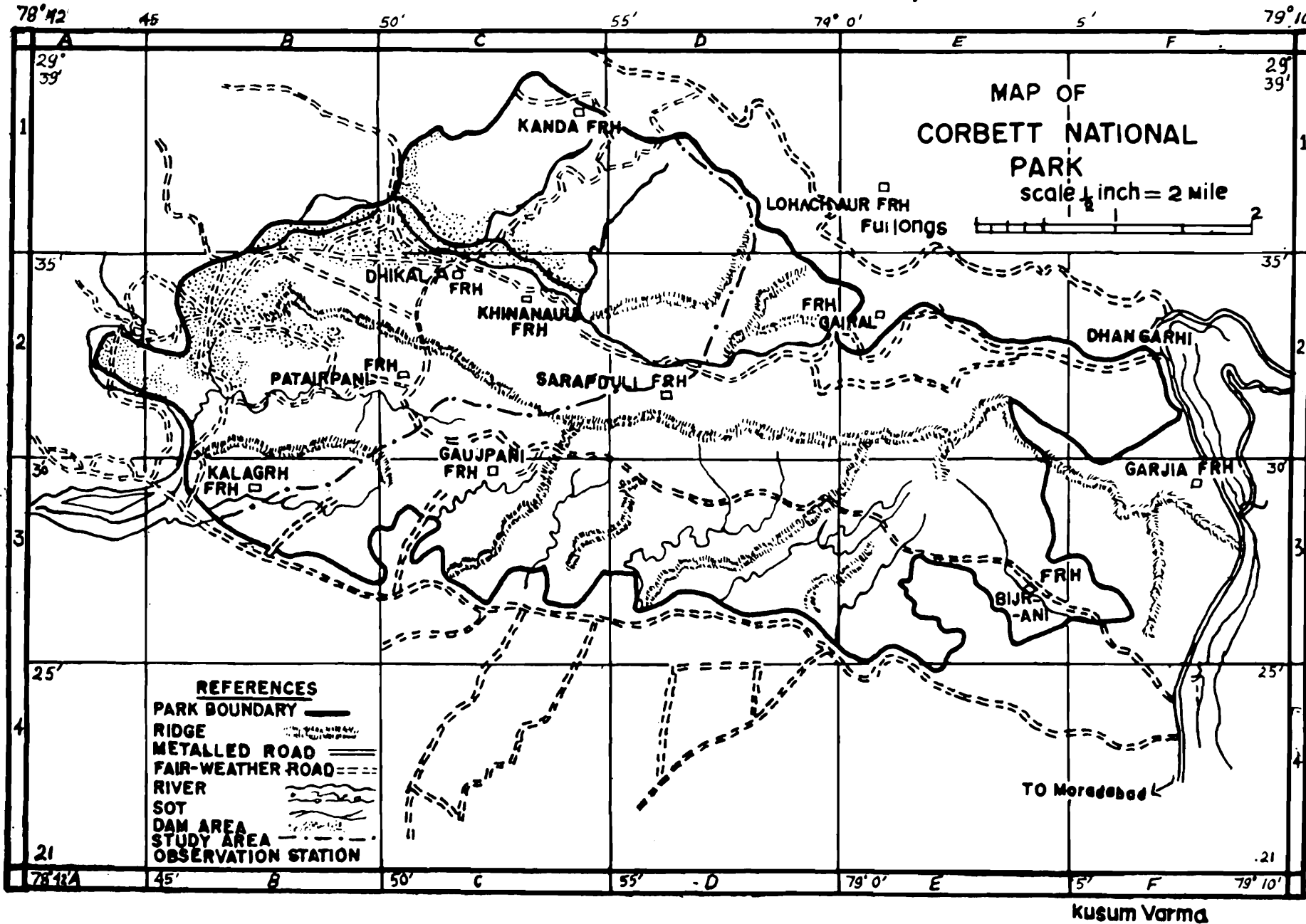


Fig. 1.

of the herds crossed the river near Khinanauly but stayed inside the park, presumably, because they could not find an alternate route. They remained in the Bamboo forests of Towlia Chowki. Others stayed in forests north of the Central ridge opposite Bijrani but did not cross over to Bijrani where they had stayed in 1977. In June 1979, when the monitoring was terminated, they had again gathered in Dhikala and Khinanuli Chauds probably searching for a new route to cross over. Apparently the 530 sq. kms., area of the Park is proving too small for more than 120 (Singh, 1979) heads of elephants. There are frequent fights among bulls resulting in the death of at least two bulls in 1978-79.

The species to suffer the worst was perhaps the Indian Porcupine (*Hystrix indica*). This large rodent lives in groups in deep underground chambers connected by long narrow tunnels, which the animals dig themselves. With the large area going under water around Dhikala in 1977 their relative density index in the winter of 1977-78 dropped to 60% of their 1976-77 index. In 1978 the inundation during rainy season was much more than that of 1977. Consequently the relative density index of Porcupines fell further to a mere 20% of 1976-77 figures in the areas adjacent to the lake at Dhikala.

Among the birds that suffered heavily on account of large scale inundation are the passerines that roost and breed in smaller trees, bushes and reedbeds top the list. In 1976 thousands of Red Ardvarts (*Estrilda amandava*), Spotted Munias (*Lonchura punctutata*) and hundreds of Weaver birds (*Ploceus philippinus*), Blackthroated and Baya (*Ploceus benghalensis*) were observed in the Dhikala Chaud and adjoining river bed upto Khinanauli. The reedbeds and smaller bushes in which these species made their nests were suddenly submerged at the height of the breeding season in 1977 and again in 1978. As a result their relative density index in 1978-79 fell to a mere 20% of 1976-77 index. In 1976 thousands of common Mynas (*Acridsitheres tristis*) congregated every evening to roost in small trees bordering the South-Western portion of Dhikala Chaud. This portion too went under water in 1978. As a result no Myna roosts were observed in the area in the winter of 1978-79.

These changes in the habitat that have proved inimical to the foregoing species have come as a boon to a large number of resident and migratory water birds. The population of the following groups of resident water birds has risen many folds :—

1. Cormorants and Darters
2. Herons
3. Egrets
4. Storks
5. Fishing eagles
6. Kingfishers

Gulls which did not reside in the Park formerly have moved in.

Migratory birds such as Storks, Herons, Ducks, Sand pipers, and plovers that previously came in meagre numbers are visiting the Park every year in increasing number.

The full assessment of the impact of these changes on the fauna of the Park will perhaps be evident after 7-10 year period from now when these changes have stabilised a little. The foregoing account is just a pointer to the shape of things to come.

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ENVIRONMENT AND MARINE LIFE

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Introduction

For years, Indian Ocean has been considered by many scientists to be the least polluted among the Oceans of the world. The unpolluted Indian Ocean promoted a luxurious growth of abundant marine fauna and flora in ideal environmental conditions. However, in recent years, Indian Ocean including the Bay of Bengal and Arabian Sea is gradually becoming polluted.

