

# ENVIRONMENTAL MONITORING

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The increasing population, galloping technology and economic development have created awareness of environmental crisis and the need for achieving a balance with nature. In the world today, higher production and consumption of profit oriented commodities are the yardstick of progress. Very often, these pursuits have resulted in the use of air, water and land as free dumping grounds. The experience of the last few decades, has, however, brought into sharp focus the fact that man must start to think of living in harmony with nature. The old concept of progress which has prevailed for the last 200 years must also take into account the means to safeguard air, water and land which sustain man. The cost of environmental protection *must* be included in the cost of basic production activities. Development of new technologies must balance benefits thus acquired against the existing benefits bestowed by nature which are required to be sacrificed. The basic recognition of ecoscience made a beginning in the sixties. A review of activities of International Council of Scientific Unions (ICSU), other major international (MAB, UNEP) and national bodies i.e. CES, NASA, NOAA, of USA reveals that substantial thrust in Earth System Sciences is being devoted to research and global measurements of changes in Geosphere and Biosphere. Apart from Satellite observation of atmosphere, oceans and biosphere, study of atmospheric chemistry, which basically affects earths environment, is receiving high priority (Anon., 1989a). The Greenhouse effect causing global warming and transport of air and water pollutants across the national boundaries has given the problem a global dimension (Hileman, 1989). The International effort is in addition to vigorous national level efforts for protection of the environment from human activities.

As a basic step towards study and management of pollution, introduction of man-made pollutants and their interference with the natural processes (and the resultant imbalance/risk) are sought to be determined. Considerable progress has been made in recent years in respect of monitoring of chemical pollutants in air, water and land as well as their complex inter-relationships. The complexity of this gigantic task requires sustained efforts and commitments. Determination of diverse chemical pollutants before and after the remedial measures is a major part of environmental monitoring. This helps in evaluating the risks involved and success achieved. This data is also necessary as basic input for policy decisions and statutory laws for environmental protection.

## AIR MONITORING

Monitoring of troposphere during early period was limited to the study of smoke and sulphur dioxide. However, with population increase, industrialisation and better standards of living, emission gases like carbon monoxide, methane, nitrogen oxides and sulphur dioxide started extensively fouling the limited resources. The effect of each of these gases cannot be read in isolation but is inter-related in a complex manner. To them, was added chlorofluorocarbons (CFC's) which inspite of their low concentration, contributed to global warming and proved to be prime culprits in the destruction of ozone protective shield around the Earth (Hileman, 1989; Zurer, 1989). Increasing release of  $\text{NO}_x$ , as pollutant emissions, causes rapid destruction of ozone while unfavourable ratios of hydrocarbon with  $\text{NO}_x$  also retard ozone formation. Both dry and wet oxidation of sulphur dioxide and nitrogen oxides by hydroxyl radical and photochemically generated oxidants like hydrogen peroxide and ozone respectively, are also leading to deposition of sulphuric acid and nitric acid, broadly termed as Acid Rain (Lee, 1988). However, air-monitoring programmes for ambient air, air pollution from mobile and stationary sources broadly cover the following :

- (i) Suspended particulate matter (SPM) : its magnitude, particle size, distribution and elemental composition;
- (ii) Analysis of  $\text{SO}_2$ ,  $\text{CO}$ ,  $\text{NO}_x$ ,  $\text{O}_3$ ,  $\text{CH}_4$ ,  $\text{CO}_2$ , chlorine monoxide, etc.; and
- (iii) Determination of benzo-(a)-pyrenes, aldehydes, ethylene, chlorofluorocarbons(CFC's) and other pollutants from specific sources.

The need for more sensitive and selective analytical techniques gradually came into focus as very low concentrations of pollutants were required to be accurately monitored. The present need for unattended continuous chemical monitoring is an important requirement when larger multi-pollutant surveys in far flung areas are to be conducted over extended periods. Consequently, the traditional wet chemical analysis techniques have been gradually replaced with compact instrumental methods with automatic recording. Some significant examples of such improved basic techniques are given in Table 1 (Lee, 1988; Liptak, 1974; Mishra, 1985).

