There is no good reason to expect that industrial wastes will contain only one component. Many industrial wastes prove to be complicated mixtures of metals, organic substances, oils and greases derived from the lubricants used for the plant machinery and any other material most easily disposed of through floor drain (Katz, 1971). As stated in previous chapter. The waste products of steel mills contain iron, phenols, cyanides, thio-cyanates, etc. (Nemerow 1971, Rao and Datta 1978, Trivedi and Goel 1984). Phosphatic fertilizer plant waste products are rich in fluoride, arsenic, organic matter and acids (Nemerow 1971, Rao and Datta 1978, Trivedi and Goel 1984); thermal power plant waste products possess high inorganic and dissolved solids, heavy metals etc. (Trivedi and Goel 1984, Pokrovsky 1981); metal plating industry waste products are loaded with cyanide, cadmium, chromium, zinc etc. (Trivedi and Goel 1984); and the rice mill wastes contain phosphates, starch and reducing sugars etc. (Nemerow 1971).

In fact the spectrum of chemicals that are discharged from industries as waste products is very broad. Their release, accidental or routine, has been proved to be
catastrophic in the past. Minamata disease caused by mercury and Itai-Itai caused by cadmium are only a few examples. However, the effect of chemicals on organisms is not always lethal. It may range from some harmless to totally lethal effects. Their cytological and biochemical effects have been studied in micro-organisms, plants, animals and man using in situ, in vivo or in vitro test systems. Consequently, extensive scientific literature has accumulated on the subject which besides giving information on threshold toxicity levels provides understanding on the mode of action of these chemicals in biological systems. A brief review on the mitotic, chromosomal and biochemical effects of some of the environmental chemicals is being presented here.

A. Effects on Cell Division and Chromosomes

As soon as mitotic division of cell had been discovered, near the end of nineteenth century, a number of investigators tried to alter its mechanism by applying various chemical substances. However, this research remained sporadic and did not draw much of the attention of the scientific world, for it was much too early to try to understand the observed fact (Deysson 1968). Later research showed that the change in cell division may lead to an increase in mitosis (mitogenic action) or more frequently to a reduction in cell division frequency (mitostatic effect). Closely related are effects on the spindle, leading to arrest of division at different stages, disorganization of the spindle and consequent disbalance in separation of the chromosome. Formation of the cell plate may also be inhibited in certain cases (Sharma 1985).

The discovery of X-ray induced mutation in Prosophila by Muller in 1927, followed by that of Stadler (1928) in
maize, provided the necessary impetus for research on the effects of external agencies on chromosomes. Then came the discovery of mutagenic properties of chemicals by Oehlker (1943) and Auerbach & Robson (1946) that have since been continued by many other workers. In the mean time, Blakeslee and Avery (1937) had disclosed polyploidizing action of colchicine.

Chromosomes become sufficiently visible only after they have finished their duplication and have condensed in the equatorial plate at metaphase. They remain visible through anaphase and into telophase, at which time the chromosomes have separated completely and begin to form their new nuclear envelope. Following radiation or chemical treatment, two principal types of chromosomal alterations have been observed (1) the chromosome and (2) chromatid aberrations. In chromosome aberration both the chromosomal strands seen in metaphase show breakage or exchange reaction at homologous sites. A breakage reaction that had occurred in the G₁ phase shows the break in both the chromatids. In the chromatid aberration only one chromatid or daughter chromosome shows a break at one site, suggesting that the DNA alteration occurred after the DNA of this chromosome area had been duplicated (Freese 1971). These breaks if not repaired timely result in deletion, inversion or translocation. Thus, the change in the chromosome may involve alteration in number or structure or both.

The effects of chemicals on mitosis and chromosomes have been investigated by several research workers and new papers on this subject continue to appear every year. Some good reviews are those of Sharma and Sharma (1960), Mehra (1960), Gelfant (1963), Levine (1963), Kihlman (1966), Deysson (1968), Singh and Sharma (1980), Sharma (1985), Fishbein
Levan (1945) investigated the cytological effects of inorganic salt solution on root-tips of *A. cepa*. Full and typical colchicine mitosis (C-mitosis) was met under different concentrations of lithium, beryllium, sodium, potassium, chromium, iron, cobalt, nickel, copper, arsenic, rubidium, yttrium, palladium, cadmium, barium, lanthanum, cerium, gold, mercury, thallium, lead, bismuth and thorium. Induction of sticky chromosomes, manifested mainly by the formation of anaphase bridge, was observed in the treatments of lithium, beryllium, aluminium, titanium, chromium, iron, cobalt, nickel, copper, arsenic, yttrium, zirconium, molybdenum, palladium, lanthanum, cerium, neodymium, erbium, tungsten, gold, mercury, thallium, bismuth, thorium and uranium. Kozlowaski et al. (1963) have found that cobalt, nickel and iron treatments induced micronucleus and granulation of nuclear material in *Vicia faba* root cells. Ruposhev and Garina (1976) showed structural abnormalities of chromosome in seeds of *Crepus cappilaris* exposed to cadmium nitrate or cadmium chloride at concentrations of 0.1 to 0.001 M for 1 hour. Aneuploidy, polyploidy and micronucleus formation occurred in *Secale cereale* by nitrous oxide treatment (Szeles 1983). Inhibition of cytokinesis and chromosome translocation to the poles during mitosis with vanadium treatment have been reported in root meristems of *Vicia faba* (Herichova 1985) as well as of *Allium cepa* (Hidalgo et al. 1988).