Man has always without any forethought or wisdom (*cf.* Silent Spring—R. Carson, 1962) tended to dump his rubbish right beside his dwelling thinking that the rivers and seas make the best and 'bottomless' receptacles. With the advancement of technology, increasing population leading to the tremendous industrialization, pollution of the rivers and seas has reached a high level/critical point. The many substances added to the environment as a result of man's activities has had a measurable and generally detrimental effect upon the environment, thereby affecting directly our natural resources. It is true that nature (especially the sea water) has a vast capacity to recover from minor modifications of the environment brought about by the development of civilization. Due to this capacity for recovery, man has used the rivers and the seas as an unlimited resource for exploitation and for the disposal of the waste products. However, there is a limit to the ability of nature to recover from continuous misuse. The results of this is seen in the depleted marine life (*i.e.*, fauna and flora), and the lethal level of pollutants accumulated in the edible fauna and thus affecting the health of the people.

Even though detailed information on pollution on the European, American, British, Australian and Japanese seas are known in great detail (*vide* 'Marine Pollution and Sea Life' Ed. by Mario Ruivo, FAO publ. 1972 ; and Ferguson Wood and Johannes 1975 *etc.*), studies on the pollution—monitoring on Indian coastal waters are limited to the investigations of Fernandez, Daniel and Nicket (1977), off Madras Coast and Fondekar *et al.* (1977), De Sousa (1977) and Verlançar and Co-workers (1977) in a series of publications from National Institute of Oceanography, Goa, off West Coast of India.

II. (a) Different pollutants of Indian Coastal regions :

In India some lengths of coastal zone have very high population density and this has been shown to be true in the case of major cities like Bombay, Calcutta and Madras and some coastal areas like Cochin, Calicut, Trivandrum, Tuticorin and Vizag. There are three different kinds of pollutants along the coastal regions of the Indian Peninsula.

(i) Sewage and Industrial pollution :

The coastal population of India has been estimated as 150 million. The discharge of wastes from domestic and hospital sewage and industrial effluent in the coastal waters is around 150 km³ for a year. The increasing tempo of industrialisation, as well as the growth of the coastal population would carry in its wake serious problems of the disposal of liquid and solid wastes and their effect on the coastal waters, which the concerned authorities would have to deal with to ensure safeguarding of the marine biological resources, safety to human beings from toxic elements in marine food products, and the hygienic safety of recreational waters. The total discharge of pesticides used in agriculture, and the detergents for washing and cleaning purposes for example is estimated to be about 1.3 million tonnes per year. About 25% of such chemicals get into the marine environment. Recent investigations have shown that fish caught around Bombay Harbour had mercury content above permissible level. Along with other wastes in the domestic sewage, the type of detergents released is of some importance. For instance, in the developed countries all the detergents are now mixed with some type of enzymes to wash the clothes much better than before. Even though this has been a boon to those industries, it is seen that due to such detergents being dumped into the fjords, fish mortality has increased. In our country too, such detergents are now being introduced in the market, the effect of which are yet to be known, once it is dumped into the sea.

The management of waste disposal systems is, therefore, of vital importance, for these wastes contain both valuable components like biological and mineral contents, as well as other undesirable elements like pathogenic bacteria and toxic agents. Hence the waste waters, before discharge into the coastal environment, should be adequately treated and diluted so that there will not be undue damage to the living system.

Along the Madras coast there are large number of canals/rivers entering into the sea carrying sewage and other wastes from various sources. The main ones are the Adyar and the Cooum rivers and the Buckingham canal, the flow in the last two being almost wholly sewage. The effluents from such industries of the thermal stations, the fertiliser factory, rubber factory, oil refineries, tanning and textile industries are also ultimately drained into the sea.

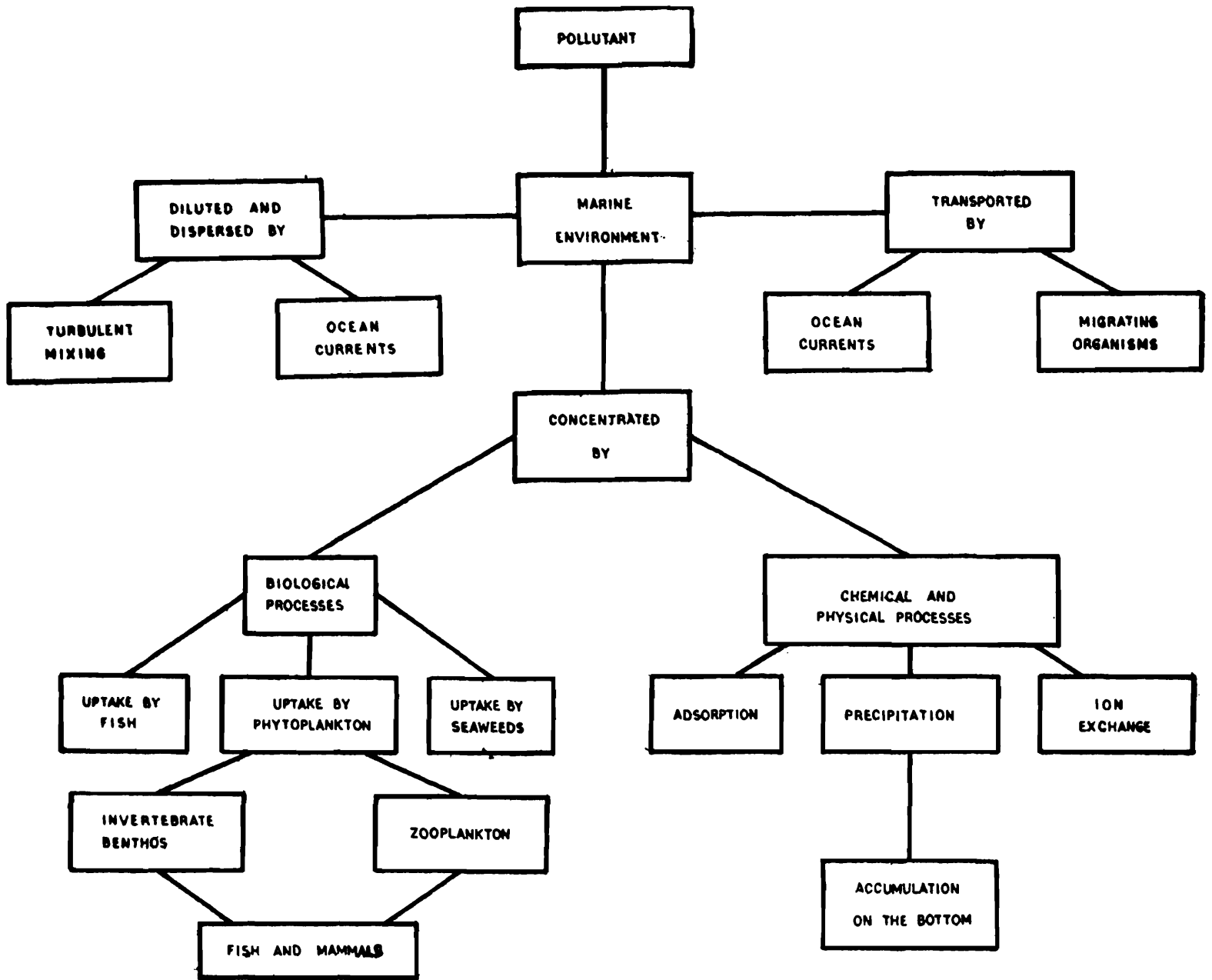
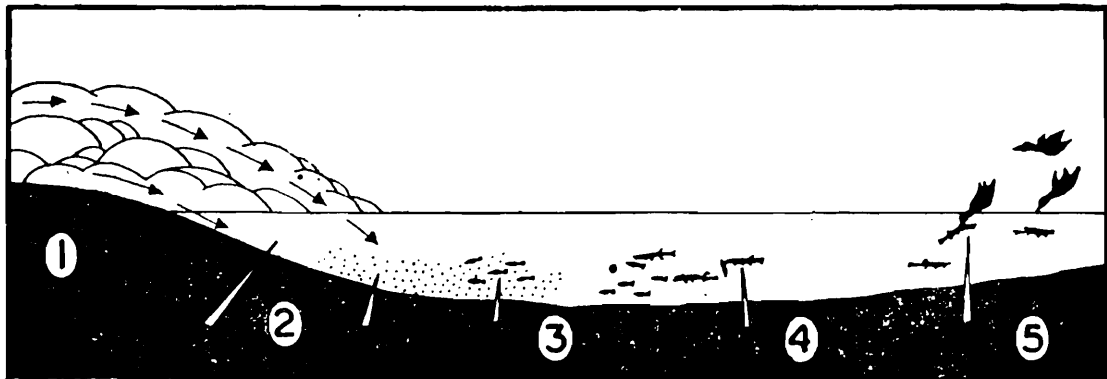