Sophisticated instruments for analysis are expensive to buy and more difficult to maintain in developing countries. Recourse to older monitoring methods is still taking place, though a gradual change is also visible. Increasing use is also being made of mobile environment monitoring laboratories (housed in a large van) which have speeded up generation of requisite data at site, covering air pollution, meteorological and other data (such as water pollution, etc.) (Liptak, 1974; Ayers, 1987). Specific statutory limits and test methodologies are stipulated at national levels in case of emissions from various industries, chemical plants and now the incinerators for high temperature burning of solid toxic wastes (Liptak, 1974; Anon., 1989a). Threshold limit values and Occupational Safety and Health Administration Standards, USA in various chemical and allied industries involving toxic emissions, ensure

**TABLE 1: Current Analytical Techniques for Chemical Species**

Chemical species	Analytical technique
Carbon monoxide	Thermister based on heat of reaction, Infrared analyser
Sulphur dioxide	Sulphation rate by spectrophotometry, UV pulsed fluorescence coulometry, Flame photometry
Chlorine monoxide	Resonance fluorescence (High altitude)
Nitrogen oxides	Chemiluminescence
Carbon dioxide	I.R. analyser
Methane	I.R. analyser/Gas chromatography
Ozone	Chemiluminescence
Suspended	Continuous analysis based on particles (SPM) Beta absorption using C <sup>14</sup> or Cr <sup>85</sup>
Elemental	Atomic absorption spectro composition of SPM photometry, X-ray spectrometry, Energy dispersive X-ray fluorescence, ICP—Atomic emission spectrometry, Neutron activation, analysis
Benzo-(a)-pyrenes	TLC with fluorescence spectrophotometry
F, Cl, NO <sub>3</sub> , NH <sub>3</sub> , etc.	Ion selective electrodes

occupational safety and are also the basis of monitoring (Wadden and Scheff, 1989). Monitoring at high altitudes using special planes involves automatically operated systems to measure ozone, chlorine monoxide, nitrogen species, water, aerosol particles and other atmospheric constituents. These efforts are primarily meant to determine changes in ozone concentration and movement of long lived tracers in air (Gunderson, 1988).

## MONITORING OF QUALITY OF WATER AND WASTE WATER

The quality of water available to man has received the earliest attention and over the years comprehensive national and international standards have been laid down for drinking water, water used in agriculture and industry as well as liquid effluents from sewage, industrial and other sources. The present list of contaminants generally monitored, covers nearly 25 items both organic (alkyl-benzene sulphates, phenolic compounds, alcohols, chloroform extracts, etc.) and inorganic radicals. Added to this would be additional contaminants such as entire range of pesticides, organic compounds of mercury and specific toxic chemicals depending upon the nature of chemical discharge (Liptak, 1974).

Ground water represents 97% of total fresh water reserves excluding polar ice-caps. Nearly 50 to 70% of domestic water supply is from ground water. Pollution of this resource occurs due to mine drainage, industrial waste, land fills, radioactive waste and agriculture pollution due to fertilizers (nitrates) and pesticides

(ethylene dibromide), chlorinated hydrocarbons, etc. Ground water monitoring for inorganic salts (chloride, nitrate) as well as organic contaminants is hence an important requirement, especially when an impact of larger use of agro-chemicals and adverse effects of leaching and drainage from toxic wastes is being increasingly discovered (Ritter, 1986).

Although initially great emphasis was placed on monitoring of water quality as per statutory standards, their intrinsic enforcement remained unsatisfactory. The emphasis has therefore rightly shifted to the control of effluents and the composition of waste water finally discharged. Consequently all the advanced and developing countries are today prescribing adequate standards for effluents from various industrial and civic sources thereby assuring minimum pollutions of water including the sea (Lee, 1988; Sharma and Agarwal, 1980).

