

Impact Of Toxic Chemicals On Living Organisms Biochemically

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ABSTRACT

Chemicals are used extensively in millions of different commercial products. These chemicals include extremely toxic substances which can cause allergies, damage vital organs of the human body like the eye, brain, liver, kidney and reproductive organs, produces deformities in babies during pregnancies of mothers and promote cancer. In case of accidental release into the environment in large quantities, as in case of Bhopal, they can lead to mass murder. What is amazing is that we know nothing about the toxic effect of 80 percent of the chemicals used. Industries which produce potentially toxic and hazardous wastes are pesticides, dyes and pigments, organic chemicals, fertilizer, non-ferrous metals, steel and chlor-alkali manufacturing plants. Some chemicals are essential at low levels but are toxic at function. The biochemical effect of some typical toxic chemical are widespread. When excessive amount of these chemicals are ingested, they replaces elements at key enzymatic sites, and causing metabolic disorders. A small fraction is bound most effectively by the body proteins while the rest is stored in the body and gradually accumulates with age.

Keywords: - Chemicals, toxicology, Biochemistry, Environment.

INTRODUCTION

The Toxic Chemicals are discharged by industries into air, water and soil. They get into the human food chain from the environment. Once they enter our biological system they disturb very long. There are many cases where one is not sure whether a particular chemical compound is toxic or not. Some useful and important chemicals are being controlled rigorously as their non-toxicity has not been proved. There are valid confusions in respect of division is artificial and can be misleading.⁽¹⁾ Many metals as environmental hazards are essential dietary trace elements required for normal growth and development of animals human beings.⁽²⁾ Even the well known toxic elements As, Pb and Cd are required in trace quantities for the growth of animals. The so called biological inert Al causes brain damage, bone disease and anaemia in patients subjected to haemodialysis water containing 100 to 1000 parts per billion of Al.

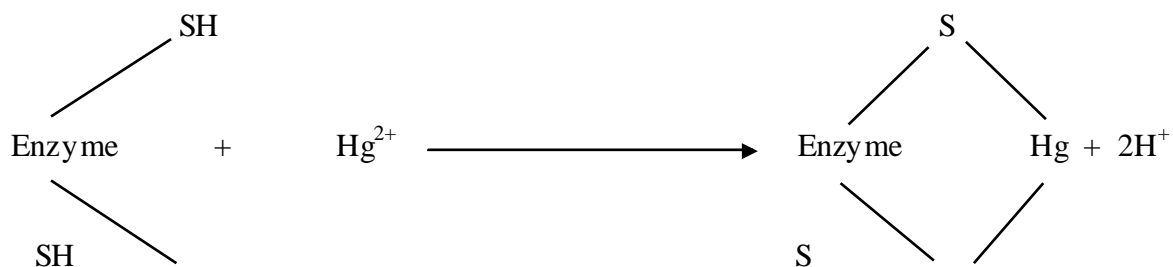
Toxic Substances may be classified according to their function and effects, such as mutagens, carcinogens etc, or food additions etc, or heavy metals, metal carbonyls, organochlorine compounds, etc. According to the “International register of potentially toxic chemicals” of the United Nations environment programme, there are four million known chemicals in the world today and another 30,000 new compounds are added to the list every year. Among these, 60,000 to 70,000 chemicals are commonly used. Apart from their benefit to increasing production, living standards and health, many of them are potentially toxic.⁽³⁾In 1978 the U.S. environmental protection agency, occupational safety and health administration, and consumer product safety commission listed 24 extremely hazardous substances in the atmosphere. Acrylonitrile, Arsenic, Asbestos, Benzene, Beryllium, Cadmium, Chlorinated solvents, Chlorofluorocarbons, Chromates, Coke oven emissions, Diethylstilbestrol, Dibromochloropropane, Ethylene dibromide, Ethylene oxide, Lead, Mercury nitrosamines, Ozone, Polybrominated biphenyls, Polychloride biphenyls, Radiation, Sulphur dioxide, Vinyl chloride and toxic waste disposal emissions and leachates.

RESULT AND DISCUSSION

Thousands of chemicals presumably pose the problems of health hazards so that it is necessary to exercise strict control on those which offer the most serious threats during manufacture and handling. A list of toxic trace elements found in nature. Some of these are essential at low levels, serving as nutrients for animal and plant life but are toxic at higher levels.

Impact of Toxic Chemicals on Enzymes

In general, toxic chemicals attack the active sites of enzymes, inhabiting essential enzyme function.⁽⁴⁾Heavy metal ions, in particular e.g. Hg^{2+} , Pb^{2+} and Cd^{2+} act as effective enzyme inhibitors. They have affinity for sulphur containing ligands, e.g. SCH_3 and $-SH$ in methionine and cysteine amino acids, which are part of the enzyme structures.