Fig. 1. Various processes determining the fate and distribution of a pollutant to the marine environment.

BIOLOGICAL MAGNIFICATION

HOW DDT CONTENT IS MULTIPLIED ABOUT 10 MILLION TIMES IN LIVING ORGANISMS. (PPM = PARTS PER MILLION)



- ① DDT REACHING SEA BY RUNOFF FROM FIELDS AND WIND-BORNE SPRAY ESTIMATED CONTENT .000003 PPM
- ② ZOOPLANKTON ABSORBED DDT . .04 PPM
- ③ SMALL FISH / ORGANISMS FEEDING ON ZOOPLANKTON: .5 PPM.
- ④ BIGGER FISH EATING SMALLER FISH GETTING MAGNIFIED CONTAMINATION 2.0 PPM .
- ⑤ FISH-EATING BIRDS GETTING BIOLOGICALLY MAGNIFIED CONTAMINATION: 25 PPM. RESULT: REPRODUCTION AFFECTED.

Fig. 2

At Madras there are many economically important organisms like shell fishes (oysters, mussels, cuttlefishes), prawns, crabs and some of the echinoderms, which are benthic. Many of these are filter-feeders, and they have a high capacity of filtering large amount of water from the medium in which they live. As such, they can concentrate and retain larger quantities of chemical impurities in their tissues depending on the substance, climate and the size of the organism.

(ii) Oil spill pollution :

One of the most serious pollution is from accidental oil spills. Ships carrying petroleum and Crude and other heavy oils constitute a serious threat of offshore pollution where they form a film on the surface of the sea thereby suffocating the animals, zoo and phytoplankton living at the surface of the sea which form food for the other fishes. This requires immediate research study because of the recent intensification of oil exploration and exploitation activities in offshore regions and increasing volume of tanker traffic. Some tests are being conducted at NIO, off Bombay High region on the probable movement of a hypothetical oil patch (Gouvêla and Kurup, 1977) and at Goa to study the efficiency of several physical means for removal of oil spills and toxicity of some chemical dispersants used to control oil spills. Recently some work has also been carried out on the effect of oil spills on the planktonic organisms in the harbour area of the Madras Coast (Fernandez, Daniel and Nicket, 1977). More detailed studies are vitally needed.

(iii) Pollution from thermal power stations :

Due to the heavy demand of power supplies, many thermal power stations are being set up along the coastline. This is because of the easy availability of sea water for the cooling-system. Apart from producing power from the industries and other domestic purpose, we have to take note of the 'Chemical and thermal' pollution of the waters by such stations. The main chemical pollution is the fly ash which mainly affect the filter feeders by clogging the gills and other filtering system of the marine organisms. Another is the chromium compounds used in the control of conversion in cooling water systems. The sea water released from the condensor tubes is so hot that it can lead to the increase of the temperature around the outlet region to the extent of killing many organisms, including fishes which are more thermolabile, for, it has to be noted that tropical organisms live closer to the upper thermal limits especially in summer. However, recently the fly ash is being used to make bricks for building construction. But not all the ash is used.

Hence, it becomes necessary to study the effect of sudden or gradual increase of temperature on the plankton, nekton as well as the benthic organisms in and around the area of such power stations outfalls. In Madras, there is

already a power plant at Ennore, and it will be interesting to study the effect of the thermal and chemical pollution along that area, on the marine ecosystem.

II. (b) Effluents disposed into the sea off Madras :

The following are the main effluents that are now disposed into the sea off Madras district from Kalpakkam in the South to Ennore and beyond in the North.

- | | |
|---|--|
| 1. Kalpakkam | : Cooling water |
| 2. Adyar river | : City sewage, sullage, wastes from Surgical Instruments factory, Dhobby Khana at Guindy, City sullage, Plating wastes |
| 3. Cooum river | : City surface drainage—hutments along bank. |
| 4. Harbour | : Tanker—Spillage—Crude oil |
| 5. Kasimedu | : Pumping of city sewages |
| 6. I. C. I. Alkali Corporation of India | : Manufacture herbicides and drugs Paraquat—Intermediate Chlorinated compound. |
| 7. E. I. D. Parry | : Manufacture Ammonia, Sulphuric acid, Phosphate, fertilizers etc. |
| 8. Ennore thermal station | : Fly ash dumped into sea—boiling waste—chromium. |
| 9. Ennore Fertilizers | : Cooling water and all wastes let into Red Hills surplus channel and this joins sea. |
| 10. Indian Organic Chemicals | : Manufacture polyester fibres wastes into sea. |
| 11. Madras Refineries | : Oil carrying wastes, cooling waters may contain chromium, discharged into Buckingham canal and then into the sea. |
| 12. Transformer oil company | : Wastes discharged into Red Hills surplus channel that flows into Ennore creek and then into sea. |

The toxic materials may be chiefly ammonia, urea, Herbicide compounds, acids, chromium salts etc.