Monitoring of water pollution is not confined to organic and inorganic constituents, but thermal pollution arising out of hot water discharge, is equally being restricted. Similarly natural radionuclides in sea water and disposal of radioactive effluents has also come under constant surveillance. A wide variety of chemical and biological tests are prescribed separately while modern water quality data collection systems, record several (8 or more) parameters simultaneously and continuously, making it possible to generate reliable and comprehensive data even at remote places. Today typical data generation on effluents both before and after treatment (decontamination), would cover pH, colour, temperature, suspended solids, dissolved oxygen, BOD, COD, oil, grease, chloride, phosphate, phenols, cyanides, sulphides, sulphates, fluoride, arsenic, bromine, sodium, cadmium, lead, chromium, mercury, nickel, selenium, silver, zinc, pesticide residues, coliform, etc. Even these estimations are often inadequate to confirm the harmlessness of the discharged effluents. Bioassay techniques based upon fish additionally help to determine the extent of effluent discharged into the natural water system which would ensure only permitted level of adverse effect to the aquatic life. Toxicants in aquatic system are often biomagnified through the food chain and hence mere low level of certain chemicals (lead, mercury, cadmium, DDT, HCH, PCB's) is not a guarantee of safety. Biological sampling and chemical analysis of fish, clams, shellfish, crayfish, leaches, blood worms, etc. for mercury, lead, pesticides (especially chlorinated hydrocarbon type) etc. has become essential requirement (Sharma and Agarwal, 1980).

## FOOD CONTAMINATION STATUS

Contaminated food could be a major health risk and this fact has been a basis of regulatory monitoring of food and feed for a long time. However, over the years, growing industrial pollution, increased use of agrochemicals, and emergence of processed/packed foods has aggravated the food contamination situation. Comprehensive monitoring and regulatory efforts in advanced countries have lead to a near satisfactory situation but this cannot be said for the developing countries at present. Considering the serious implications of contaminated food for human consumption, a Joint UNEP/FAO/WHO Food Contamination Monitoring Programme

(GEMS/Food) was initiated in 1976. At present nearly 35 countries are involved and about 20 specially selected contaminants are being monitored. This Programme basically attempts a global presentation, synthesis and evaluation of major contaminants in food (Anon., 1988b). FAO and WHO have also several programmes (Codex Alimentarius Commission) concerning establishment of contaminant residue limits (pesticides, heavy metals, etc.) in agriculture produce and other foods as well as limits of Average Daily Intake (ADI) of contaminants, through diet. However, within limitations of international and national standards and the available monitoring data, it has been possible to determine the extent of contamination and effectiveness of the regulatory measures instituted. An overview of some of the major contaminants in food is presented in Tables 2 and 3 (Anon., 1988b; Ware, 1989; Mehrotra, 1985).

Heavy metals (lead, cadmium, nickel, mercury, etc., Table 2) and industrial organic contaminants like polychlorinated biphenyls (PCB's), dioxins, acrylamide, vinyl chloride, etc. (Table 3) are derived from diverse sources and hence their reduction is dependent on industrial management and introduction of major strategies for utilisation of substitutes or altering the production/use pattern. For instance, elimination of lead as contaminant from petrol car exhausts would require alternate lead-free fuels and modified automobile engines. Similarly, regulated use and substitutes for PCB's are slow in introduction, more so, in developing countries.