Some chemicals which have been reported to intercept mitosis or induce chromosomal abnormalities or both in the plant systems are: mercury compounds in *Allium* root tips (Ramel 1969, Fiskesjo 1969, 1979 and Nandi 1985) and in apex.
bud and root of *Elodea densa* (Czuba 1982) as well as in *Hydrilla verticillata* (Pal and Nandi 1989). Effects of zinc in *V. faba* (Glass 1958), and in *A. cepa* (Herich 1969), copper sulphate in *Chara globularis* and *C. setosa*; ferric chloride in *Vallisneria spiralis* and *A. sativum*; inorganic iron salts in *A. cepa* (Singh and Sharma 1980, Von Rosen 1957); cadmium chloride and zinc chloride in *A. sativum* (Mukherjee and Sharma 1987); cadmium chloride and sodium selinite in *A. sativum* (Mukherjee and Sharma 1988); cadmium, cobalt and bismuth in *V. faba* (Wojciechowska and Kowk 1987); sodium cyclamate and cyclohexylomine in *Pterotheca falconeri* (Mehra and Dhiman 1983), thallium compounds in *A. cepa* (Ravindran 1971), calcium salts in *A. cepa* (Singh and Sharma 1980), etc. have also been reported as mitotoxic.

Amer and Ali (1969) studied the effects of o-nitrophenol, p-chlorophenol, 2, 4-dichlorophenol, pentachlorophenol, 2-naphthol and 2,4-dichlorophenol on root mitosis of *V. faba*. They found that o-nitrophenol, p-nitrophenols and 2-naphthol produced c-mitosis. The phenols in general affected a considerable decrease in the mitotic index and induced lagging, stickiness, fragmentation and cytomixis type of abnormalities in dividing cells. The genetic and cytological effects of phenols have been reported by Hadron and Niggli (1946), Levan and Tjio (1948), Tjio (1951), Avanzi (1950, 1954), Nuhling, et al. (1960), Hindmarch (1951), and Amer and Ali (1968). Extensive studies on the cytological effects of fluoride have been conducted mainly on plants. Aqueous sodium fluoride in a concentration of 1 x 10^{-2} M has been shown to produce chromosomal changes in onion root tip chromosomes (Mohamed et al. 1966). Studies on the effects of HF (3 mg/m^3) on mitotic and meiotic chromosomes in tomato plants (Mohamed 1971 and Mohamed et al. 1966) and on the meiotic chromosomes in maize (Mohamed 1970).
found a positive correlation between the frequency of chromosomal aberration and treatment duration.

(ii) Animals and Man

The effects of methyl mercury compounds and other organic mercury compounds on cell division have been studied in rats (vassileva et al. 1979), insects (Ramal and Magrusson 1969 and Klasterka and Ramal 1978), Japanese quail (Eskeland and Nafstad 1978) and Ciliates (Thrasher and Adams 1972 and Sharma 1984). Exposure to mercury compounds is known to produce chromosome breakage (Skerfving et al. 1979) and C-mitosis in blood cells (Fiskesjo 1970). Both, positive as well as negative results have been reported with regard to the occurrence of chromosomal aberrations in people occupationally exposed to lead. O’Riordan and Evans (1974) did not find in any case chromosomal abnormalities in lymphocytes culture of humans exposed professionally to lead. However, an increase in chromosome aberration have been reported by Schwaintz et al. (1970) and Forni and Secchi (1972) in people occupationally exposed to lead. Bhunya and Pati (1987) have reported mutagenic effects of copper sulphate in vivo by chromosome aberration, sperm abnormality and micronucleus tests in mice. The effects of zinc have been reported to be mutagenic in Drosophila (Carpenter and Ray 1969) and human lymphocyte culture (Bijlsma and France 1976). Preventive action of zinc from the toxicity of lead (Kielan-Bak et al. 1984) and nickel (Wealkers et al. 1985) have also been reported. Bigaliev et al. (1976) showed increased frequency of cells with chromosome aberration in bone marrow of rat treated with chromium compound. Bhunya and Pal (1986) reported c-mitosis, chromosome break & gap by nickel fluoride treatment in bone marrow cells of mice. Incubation of rat liver or purified DNA with ferric chloride stimulated single-stranded DNA break (Burger et al., Sausville et al. 1978, Shris 1982
and Takeshita et al. 1978).