Now arsenic is not a factor because the fertilizer industries appear to have discontinued the process using arsenic.

Organic materials, biologically degradable compounds etc. exert demand on oxygen resources. Does this exceed reoxygenation rate from air, and photosynthetic activity of chlorophyll bearing organisms ?

III. Various Processes determining the fate and distribution of a pollutant :

The various processes which determine the fate and distribution of a pollutant added to the marine environment is presented in Figure I.

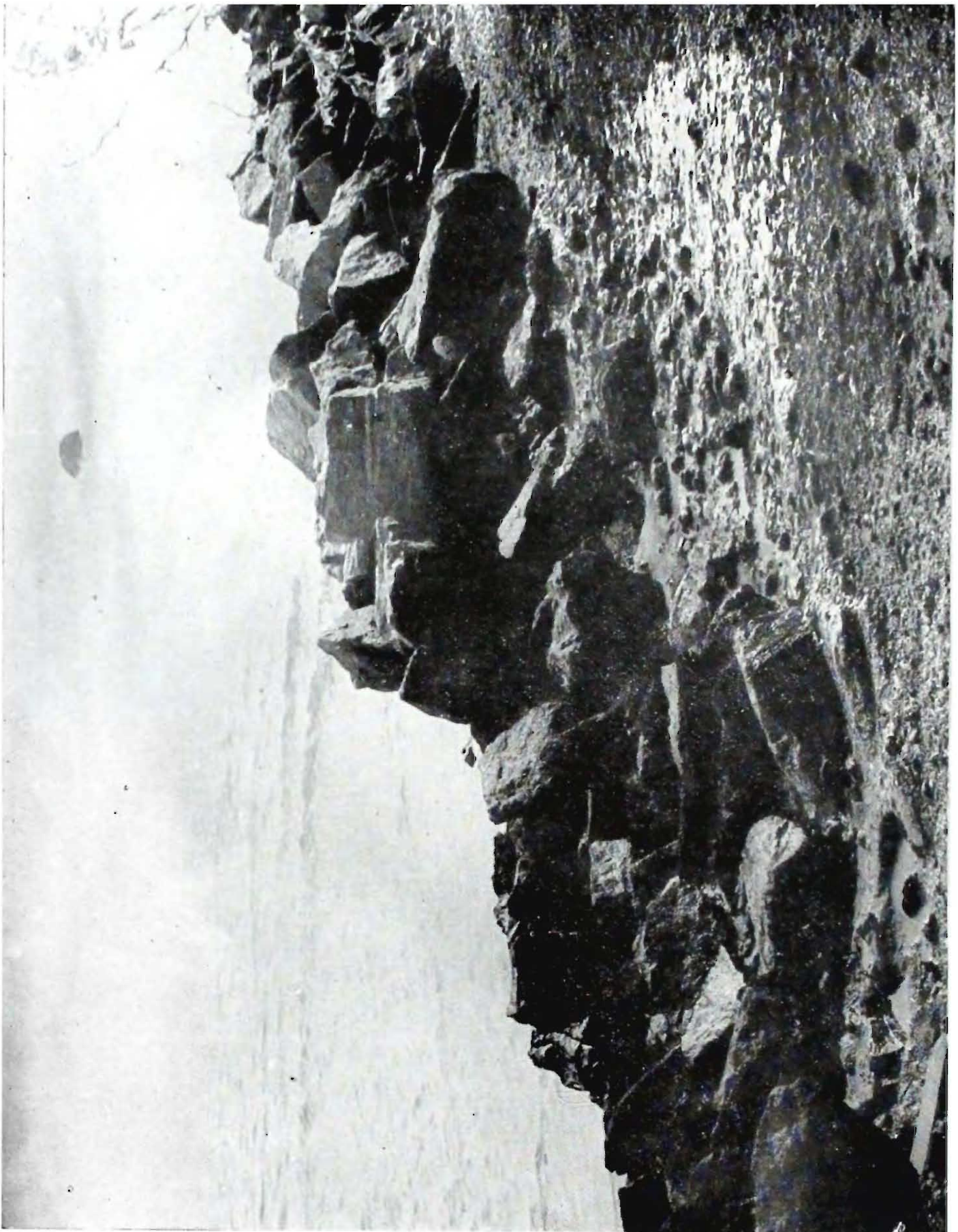


Fig. 3. Showing oil-polluted intertidal region at Skimmer Bay-Tuticorin at low tide.



Fig. 4. A closer view of the same intertidal region showing the fauna affected by oil pollution.

IV. Biological magnification of pollutants :

Dichloro-diphenyl-trichloroethane, commonly known as DDT, has been widely used as a pesticide all over the world. Long after exterminating the insects for which it is used, DDT gets washed from the fields, homes etc. into rivers through channels, and sewages reach the sea ; lingers on leaves of plants and trees ; and becomes airborne in the atmosphere contaminating everything. Scientists estimate that as much as two thirds of the 1.5 million tons of DDT produced by man may still be adrift. It is found in every kind of aquatic life and in almost every animal.

Like the other organochlorine pesticides (the deadly seven dieldrin aldrin, endrin, heptachlor, chlordane, and lindane also called chlorinated hydrocarbons) DDT does not dissolve in water and therefore it accumulates in rivers, lakes and seas for years (its half-life extends to 10-15 years) retaining 50% of its effectiveness more than a decade after it is used. However, DDT is easily soluble in fats and therefore highly susceptible to "biological magnification" as it make its way up the food chain.

By experiments it was found that after some mosquito-infested marshes were sprayed with DDT, it was found in the nearby water in a "safe" concentration of 0.000003 parts per million (ppm). But this gets concentrated in the tiny zoo-plankton (0.04 ppm). Then it builds up further in the fatty tissue of plankton eating fishes (0.5 ppm). These small fishes in turn were eaten by bigger fishes where the concentration of DDT becomes 2.0 ppm. By the time the chemical had passed into the bodies of fish eating birds its concentration had increased to 25.0 ppm., showing an astounding 10 million times increase over the original amount.

DDT is well known to affect the reproductive cycle of fishes and birds. Adult fish, for example are able to tolerate relatively high levels of DDT but the fish embryo, on the other hand, dies almost immediately when it begins to absorb the pesticide through the fatty yolk sac. In birds, it affects the liver and other cells in the body and excess of enzymes are produced which in turn break down such steroids as estrogen that are essential to the manufacture of calcium. The birds eggs become thin shelled and flaky, offering very little protection to the developing embryo.

Many fishes have become unsuitable for eating in many places of the world—due to the unacceptably high level of concentration of DDT. It has caused disastrous decline in the population of fish eating birds. (Fig. 2)

Beyond the danger to fish and birds lies DDT's threat to the whole ecological system. Even very low concentration of DDT can substantially hinder the photosynthesis process. On a larger scale, such interference could have devastating effect, since phytoplankton produces 70% of the earth's oxygen.