Metalloenzymes contain metals in their structures. Their action is inhibited when one metal ion of a metalloenzyme is replaced by another metal ion of similar size and charge. Thus, Zn^{2+} in some metalloenzymes is substituted by Cd^{2+} which leads to cadmium toxicity. The biochemical effects of some typical toxic substances are discussed here.

Some toxic trace elements

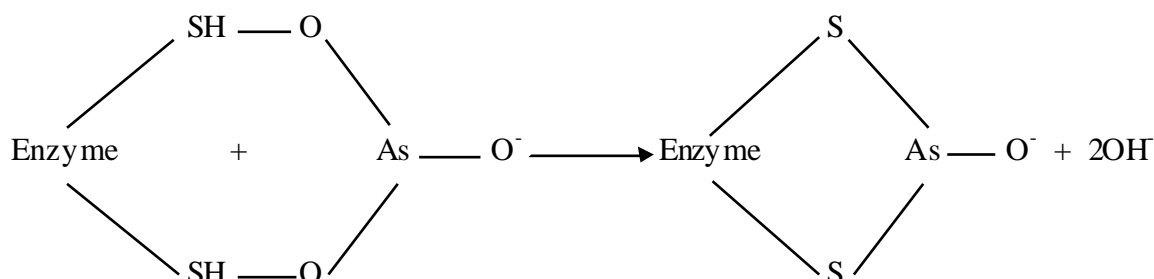
ELEMENTS	SOURCES	EFFECTS AND SIGNIFICANCE
Arsenic	Mining by-product, pesticides, chemical waste	Toxic, possibly carcinogenic
Cadmium	Industrial discharge, mining waste, metal plating, water pipes	Replaces zinc biochemically causes high blood pressure Kidney damage.
Beryllium	Coal, nuclear power and space industries	Acute and chronic toxicity possibly carcinogenic heart and lung toxicity
Chromium	Metal plating, industrial wastes, water additive	Essential trace elements possibly carcinogenic
Copper	Metal plating, industrial and domestic waste, mining, mineral leaching	Essential trace elements, not very toxic to animals, toxic to plants and algae at moderate levels.
Lead	Industry, mining, plumbing, coal, gasoline	Toxic, anaemia, kidney disease, nervous disorder, wild-life destroyed.
Manganese	Mining Industrial waste, acid mine drainage	Relatively non-toxic to animals, toxic to plants at higher levels.
Mercury	Industrial waste, mining, pesticides, coal	Highly Toxic
Molybdenum	Industrial waste, natural sources	Possibly Toxic to animals essential for plants
Selenium	Natural geological sources, sulphur, coal	Essential at low-levels but toxic at higher levels
Zinc	Industrial waste, metal plating, plumbing	Essential in many metalloenzymes, toxic to plants at higher levels.

Biochemical effects of some elements

- **Arsenic**

Arsenic commonly occurs in insecticides, fungicides and herbicides, among its compound, those of As III are the most toxic. As III exerts its toxic action by attacking SH groups of an enzymes, there by inhibiting enzyme action. The enzymes which generate cellular energy in the citric acid cycle are adversely affected. The inhibitory action is based on inactivation of pyruvate dehydrogenase by complexation with as III, where by the generation of ATP is prevented. By virtue of its chemical similarity to P, as interferes with some biochemical processes involving P. This is observed in the biochemical generation of the key energy yielding substance, ATP. An important step in in ATP generation is the enzymatic synthesis of 1,3-diphosphoglycerate from glyceraldehyde-3- phosphate. Arsenite interferes by

producing 1-arseno-3-phosphoglycerate instead of 1,3-diphosphoglycerate. Phosphorylation is replaced by arsenolysis which consists of spontaneous hydrolysis to 3-phosphoglycerate and arsenate.



Arsenic III compounds at high-concentrations coagulate proteins, possibly by attacking the sulphur bands maintaining the secondary and the tertiary structures of proteins. The three major biochemical actions of As are coagulation of proteins, complexation with co-enzyme and uncoupling of phosphorylation. The general Antidotes for as poisoning are chemicals having -SH groups capable of bonding to As III e.g. 2,3-dimercaptopropanol.⁽⁶⁾

• **Cadmium**

Cd occurs in nature in association with zinc minerals. Growing plants acquire Zn and they also take up and concentrate Cd with the same biochemical setup. The outbreak of Cd poisoning occurred in Japan in the form of itai disease. Many people suffered from this disease in which their bones became fragile. At high levels, Cd causes kidney problems, anaemia and bone marrow disorders. The major portion of Cd ingested into our body is trapped in the kidneys eliminated. A small fraction is bound most effectively by the body proteins, metallothionein, present in the kidneys, while the rest is stored in the body. When excessive amounts of Cd²⁺ are ingested, it replaces Zn²⁺ at key enzymatic sites, causing metabolic disorders.