Mohamed and Chandler (1982) have reported that mice when given drinking water containing 200 ppm sodium fluoride showed translocations, dicentrics, ring chromosomes, bridge, and fragments in bone marrow cells. Some investigators (Kram et al. 1978, Leonard et al. 1977, and Martin et al. 1979) have pointed out that fluoride, especially at low concentrations, failed to induce significant adverse chromosomal charges in mammalian cells.

(iii) Micro-organism

Bacteria have numerous advantage for the detection of mutagens. Bacteria are system of choice for screening of a new compounds on the basis of simplicity, sensitivity, economy and range of compounds (Amer 1971).

Sakai et al. (1985) reported mutagenic effects of zinc acetate in Salmonella typhimurium. Nishioka (1975) reported the mutagenic activity of sodium arsenite in Bacillus subtilis. Lack of mutation in Salmonella receiving sodium fluoride is also known (Martin et al. 1979). Kalinina et al. (1977) determined that cadmium chloride exhibited a mutagenic effect on Salmonella typhimurium without metabolic activation. However, Polukhina et al. (1977) found that cadmium had a negligible mutagenic effect on Salmonella system with metabolic activation utilizing enzymes of mouse liver. Manganese is mutagenic for bacteria and phages and is produces mainly transition (Orgel and Orgel 1965). Since manganese also interferes with DNA polymerase, causing the incorporation of RNA nucleotides into DNA, it may cause mutation by altering the accuracy of the base copying mechanism during DNA duplication (Freesc1971).
B. Biochemical Effects

A large member of publications describe alterations in the level of DNA, RNA, proteins and free amino acids under the influence of hazardous environmental chemicals.

The most direct means by which these alterations arise is by interference of the chemical with the synthesis or breakdown of the bioconstituents. Also the deviation from normal may represent secondary response, reflecting generalized morphological tissue injury in conjunction with the shifts in cell population (de Bruin 1976).

Badr and Ibrahim (1987) reported the inhibitory effects of glean on nucleic acid content in root tips of *Allium cepa* and *Vicia faba*. Ramiah et al (1982) observed that sodium chloride and sodium sulphate markedly decreased the activities of RNase and protease with a corresponding increase of nucleic acids particularly RNA and protein in the cotyledons of germinating chickpea (*Cicer arietinum*). Decreased protein and amino acid contents were observed in *A. cepa* root tips exposed to raspberry and pear, the icecream colourants (Younis et al. 1986). In *Oryza sativa*, copper decreases RNA contents of embryo but increases that of endosperm.

It also increases the amount of alkali soluble protein, reducing RNA/Protein and DNA/protein ratio (Das Gupta and Mukharjee 1976).

Kumar and Ansari (1985) exposed four month-old adult siblings of zebrafish, *Brachydanio rerio* to 0.5, 0.7, 0.9 and 1.1 mg/l of malathion for 7 days. They noted a significant reduction in the contents of DNA, RNA and protein while the total free amino acid contents increase in the liver tissue.
Haqqi and Adhami (1979) reported the inhibitory effect of apholate on nucleic acids and total protein content in the liver of male albino rats. Chronic oral administration of mercuric chloride in rat led to an initial increase in the amount of DNA and RNA up to 10 days followed by decrease of these components in kidney tissues (Das et al. 1981). Mehra and Kanwar (1980) have observed decrease in kidney DNA and increase in liver and testis RNA in mice exposed to mercuric chloride and methyl mercuric chloride.

Occasionally the change in nucleic acid content serve as diagnostic criterion of early poisoning. This holds true for the nucleic acids contained in leucocytes. Workers exposed at risk to such compounds as lead benzene or styrene exhibited a marked fall in RNA-DNA in their leucocytes. In such occupational situation the DNA level of monocytes or lymphocytes shows an increased metabolism of nucleic acid in chemical carcinogenesis (Engebrecht & Bester 1968). Vorwald and Reeves (1959) reported reduced RNA level in microsome and Reeves (1959) reported reduced RNA level in microsome and also, reduced nucleic acid level in nuclei of rat exposed to beryllium.