V. Impact of pollutants on marine life :

(a) *Oil pollution* : The work of Fernandez, Daniel and Nicket has shown that the neuston plankton biomass was very low in the oil polluted zones (Madras harbour) and the nearby areas, whereas in the adjoining waters off Santhome it was 4.5—6.5 times higher. The biomass in the oil polluted areas was constituted mainly of certain hardy species of crustaceans and coelenterates [*i.e.*, Copepods, amphipods, mysids, and cirripede larvae, Scyphomedusae, (*Rhizostoma* sp.) and hydromedusae (*Aequora* sp.)], whereas in the non-polluted areas in addition to the hardy species, larvae of Mollusca, Polychaeta, Echinodermata, Crustacea, fishes, and cladocerans and many coelenterates occurred in greater density. Oil pollution in the marine environment at Skimmer Bay, off Tuticorin and off Port Blair causing mortality to marine life is presented in Figs. 3—8.

Fish mortality due to industrial pollutants was observed in Cochin backwaters (Unnithan, Vijayan, Radhakrishnan & Ramani 1977). In non polluted environments there is a diversity in the qualitative and quantitative structure of the community. In polluted environments, there is less diversity. Pollution-intolerant species die, leaving room for the more tolerant forms. The tolerant forms, in turn, become predominant because of the decrease in competition.

Thus, the importance of environment preservation, through careful monitoring of the pollutants deposited into the sea must be emphasized by educating the masses on these aspects.

Acknowledgement

I am grateful to the Director, Zoological Survey of India for suggesting this problem on pollution during our visit to Port Blair and for his consistent encouragement and helpful suggestion for this study.

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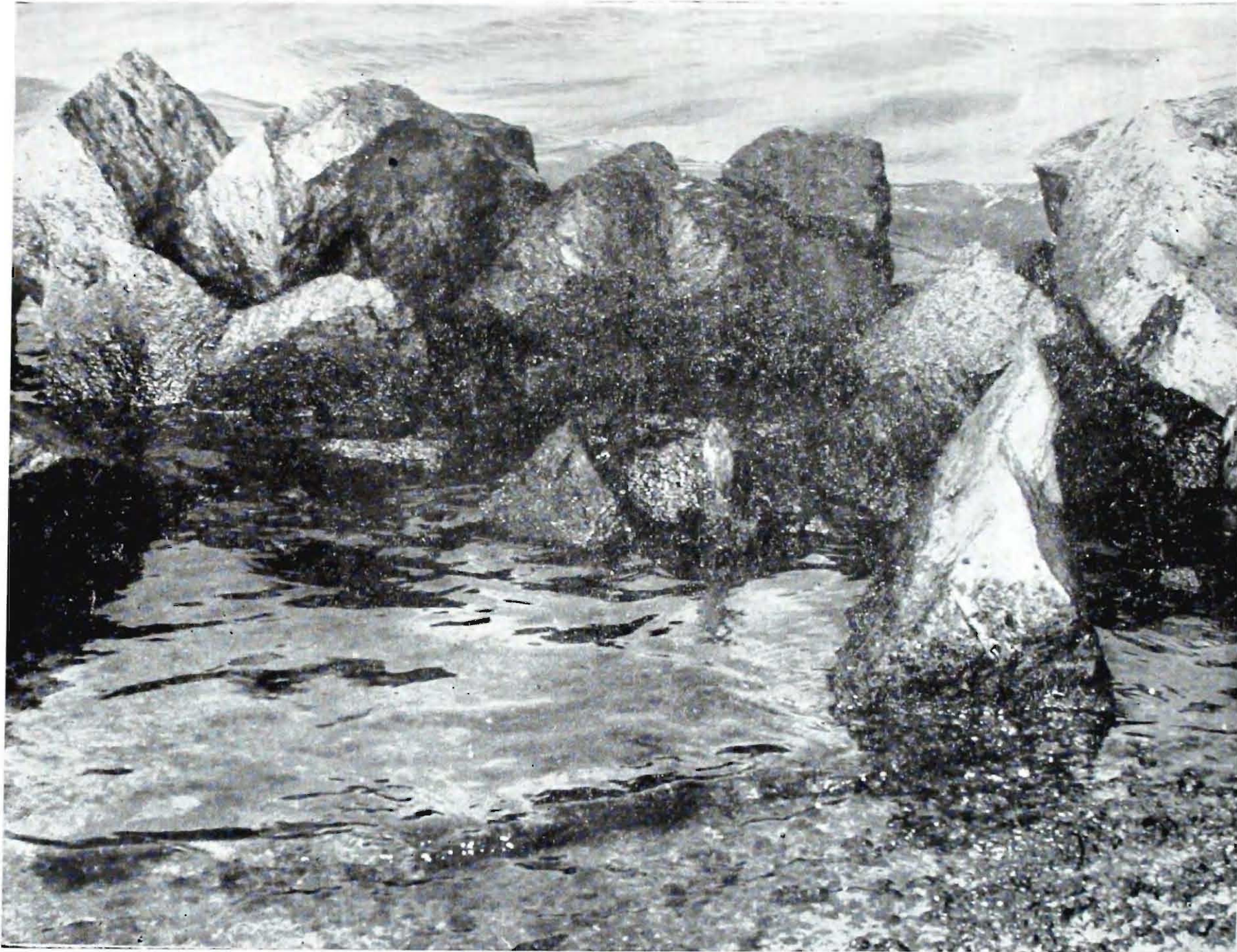


Fig. 5. *Intertidal region at Skimmer Bay-Tuticorin—showing floating oil patches and dead barnacles at high tide.*