Persistent organochloro group of pesticides (DDT, HCH, Lindane, Aldrin, Dieldrin, Chlordane, Endrin, Toxaphene, Heptachlor, etc.) have been gradually replaced with less persistent and easily degradable molecules such as organophosphorus compounds, carbamates and synthetic pyrethroid group of pesticides. Since the seventies a progressive decrease in the environmental presence of organochloro group of pesticides to acceptable levels has been ensured in the advanced countries. But this is not the case in several of the other developing countries, which continue to use DDT, HCH, Lindane, etc. due to their low cost and requirement for poor farmers and the public health programmes for control of malaria and other insect borne diseases (Anon., 1988b; Mehrotra, 1985; Barni, 1987). Recently a comprehensive survey in USA involving monitoring of nearly 15,000 samples of food (both local and imported) confirmed that less than 1% of the samples contained residues that exceeded permitted tolerances for the entire range of pesticides (Yess, 1988). Total dietary studies in USA in respect of pesticides, heavy metals and PCB's have also clearly indicated a low level of contamination well below the international and national statutory limits (Gundenson, 1988; Anon., 1988b). It is therefore clear that choice of pesticides coupled with good agricultural practices have offered the desired protection from this source. However, if for economic or other reasons, use of persistent pesticides is being continued, the problem of contamination and resultant hazards are inevitable. The society will have to bear the cost of change over.

## MONITORING OF GENERAL INDUSTRIAL POLLUTION

Nearly 70,000 chemicals are at present in general use and 500-1000 are being added yearly with no limit in sight. In fact quadrupling of global economic activity

TABLE 2: Chemical Contaminants in Food

Sl. Contaminants No.	Sources	Toxicological properties/Health effects	Tolerance limits and analytical methodology	Present status
1	Barium (as sulphate and chloride)	Drilling mud, pigments, X-ray contrast medium, barium salts in water and food	Maximum contamination level 1 to 4 mg/L. <i>Method:</i> A.A. Spectrometry	Less than 200 µg/L generally concentrations over 1 mg/L also encountered in drinking water. Low levels in food.
2	Cadmium (chloride and oxide)	Rock phosphate, alloys, batteries, pigments, plastics, electroplating and even in cigarettes, municipal wastes, potteries, etc.	Provisional tolerable weekly intake 7mg/kg b.w. Limit in food around 10 to 100 mg/kg. Maximum WHO limit for water 5µg/L <i>Method:</i> A.A. spectroscopy	Low levels in food
3	Mercury (mercuric salts and methyl mercury)	Electrolytical processes, catalysts, dental amalgam, paper and pesticide manufacture.	WHO drinking water limit 1 µg/L. Provisional tolerance weekly intake 3.3 µg/kg b.w. Limit in food/fish 0.5 mg/kg generally. <i>Method:</i> A.A. spectroscopy (cold vapour technique)	Dietary intake high due to contaminated fish mainly
4	Nickel (nickel chloride and oxide)	Nickel salts in geological materials, plumbing and from industries	Acceptable intake 1.46 mg/kg b.w./day. Ambient water 632 µg/L. <i>Method:</i> A.A. Spectrometry	Contamination levels generally low. Hazard only through inhalation (nickel carbonyl)

(contd.)

(Table 2 Contd.)

Sl. Contaminants No.	Sources	Toxicological properties/Health effects	Tolerance limits and analytical methodology	Present status
5	Lead (as salts) Batteries, solder, ammunition, pigments, galvanising, plating and fuels (as tetraethyl lead), lead pipes, and lead soldered containers.	Accumulative poison affecting haematopoietic and nervous systems, kidney. Exposure by inhalation, food and water.	Provisional tolerable weekly intakes 25 µg/kg b.w. Maximum level in fruit juices, etc. 300 µg/kg. <i>Method:</i> A.A. spectrometry	Variable residues in food, human milk and infant foods. Dietary intake higher in industrial and high traffic areas.
6	Nitrate and nitrite Inorganic fertilizers, explosives, glass, heat storage systems, cured meat, printing. Also part of nitrogen cycle.	Toxicity of nitrate due to its reduction to nitrite which interferes with transport of oxygen. Formation of nitroso compounds with secondary and other amines.	Nitrate, nitrogen limit in water 10 mg/L while for nitrite only 1 mg/L. <i>Method:</i> Nitrate is reduced and combined nitrites estimated	High dietary intake by water due to fertilizers and wastes.