• **Chromium**

Main sources of chromium are paint industry, alloy industry, glass industry, electroplating effluents and tannery wastes. Hexavalent Chromium is more toxic and causes dermatitis, Ulceration and perforation of nasal septum. Chronic mist causes chest problem, Cr(VI) compounds cause lung cancer to workers working in paints, pigments and tannery industries⁽⁷⁾. Today there are evidence of the harmful effects of chromium pollution. All-natural chromium is found in trivalent state, chromium could transform to the mobile hexavalent state, Cr (VI) if it is strongly heated with a corrosive oxidizing agent like soda ash to prepare chrome chemicals. The traces of the biologically active chromium received through food have therapeutic value⁽⁸⁾. There are two types of chromite deposits in nature. One is layered type, which is subject to little alteration, and the alpine type, which is subject to alteration when contact in water. The alpine type, when extensively oxidized could convert Cr (III) to Cr (VI).

Options currently available in India for cleansing water from hexavalent chromium include

- Water is treated by dosing ferrous sulphate in effluent treatment plants but some experts feel that ferrous sulphate can introduce other pollutants.
- An electrolyte method has been developed to treat contaminated water, which is cost effective and eco-friendly.
- Biological treatment which is modern method of treating water. Pollution free and inexpensive bacterial strains are applied in industrial toxic water.

• **Lead**

Lead is occurring in lead minerals. In the atmosphere it is relatively more abundant than other heavy metals. Major source of airborne Pb is the combustion of leaded petrol, gasoline. Pb is added in the form of tetra alkyl lead together with the scavengers 1,2-dichloroethane and 1,2-dibromoethane. In common with other particulate pollutants, Pb is removed from the atmosphere by wet and dry deposition processes. As a result, street dusts and roadside soils become enriched with Pb. The most of the Pb in take by a typical city dweller is from diet, air and water.

The major biochemical effect of Pb is its interference with heme synthesis, which leads to hematological damage. The overall effect is the distribution of the synthesis of haemoglobin as well as other respiratory pigments, such as cytochromes, which require heme, Pb does not permit utilisation of O₂ and glucose for life-sustaining energy production. At higher levels of Pb in the blood (more than 0.8 ppm) there will be symptoms of anaemia due to deficiency of haemoglobin. Elevated Pb levels in the blood cause kidney dysfunction and finally brain damage. Due to the chemical analogy of Pb²⁺ with Ca²⁺, bones act as repositories for Pb accumulated by the body. Subsequently, this Pb may be remobilized along with phosphates from bones which exert a toxic effect when transported to soft tissues. Lead poisoning can be cured by treatment with chelating agents which strongly bind Pb²⁺ displaces Ca²⁺ from the chelate and the resulting Pb²⁺ chelate is rapidly excreted in the Urine. ^(9,10) e.g. Pb-EDTA chelate, Pb-d-penicillamine chelate etc.

• **Mercury**

In nature, Hg occurs as trace component of many minerals, continental rocks containing an average of about 80 parts per billion of Hg. The principle ore is Cinnabar, HgS, Fossil fuels, coal and lignite contain about 100 parts per billion of Hg. The natural abundance in soil is 0.1 parts per million. Hg finds a wide variety of applications. The consumer is the chlor-alkali industry which manufactures Cl₂ and NaOH by an electrolytic process using Hg electrodes. The second largest consumption of Hg is in the production of electrical apparatus, e.g. Hg vapour lamp, electrical switches, Hg batteries etc. The third largest consumer is the agricultural industry using a large number of fungicides for deed dressings.

The toxicity of Hg depends on its chemical species. ⁽⁷⁾

Species	Chemical and biochemical properties
Hg	Elementary mercury: Relatively inert and nontoxic, vapour highly toxic when inhaled
Hg ⁺	Mercurous ion: Insoluble as chloride: low toxicity

Hg ²⁺	Mercuric ion: Toxic but not easily transported across biological membranes
R Hg ⁺	Organomercurials: Highly Toxic, particularly CH ₃ Hg ⁺ (methyl mercury) causes irreversible nerve and brain damage; easily transported across biological membranes, stored in fat tissue.
R ₂ Hg	Diorganomercurials: Low toxicity but can be converted to RHg ⁺ in acidic medium.
HgS	Mercuric Sulphide: Highly insoluble and non-toxic, trapped in soil in this form.