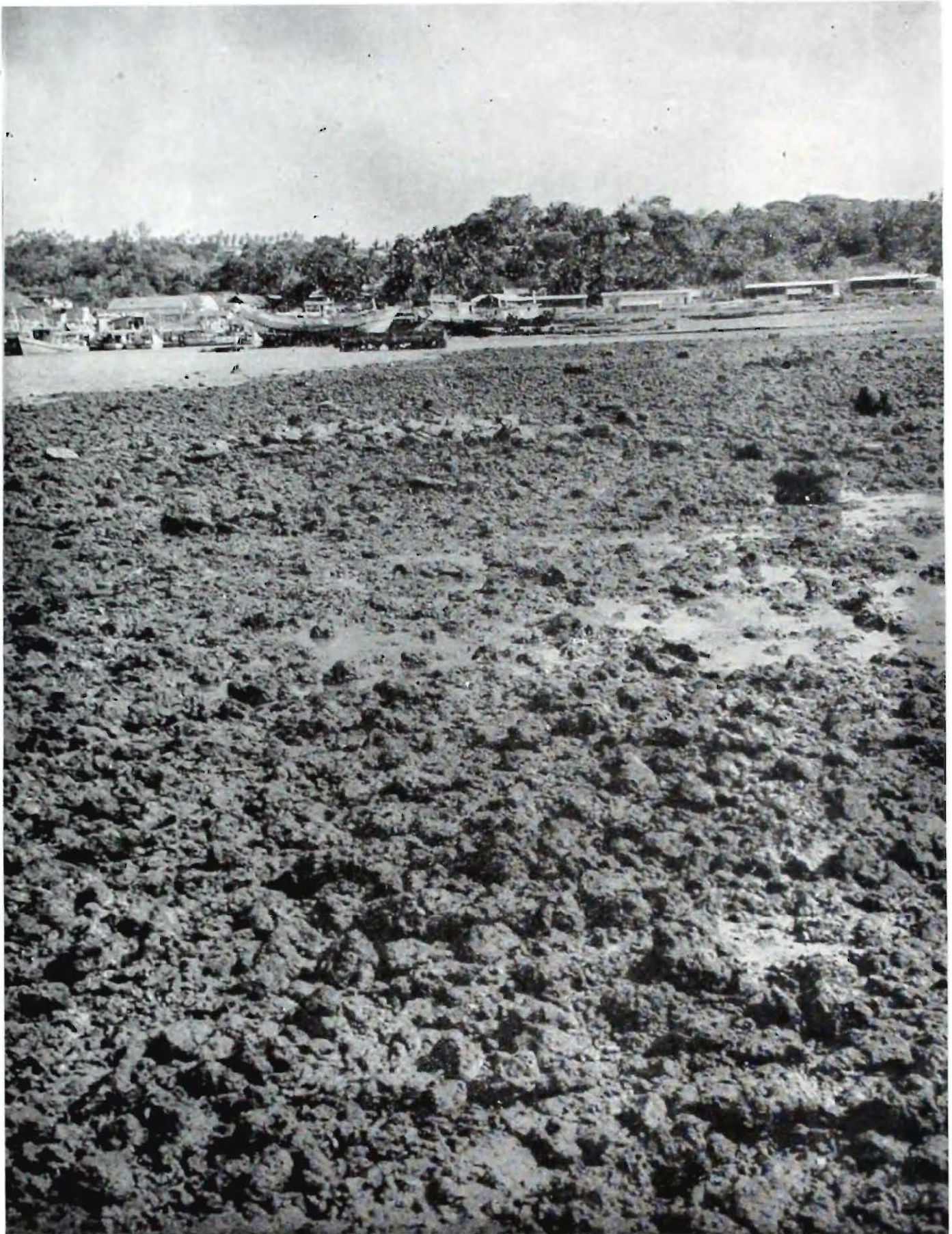


Fig. 6. Coral beds affected by oil pollution off Fishery Jetty (Phoenix Bay) Port Blair, Andamans.



Fig. 7. *A view of the intertidal region opposite to the hospital Port Blair showing depletion of marine fauna due to oil pollution and other pollutants. In 1971-1972 this area harboured a rich bed of living corals and associated marine fauna.*



Fig. 8. *A view of the intertidal region at Phoenix Bay showing the effect of oil and other pollutants on the marine fauna especially corals, which are on the process of eradication.*

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POLLUTION AND ITS MENACE

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The green revolution has brought with it a remarkable increase in the use of insecticides and pesticides in many parts of the world, especially in India. In countries where about 15% of the standing crop is damaged due to pest and plant diseases this is a welcome development. However, this resulted in the establishment of large industrial complexes for the mass production of insecticides and fertilisers. The sweet fruits of industrialisation have been accompanied by the bitter one's of pollution. The nature balance is disturbed by the use of it as a sink to dump industrial waste. Number of times the attention of industrialist has been drawn to the growing threats of pollution.

In western countries the Government has brought laws and legislation to contain pollution, but industrial polluters have made a mockery of these laws. Apart from the anti-pollution legislation, a new culture based on environmental principals has come into use in the western countries. Pollution is not a new environmental problem. Only it has come to our notice recently because of its extent and because some type of pollution are extremely dangerous and are cumulative in nature. There is a notion that pollution is a problem of advanced countries, that a country like India need not bother about environment. Industrial pollution is not as common in India as in other western countries. In few big cities where there is a concentration of big industries, the pollution is worst than in west. In big cities, the diesel vehicles, with thermal power plant is fouling the air. Together they account for most of the carbon monoxide, oxides of sulphur, nitrogen, hydrogen sulphide and hydrocarbon that are discharged into the air. The automobile is responsible for a high volume of pollutant. Lead mostly from automobile is rising in human body. The carbon monoxide level in Calcutta is more than in New York (U.S.A). In Chembur (Bombay) the sulphur dioxide concentration in the air is twice the permissible limit. The turbidity in Delhi has increased by more than 100% since 1957. In Bombay 445 million litres of untreated sewage is being discharged daily into the Arabian sea. In Varanasi more than 3000 gallons of sewage is being poured every day into the Ganga. The Barauni Oil Refinery also release tonnes of waste product into the river. The water of the Ganga at Kanpur is so badly

polluted by effluents flowing out of large number of tanneries, textile mills and other industries, that water is unfit for water supply project. A river is capable of taking in a certain amount of waste depending upon its assimilation capacity that is the amount its flora and fauna can use up. But once this level is exceeded than pollutants destroys the flora and fauna. These pollutants have practically destroyed the aquatic life in these regions.

Owing to rapid industrialisation, the let out of poisonous gases is so heavy that the nature fails to cope with it. Installation of machinery for treating the effluent and making them harmless is necessary. In India, Cigarette filter manufacturing unit let out huge quantities of acetone vapours. Acetone can be recovered and re-used. Similarly the spent wash from distillaries can after proper treatment be used for the expansion of agriculture production. Chemical factories can recover mercury from their effluents. Pollution is not a new environmental problem. It has come to our attention now because of its extent and because some types of pollutions are extremely dangerous and are cumulative in nature. Chronic toxicity may ultimately cause death or may result in the elimination of species or individual over a long period of time through induced sterility. Fishes have long been employed as biological indicator in bioassay of water pollutant, insecticides and other substances. The pollution of water by various substances also has a serious adverse effect on fishes. Pollution destroys the reproductive conditions, and it also disrupts the metabolism of fishes and leads to the mortality of fish-food organism. Destruction of fish-food organism may result in the starvation of fish.

The bioassays with various insecticides have shown that fish obtained from different sources display different tolerance. Geographic location, water quality, pond fertilization, herbicide application etc., influence the relative tolerance of a specimen to a toxicant. The toxic effects of metallic compound leads firstly to the coagulation of the mucous secretion of the gills in fishes and protoplasm of the living cells, which disrupts the metabolism. In iron-poisoning the gills become covered with a dense brown-coating, which makes respiration difficult. Certain acids such as acetic acid, which burn the gills, bring about the disruption of respiration and thus causing death of the fish, others act through the alimentary canal, penetrating through the intestinal walls into the body fluid and disrupting the normal course of metabolism. Industrial effluents containing sulphuric acid affect the eggs and larvae of fishes. Both the H and SO₄ ions affect the fish. The effect of the SO₄ ions is particularly great on developing eggs, destroying their metabolism. Other substances, such as phenol, cause paralysis of the neuro-muscular apparatus and haemolysis of the blood. Amyl alcohol destroys the Co-ordination of the movement in fish and also produces a semiparalytic condition.