TABLE 3: Organic Contaminants in Foods

Sl. Contaminants No.	Sources	Toxicological properties/Health effects	Tolerance limits and analytical methodology	Present status
1	Acrylamide-(2-propenamide or ethylene carboxamide) Used as ground and soil stabilizer. As polyacrylamide in water treatment, adhesive, food packing, photography, oil recovery, metal coating, etc.	Cumulative poison, damages central and peripheral nervous system. A probable human carcinogen.	Polyacrylamide products should not have more than 0.5 µg/L of monomer. No safety limit prescribed due to cancer risk. <i>Method:</i> HPLC	Low levels in food and water in USA and UK
2	Vinyl chloride (monochloroethylene). Vinylchloride and PVC are used in plastic, rubber, paper, glass, automotive industries, insulation, pipes, equipments, packing and building materials.	Clinical symptoms on inhalation exposure only. Risk of carcinogenicity but rapidly degraded with no bio-accumulation	Limit in water 2 µg/L. Tolerance in food not required due to easy metabolism. <i>Method:</i> GC	Contamination if present is low  (Contd.)

(Table 3. Contd.)

Sl. Contaminants No.	Sources	Toxicological properties/Health effects	Tolerance limits and analytical methodology	Present status
3 TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) (Dioxin)	By-product in several chlorinated phenolic compounds. Present in flyash, flue gases	Results in chloracne, liver damage, etc. Evidence of carcinogenicity in animals.	Limit in man 0.1 µg/kg b.w./day. Fish with more than 50 ppm unfit for eating. Method: GC/MS	Bioaccumulation in fish and mammals. Low level in food including meat.
4 Polychlorinated biphenyls (PCB's)	Dielectric, heat transfer and hydraulic fluids, lubricants, plasticisers, adhesives, plastics, copying paper, etc.	A possible carcinogenic risk to humans. Contamination of edible oils leads to intoxication	No FOD/WHO ADI but USA prescribes limits of 1 µg/kg b.w./day Method: GC/MS	Often high values in human milk and fish in Developed countries. Decreasing trend due to use restriction/replacement.
5 Organochloropesticicides (a) DDT	Since 1940 used as insecticide extensively in agriculture and public health. At present mainly used in developing countries.	Storage of DDT in body tissues but no ill effect even in infants taking high DDT content human milk. Bioamplification through food chain.	ADI for DDT 20 µg/kg b.w./day. Maximum residue limits 50 to 1000 µg/kg in different foods. Method: GC	Contamination low where DDT use discontinued. Otherwise persistent presence in environment and human milk.
(b) HCH (and gamma isomer- LINDANE)	Technical HCH (BHC) a mixture of alpha, beta, gamma and delta. Being banned/restricted for many years but Lindane still used.	Storage of HCH isomers (beta persistent) in body tissues and human milk. Bioamplification through food chain. Suspected potential carcinogen only.	ADI for gamma HCH 10 µg/kg b.w./day while proposed for alpha isomer 5 µg/kg b.w./day, beta isomer 1 µg/kg b.w. Variable MRL's for lindane in foods. Method: GC.	Contamination and dietary intake low where use of HCH discontinued. Otherwise high values in food feed and human milk.
6 Aflatoxins ( <i>Aspergillus flavus</i> and other mould products)	Four major aflatoxins in plants and foods under specific temperature, humidity and soil conditions. Contaminated feed leads to Aflatoxin M1 in cow's milk.	Potential human carcinogens. Reves syndrome, kwashiorkor impaired immune functions and other adverse effects.	Limits of aflatoxins in food (5-20 µg/kg) and feed (10-50 µg/kg). Limit in milk 0.05 to 0.5 µg/kg. Method: HPLC, TLC, RIA, ELISA.	Variable food contamination due to temperature, humidity and post harvest handling. Residues generally low.



since 1950 has lead to increasing chemical wastes, not to mention the application of fertilizers, pesticides, detergents, food additives, etc. The chemical monitoring of heavy metals had commenced early but a big alarm was sounded by Rachel Carson (1962) on the ill-effects of DDT in the environment. Since then, there has been no looking back. Chemical and toxicological monitoring of contaminants belonging to diverse chemical groups has become integral part of extensive national and international programmes to safeguard man and his environment. Monitoring of hazardous wastes deposited on land (sanitary land fills) and their disposal by incineration, are other areas which have received intensive attention during the last two decades. The problem is acute in the case of industrialised nations but the third world countries are also catching up with increase in their population and industrial development.