The most toxic species are the organomercurials, particularly methyl mercury (CH₃Hg⁺), which are soluble in fat, the lipid fraction of membranes and brain tissue. The covalent Hg-C bond is not easily disrupted and the alkyl mercury is retained in cells for prolonged periods of time. The most dangerous aspect is the ability of RHg⁺ to move through the placental barrier and enter foetal tissues. Minamata Incident ⁽¹¹⁾ at Minamata Bay in Japan more than 100 people lost their lives and many thousands were permanently paralysed from eating mercury contaminated fish. Genetic defects are observed in some babies. The Minamata incident was followed by a more tragic report of Hg poisoning from Iraq in 1972 where 450 villagers died after eating wheat which has been dusted with mercury-containing pesticides. ⁽¹²⁾ These two tragic events boosted the awareness of Hg as a pollutant. Further environmental pollution by Hg can be prevented by adopting that the all chlor-alkali plants must stop using Hg electrodes and switch to new technology, all alkyl pesticides must be banned.

• **Pesticides**

Biochemical processes constitute the major mechanism by which pesticides in the environment are degraded and detoxified. Among the pesticides, the biological action of DDT on the environment has been extensively studied. ⁽¹³⁾ The central nervous system is the target of DDT, like many other insecticides. DDT dissolves in lipid tissue and accumulates in the fatty membrane surrounding nerve cells. The net result is the disruption of the central nervous system killing the target insect DDT, the first pesticide to be introduced during World War II found widespread agricultural use and saved millions of lives through malaria control programmes. ⁽¹⁴⁾ DDT was banned in USA because of concern about its long-term health effects. Although DDT does not act on the human nervous system in the same way it does on insects, it stays in human bodies for a long time. In developing countries, however it is still in use, particularly in those regions where malaria is still endemic. ⁽¹⁵⁾

While DDT is fairly stable and persists in the environment, the other groups-organophosphates and carbamates- degrade quite rapidly in the environment. The latter react with O₂ and H₂O undergoing decomposition within a few days in the environment. The products are not toxic. Methyl isocyanate is the raw material for the production of carbamate pesticide. ⁽¹⁶⁾ Workers exposed to MIC suffer from chest tightness and breathing troubles due to irritation of the respiratory tract. Since it is accomplished by COCl₃, the combined effect becomes fatal within 24 hours for most victims. Phosgene is a deadly gas, used as a poisonous gas during World War I, Immediate symptoms of phosgene poisoning are bronchospasms, coughing, and pain in the chest.

Threshold Limiting Value (TLV)

TLV is a measure of toxicity of a substance. This refers to airborne concentrations of substances and indicates conditions under which a person or worker is continuously exposed day after day without any harmful effects. However, there is a wide variation in the individual's susceptibility because of immunity. The TLV represents time weighted average concentration for 7-8 hours work day or 40 hours per week. TLV is helpful in controlling the health hazard. TLVs are passed on best available information from human or animal studies of exposures. Moreover, the working conditions differ from place to place and country to country. Threshold limits of some metals are given in table.

Table: Threshold limits of selected toxic metals

S.No.	Metal Pollutant	TLV, mg/m ³	S.No.	Metal Pollutant	TLV, mg/m ³
1	Arsenic	500	6	Lead	200
2	Cadmium	200	7	Manganese	5000
3	Beryllium	2	8	Mercury	100
4	Chromium	500	9	Selenium	200
5	Copper	100	10	Zinc	500

CONCLUSION

Very few people have paid any attention to the dark side of chemical industrialization, particularly to the growing dangers it poses to the health of people. Hardly a day passes when hundreds do not succumb to the accidents or diseases caused by growing pollution of the environment. Industrialization is creating a high-risk environment for all. But it is the poor workers who suffer the most. They get the dirtiest and most hazardous job and compelled to live in the dirtiest environment in close proximity to the industries.⁽¹⁷⁾ During the last 50 years about 6 million chemicals have been synthesized at rate of 10,000 new ones every month. Some 60,000 to 70,000 chemicals are used extensively in millions of different commercial products. The world produces chemicals faster than it can manage.

Phosphatic fertilizer factories and thermal power plants generate large quantities of conventional solid waste which are stored near the sites. Some 5 million tonnes of by product

phosphogypsum are generated at 12 major phosphatic fertilizer plants. 20% of this waste is used to produce ammonium sulphate, while the rest containing thousands of tons of heavy metals and toxic metals such as chromium, copper, lead, manganese and fluorides etc. are dumped into low lands for land filling into lagoons in the form of slurry. From pesticide industries some 15 tonnes of DDT and 25 tonnes of BHC are carried as wastes every year which ultimately travel in the environment, enter our food chain and finally enter our body tissues where they are retained. All professional chemists are required to possess a basic concept of chemical toxicology and remain fully conscious of the chemical hazards of toxic chemicals.

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