Naturally the substance dissolved in the water affects not only the adult but their spawn as well. The paper mill effluents, disrupts the normal course of division of the eggs and the development of the embryo, even when present in negligible quantities, and rapidly kill them at higher concentration. The effect on aquatic organism of the minute amount that trickles into rivers and lakes may be no less catastrophic in the long run than the sudden appearance of lethal quantities of these compounds. Some compounds are known to alter the reproductive cycle of fishes. A pollutant may not kill the organism but yet have disastrous effect by impairing reproduction. Their normal behaviour is upset by delayed breeding or failure to breed.

The chlorine hydrocarbon insecticides are also causing severe spinal defects in fish, incapacitating them for life. The toxic chemicals reduce the vitamin C contents of the body. This leads to the reduction of collagen, a protein that forms the basis of fibrous tissues. This ultimately makes the backbone extremely brittle. Once the backbone breaks, the fish cannot swim. Pollution control is a necessity and must be given the highest priority if we are to restore, maintain and develop our aquatic resources. If care is taken to keep the poison out of ponds, lakes etc., there will be no ill effect. Aquatic fauna especially fish in streams and lakes is practically getting dwindled due to these pollutants. Many lakes, ponds and streams are practically depleted of aquatic fauna due to the regular usage of toxic chemicals.

In general the effect of toxic chemicals on aquatic life is reduction in species diversity, community and stability. 'With the contamination of aquatic environment by these toxic pollutant, behaviour studies should be performed on both exposed and unexposed fishes. The observations on exposed fishes should include general behaviour ; their swimming activity ; pigment discolouration ; coagulation of mucous ; respiration rates ; alimentary response ; and sensitivity to movement ; sound and touch.

Human deaths and disabilities have resulted in some countries from consumption of mercury contaminated fish and meals. In Japan several fishermen were affected who ate contaminated fish with organic mercury. Maximum pollution is caused by chemical plants, paper and pulp factories and tanneries. These industries freely discharge their highly corrosive and toxic waste into the nearby rivers and streams. Monitoring programme should be accompanied by histopathological and ecological studies. The study of histopathological changes in the tissues of fishes exposed to these insecticides is of great economic importance. Exposure for a short duration affects the central nervous system, however, long exposure produces histopathological changes in the liver, intestine, kidney, heart and brain. Liver of fishes demonstrated cellular changes which could be definitely attributed to chlorinated hydrocarbon insecticides.

Great emphasis now should be placed on finding levels of pollutant which will cause no significant harm to aquatic life. During the past few years the fisheries biologists are in search for the development of a compound that exhibits selective toxicity and for the use in the control of undesirable fishes. However, these chemicals can be safely used for the control of fish predators and parasites.

ENVIRONMENT AND SOIL LIFE

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“The material wealth we are creating will not be worth having if creation entails the raping of nature.”

Rene Dubos (1972)

The dearest “commodity” man ever has possessed is the soil ecosystem. The entire human civilisation and the environment it enjoys rests on this precious object. Soil indeed is a living system with its self-replenishing property which is largely accomplished by the soil organisms. Leaving these, soil would appear as a nonporous solid substrate where germinating seeds will fail to take root and perish eventually.

Man began to cultivate soil and raise plants from seeds at the onset of the Neolithic or New Stone Age, about 10,000 years ago in the uplands. As the practice of cultivation spread, farmers came down out of the highlands onto more level ground, where larger fields could be planted and cultivation was easier. Man’s capacity to produce more food than ever before along with rotation of crops (started during 8th Century) led to steadily rising populations in all the centres of cultivation. This consequently led to the clearing of trees and turning the luxuriant forests into arable lands. This conversion had far reaching consequence on entire ecosystem since it was an act of direct tampering with nature. Majority of the arable lands we see today originated from forested regions for ever increasing human needs and this continues unabated till today.

The utilisation of land for cultivation through ploughing (perhaps developed before 3000 B.C.) and subsequent deforestation had profound effects on soil fauna. Ploughing (Fig. 2) and deforestation disturbed the microecological niches in soil and this in turn reduced the diversity and density of the species of soil fauna resulting in the loss of natural productivity of soil ecosystem. The detrimental effects of ploughing on soil ecosystem have always been lopsided as compared to the beneficial ones. Overgrazing has also a direct effect on the productivity of pasture lands (Fig. 3) and its associated fauna. In the United States, for instance, overgrazing reduced the productivity of the vast range lands to the east of the Rockies by more than half during the first 40 years of this

century. Continuous grazing hardly allowed new grasses to grow and thereby soil fauna resulting in the crumbling of soil structure and formation of large dust bowls. Agriculture, whether crop-growing or stock-raising, represents an interference with natural processes and affects directly life in the soil.

The term "Industrial Revolution" conjures a variety of pictures in the mind's eye, but the revolution's impact on agriculture was tremendous. Sharp rise in population almost everywhere in Europe from the mid 18th century onward demanded more food as well as enhancement of economic status. The development of fertilisers (man-made chemicals) was the logical sequel to research in the late 18th and early 19th centuries; the fertilisers began to be mass-produced and applied during the first half of the 19th century. Application of chemical fertilisers alone while reduces the density and diversity of soil animals in the fallow plots without any vegetational cover, these are useful for arable lands having cultivated vegetation. Prolonged application of chemical fertilisers alone without organic compost leads to the reduction in numbers and diversity of soil fauna and humus content of soil.

Continuous application of fertilisers and cultivation of a particular crop over vast stretches of land often with the use of high-yielding varieties increased the incidence of pest attacks. The development of insecticides, like that of fertilisers, is one of the most important products of the Industrial Revolution. The most serious aspects of pesticide problem is the fact that repeated applications result in a steady accumulation of compounds in the soil, owing to the slow decay rate of many of the chemicals used. This is particularly true of the chlorinated hydrocarbons like DDT, benzene hexachloride (BHC), heptachlor, aldrin and dieldrin. Pesticides though are applied on the upper part of the vegetation (leaves, twigs, etc.), nevertheless the soil acts as the ultimate repository where these come down through percolating rainwater as well as some of these reach directly on to the surface of soil during application. Pesticides, not being selective in nature, completely eliminate vast majority of soil fauna so useful for soil productivity. The persistent insecticides like DDT and dieldrin, continue to kill soil arthropods for a pretty long time even after land has been returned to normal conditions. Pesticides also suppress the activities of microflora, which are responsible for chemical decomposition of organic matters and upon which many mites and Collembola rely for food material. Thus pesticides, specially the chlorinated hydrocarbons, cause longterm imbalance in the soil ecosystem affecting adversely the fertility status of soil. Persistence of pesticides in tropical soils is, however, less as compared to those of temperate regions.