It would be pertinent to note that with respect to 70,000 chemicals in general use, majority of them have not been evaluated with respect to their toxicity. Such data generation may need US \$ 500,000 per chemical and several years of effort. Experimental data also cannot be directly correlated to human risk (say carcinogenicity) and even epidemiological studies fail to give clear answers as man is exposed to a host of chemicals at the same time. However, major incidences such as at Minamata, Japan, 1959 (mercury). Bhopal, India, 1984 (methyl isocyanate) and Chernobyl, USSR, 1986 (radioactive fall out), have further brought into focus specific pollutants and triggered the need for intensive surveillance and adequate preventive measures. Some specific areas of topical interest are briefly cited below.

TCDD (2,3,7,8-tetrachlorodibenzo-*p*-dioxin) is highly toxic member of a family of 75 isomers of polychlorinated dibenzo-*p*-dioxins while TCDF (2,3,7,8-tetrachlorodibenzo-furan) is also a highly toxic major member of a group of 135 isomers of this class. These dioxins as a class, are present in the environment from sources like production of chlorinated phenol group of pesticides, PCB's, car exhausts and burning/incineration of wood, coal, municipal wastes, etc. The presence of this group of highly toxic contaminants has to be regularly monitored at different stages to ensure safety. In fact by 1985, USA had spent \$150 million on research in this area. The problem of dioxins is however more serious in industrially advanced countries due to high production of chlorinated phenols and extensive municipal refuse incineration (Eduljee, 1988).

Automobile exhaust as well as fuel volatility on handling, especially in industrialised countries and urban areas, are sources of serious environmental pollution due to emission of lead (from tetraethyl lead), CO, hydrocarbons, acrolein and crotonaldehyde, etc. Continuous monitoring in this regard has been introduced concurrent with steps to reduce/replace lead in fuels and improvement in engine performance. Similarly, asbestos (hydrated silicate material crystallised as bundles of fibrils) is in use for 100 years. Till lately it was regarded only as an occupational hazard, but it is now considered as an indoors air pollutant. Monitoring air for milli-micron size asbestos samples involves phase contrast microscopy, SEM and

transmission electron microscopy. Although there is little evidence of serious health hazard so far, there are moves to restrict asbestos use (Zurer, 1985).

Monitoring and disposal of "Radioactive Waste" on land and sea has become a matter of major importance. Extensive use of radioactive materials in power generation, hospitals, industry and defence has led to this concern. Wastes with both medium and long lived radio-nuclides are required to be transformed into solid form and then suitably packed and buried in deep geologically stable sites. Disposal technologies are being so perfected that risk is no greater than one chance in a million a year of any adverse health effect leading to premature death (Saunders and Wilkins, 1987). Recently radioactive noble gas radon (natural decay product of radium-226) has been considered as an indoor pollutant with cancer hazard, requiring monitoring and statutory control on its concentration.

Soil was considered a safe waste repository earlier with the belief that organic chemicals will be degraded, adsorbed, immobilized and volatilised to render them harmless. Use of agrochemicals and waste disposal thus continued with little monitoring of soil, atmosphere and ground water resulting in damage to the environment. In the absence of complete understanding of fate and transport of organic chemicals in soil system, recourse to actual monitoring has been indispensable (Jury *et al.*, 1987). Chemical monitoring has now been directed towards pollution created by industrial processes as well as subsequent waste disposal by land fills. Monitoring of North Sea Oil producing installation has revealed that the deleterious effect of the discharge of oil-based mud is confined to 1000 meter zone. While high concentration of organic pollutants and heavy metals in production water are rapidly diluted with little environmental significance (Gillman and Gibson, 1986). Disposal of non-degradable waste through ocean dumping is prohibited since 1972, while land fill as an alternative (though cheaper than preferred high temperature incineration) has resulted in leaching of pollutants into ground water. If this alternative is used for industrial waste disposal, regular monitoring including use of monitoring wells around the site is also considered essential (Ayers, 1987; Sharma and Agarwal, 1980).

Monitoring and control measures for excessive and continuous noise have been instituted as a part of environmental protection. Noise pollution mainly arising out of mechanical industrial operations, aircrafts, traffic, etc. causes harm to health and impairs working ability. The acoustic noise is measured in decibels (dBL) using portable Sound-level Meters and also other electro-acoustic transducers coupled with recorders and microprocessors. Regulatory standards for noise pollution are prescribed for occupational health as well as general pollution control.

Apart from direct monitoring of pollutants and studies on hazard to man, selection of a biotic community other than human has also been used as an indicator of environmental damage. Observations on wildlife are often more rewarding because these are unbiased and both presence as well as accumulation of contaminants is natural. The biotic communities best selected for monitoring covered insect, flesh and fish eating birds as well as fishes (Mehrotra, 1985; Hileman, 1988; Narayan and Verma, 1980). These studies have been extended to include reptiles, lizards, turtles specially in respect of residues of organochloro pesticides (Hall, 1980). A random

monitoring study with wild dolphins and whales revealed high levels of Pb, Hg and Cd as well as PCB's and DDT in particular. These findings are significant proof of bioaccumulation and point to possible harm arising out of industrial and related pollution of the environment (Muiz *et al.*, 1988).

### MONITORING AS STATUTORY REQUIREMENT AND FACILITIES

Regulatory control of toxic chemicals like lead and mercury started in the second half of the 19th century. By the middle of this century, however, all industrialized countries had some regulatory laws covering this field. Nevertheless, environmental accidents involving mercury, cadmium, PCB's, organochloro pesticides, etc. highlighted the environmental risk from anthropogenic chemicals and the need for stricter regulatory controls in more recent years. Realising that a major cause of environmental pollution arises out of industrial effluent discharge, solid wastes and air emission, these aspects formed the basis of legal provisions in sixties and seventies, at national level in respect of specific pollutants to the environment. These legal provisions and the stipulated limits of pollution are being reviewed and upgraded from time to time. However, compliance to the statutory safety standards involves in-house monitoring of original and treated wastes as well as surveillance of the final waste products released to air, water or on land. Monitoring at all these levels must be comprehensive to ensure effective help in control of environmental damage eventually. The laws are effective for achieving environmental safety only if these are implemented comprehensively, especially with respect to monitoring. This in turn needs large sophisticated testing and measuring facilities for which adequate support is most essential.

Under the Federal Insecticides, Fungicide and Rodenticide Act, USA 1972, as amended over the years, and the Environmental Protection Agency, comprehensive guidelines are provided for data generation to ensure safety with respect to environmental pollution. Similar legislations are also adopted by other industrially advanced countries with procedural differences and emphasis as per specific needs. In most of the developing countries, the last two decades, have witnessed considerable progress in establishing statutory monitoring and control measures for the industrial emissions, effluents, waste disposal as well as regulation of pesticides, food additives etc. The work of environmental pollution control is thus being upgraded and the government agencies, as well as industry are increasingly committed to make adequate investment in reduction of pollution due to solid, liquid and gaseous wastes. The task in India in this respect is entrusted to Central and State Pollution Control Boards under a recent comprehensive Environment (Protection) Act, 1986, as well as the Air (Prevention and Control of Pollution) Act, 1981 & 1987 and the Water (Prevention and Control of Pollution) Act, 1974 & 1977 (Anon., 1989b).