During the present century, chemists have provided some more chemicals like weedicides/herbicides and a variety of defoliant. The latter was used to kill off jungle foliage in Vietnam in order to deprive Vietcong of concealment.

The longterm ecological effects of this chemical on soil and its organisms remain unknown. The effects may be catastrophic or negligible but probably has got very little to do with human welfare. Herbicides/weedicides affect soil animals directly or indirectly by eliminating weeds and removing much of the organic matter from soil surface serving as food source of the soil fauna and also depriving the soil of natural manuring. These chemicals are highly selective. It takes a few months for the recovery of soil fauna in the treated soil after the application of some herbicides like DNOC, Simazine, etc.

Industrial pollution discharged from the factories and plants affects directly the soil animals, particularly in the vicinity of industrial areas. Industrial smoke with a high SO_2 content causes not only changes in the vegetation but also changes the composition of soil fauna. For soil nematodes, it is noted that semiparasitic and free-living ones are replaced by saprophagous and predatory species due to action of SO_2 . Industrial chlorine effluents reduce the population of mesofauna nearly by 46% thus hampering the mineralisation and productivity of soil ecosystem. Other kinds of pollutants, though less toxic, reduce certainly the species diversities giving rise to "dominants" in such areas.

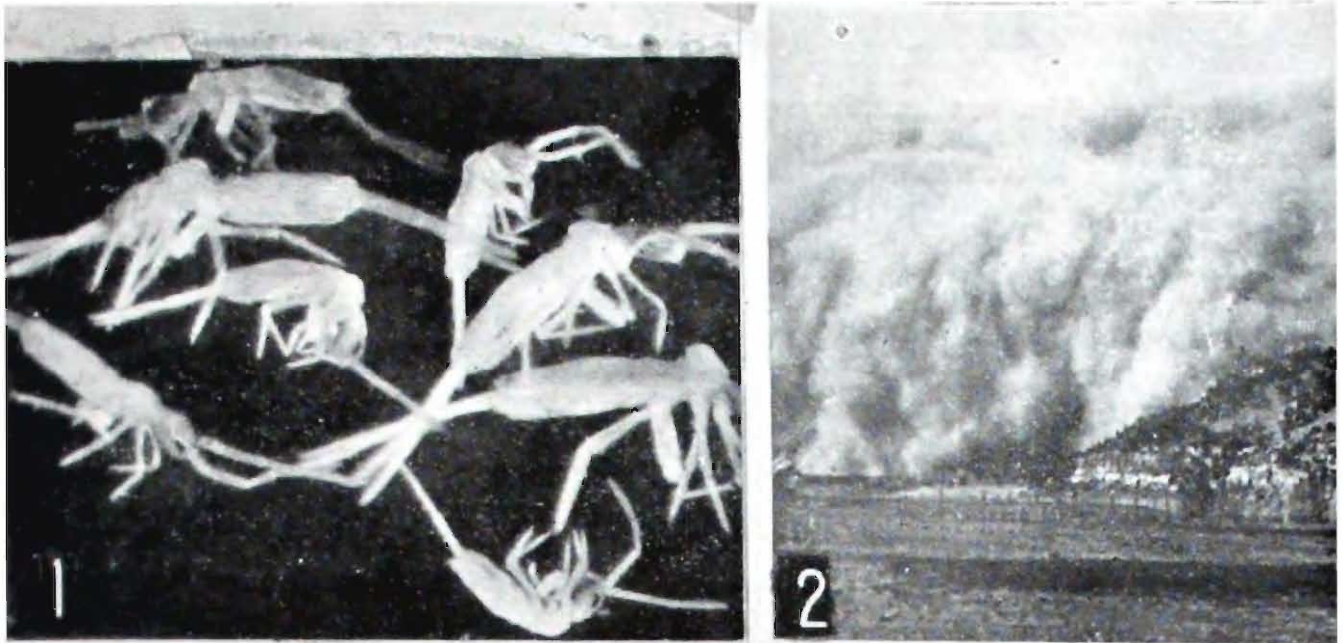
Accumulation of sewage and human wastes of the ever increasing human population pose a serious threat to this biosphere. As René Dubos (1972) puts it: "Waste disposal is becoming as critical as resource production. It is obvious, from the law of the conservation of matter, that waste is produced exactly in the amount that resources are used. What is not so obvious is that in the long run the reverse must also be true: resource production depends upon the utilisation of waste. Otherwise man will convert the biosphere into a global dump." Researches in this direction have of late been initiated by discharging municipal sewage effluents into terrestrial sites with various plant communities. In general, such effluents initially resulted in the decrease of species diversity of soil fauna although it caused an increase of a particular species of earthworms. Thus, in sites treated with sewage effluents ecological emphasis shifts from saprophagous microarthropods to the lumbricid earthworms. There was, however, an increase in the organic matter content of soil in the treated plots with a better growth of cultivated vegetation (white spruce) than untreated plots.

The most dangerous pollutants of all are present in the radioactive fallout—the by-products of nuclear bomb explosions or of atomic power stations. When a nuclear bomb explodes nuclear elements become attached to tiny particles of dust, which are shot high in stratosphere by the force of explosion. Eventually, the contaminated dust falls to earth, often in rain or snow. Although some regions of the earth, notably the equator and polar ice caps, have received

less fallout than others, there is no doubt every part of earth's surface and all its inhabitants have been contaminated by radioactive elements. The overwhelming mass of this fallout is due to the intensive series of atomic and hydrogen bomb tests conducted by several countries from 1948 till today. Underground explosions also result in considerable radioactivity in soil, though to a lesser extent than the explosion on the surface. These deadly products of atomic explosions are poisoning our soil to a great extent. The fallouts, as recent researches prove, considerably reduce the productivity of soil through eradication of entomofauna, microfauna and microflora which exhibit sensitivity specially to such radioactive substances. Even collembolans (springtails), which exhibit sustained tolerance (Fig. 1) against various doses of pesticides including the most toxic DDT, dwindle and in some cases perish completely due to such radioactive elements.

The impact of changing environment on soil life due to Man's various activities including cultivation are though subtle, are of utmost importance for the existence of mankind. An ecological attitude is essential for protection of soil ecosystem. This will help us to establish an "alliance" with this precious substrate in our own interest. Till now, to quote Prof. Aldo Leopold, "We have abused land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."

Of late researches in these directions have been initiated in the Zoological Survey of India as a part of an integrated project on "Soil Microarthropods and soil fertility" of the Department of Science and Technology, New Delhi.



- Fig. 1. *Springtails (Collembola), commonest soil insects, remain unaffected and exhibit sharp rise in their population with the application of D.D.T.*
- Fig. 2. *Continuous ploughing affects the soil structure adversely exposing the precious top-soil particles to be carried by storm for hundreds of miles.*
- Fig. 3. *A deserted farm house consisting of dusty sand underlain by infertile hardpan as a result of overgrazing.*