There has been significant regulatory effort at the international level by organisations like FAO, WHO, UNIPCS, OECD, EEC, UNESCO, etc. to harmonize environmental protection at apex level (Sheehan *et al.*, 1985). For instance, United National Economic Commission for Europe has got a protocol agreed by large number of members for reduction of air pollutants after a convention on "Long Range Trans-

boundary Air Pollution" in 1983. Recently under Montreal Protocol, a major effort is underway to phase out CFC's and replace them with safer substitutes on high priority (Anon., 1989a). WHO/FAO Food Contaminant Monitoring Programme since 1976, covering a wide variety of chemicals coupled with action under comprehensive national legislations on food, fertilizers, pesticides, etc. has also helped to significantly reduce the environmental damage (Anon., 1988b).

A survey of analytical methodologies currently in use clearly indicated diverse legal procedures and variable testing standards and facilities. This is expected for a growing scientific field. However, manual operations involving basic wet chemical analysis will have to remain acceptable till sophisticated automatic recording instruments are universally inducted. Development of compact and reliable self-recording analytical instruments, simultaneous recording of several parameters and development of mobile outfits has further streamlined the difficult analytical tasks (Mishra, 1985). For individual trace metals, analysis by graphite furnace A.A. Spectrometry is most widely accepted technique due to high sensitivity and selectivity. ICP-atomic emission spectrometry does offer a multi-element analysis capability but the sensitivity is low. For microestimation of organic contaminants a wide range of sophisticated, sensitive and accurate methods such as GC, HPLC, GC/MS, FT-IR, visible and UV spectrophotometry, etc. have been adopted. As the concentrations encountered are usually very low (microgram, nanogram levels), adoption of specific analytical technique often requires preliminary concentration or removal of interfering materials. For example, monitoring of microgram per litre concentration of trace metals in sea water required special extraction of metals as chelates followed by graphite furnace. A.A. Spectrometry in preference to other techniques like Anodic-stripping voltametry and ICP- atomic absorption spectrometry (Aston and Chan, 1987). As accuracy and reliability of monitoring data is a fundamental prerequisite for technical and regulatory actions, constant endeavour for improvement in this area is vital. Uniformity in sampling, sample preparation and selection of analytical methods specific to the concentration of chemical species in environment are major areas of research and development. Quality control/quality assurance procedures would further improve capabilities to interpret and compare trends in contamination (Delia *et al.*, 1989).

## CONCLUSIONS

Conventional monitoring of chemical contaminants within soil, water and atmosphere is now being supplemented by specific screening model studies on major pathways for organic chemical transport and transformation within soil and atmosphere. Several experimental models have been tried with specific reference to toxic organic chemicals in soil-air-water ecosystems (Jury *et al.*, 1987). The data generated and predictions made fall short of complete understanding. The goal still remains to develop a unified transport and fate model, which could describe comprehensively chemical, physical and biological transformation processes occurring in case of organic chemicals in nature. At present development of such computational models is limited by paucity of detailed and accurate experimental data on the transport and fate of more complex industrial and agricultural chemicals available in the

ecosystem. Major interdisciplinary programmes both in the field and laboratory will thus be needed to understand all the important parameters on which determination of total fate of the chemicals can be rationally based. However, any such attempt would still require comparison with results obtained by actual monitoring of the chemicals in the environment.

Extensive chemical monitoring of industrial wastes and their potential for harm have lead to specific technologies to reduce hazards from such sources. Efficient treatment systems, scientific land fills and high temperature incineration of wastes are providing a good measure of protection. Recycling and reusing of the industrial wastes is another fruitful area in which Japan has taken a lead (50% wastes recycled in 1983). Major emphasis is also directed towards rational use of pesticides, fertilizers, food additives, etc. and phasing out/substituting hazardous chemicals like lead, PCB's, CFC's persistent pesticides, carcinogenic chemical, etc. (Anon., 1988b, Anon., 1989a). Cleaner technologies and efficient waste management systems are thus being vigorously enforced as intrinsic measures to contain environmental pollution. Monitoring, both before and after such measures, to determine the success achieved and as an input for further regulatory and technological improvements, remains the key requirement.

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