THE SCIENTIFIC STUDY OF THE HEALTH EFFECTS ASSOCIATED WITH EXPOSURE TO TOXIC CHEMICALS LIKE HEAVY METALS (ARSENIC, LEAD, MERCURY AND CADMIUM): ENVIRONMENTAL TOXICOLOGY

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***Abstract*- Environment toxicology is the field of study in the environmental sciences that is concerned with the assessment of toxic substances in the environment. Environment toxicology is related to the study of the harmful effects of various chemical, biological and physical agents on living organisms. Organisms can be exposed to various kinds of toxicants at any life cycle stage, some of which are more sensitive than others. Harmful effects of such chemicals and biological agents as toxicants from pollutants insecticides, pesticides and fertilizers can affect an organism. Environmental toxicants are toxic agents found in many things people come in contact with on a daily basis. Toxicants come in all shapes and sizes, and while they can come from both natural and human-made sources. There are many sources environmental toxicity that can lead to the presence of toxicants in our food, water and air. Toxicants may enter in the body of living organism by different ways, resulting in a harmful effect on health. Heavy metals found in food sources, such as fish can also have harmful effects. In present paper we will discuss about the environment toxicology of heavy metals like cadmium, mercury, arsenic and lead.**

***Key words*: Environmental Toxicology, Toxicants, Pollutants, Insecticides, Fertilizers, Heavy Metals, Toxicity**

INTRODUCTION:

Environmental toxicology is a multidisciplinary field of science concerned with the study of the harmful effects of various chemical, biological and physical agents on living organisms [1,2].

Harmful effects of such chemicals and biological agents as toxicants from pollutants , insecticides , pesticides and fertilizers can effect an organism and it's community by reducing its species diversity and abundance . Such changes in population dynamics affect the ecosystem by reducing its productivity and stability.

Environmental toxicology is concerned with the assessment of toxic substances in the environment of toxic substances in the environment draws heavily on principles and techniques from other fields, including biochemistry, cell biology, development biology and genetics,

Study of environmental toxicology includes the assessment of toxic substances in the environment the monitoring of environments for the presence of toxic substances the effects of toxins on biotic and abiotic components of ecosystems and the metabolism and biological and environmental fate of toxins.

The modern science of toxicology was born in the early 19th century. Environmental toxicology is a relatively young field with its origins in the mid 20th century.

Toxins affect the environment and organisms in a variety of ways, from having little negative impact on certain abiotic factors or resistant organisms to killing animals and destroying major components of ecosystems. The extent of damage depends on the toxic substance, the age , the size and the species of the organism and the temperature and the physical and chemical characteristics of the environment.

Toxic wastes like heavy metals from a variety of industrial processes foul the air, water and soil . The concentration of persistent heavy metal pollutants, mercury (hg) , lead (pb) , cadmium (cd) and arsenic (as) in the fish, fruits , and vegetables most consumed by the reversible inhabitants represent a danger to public health.

The contamination of soil , air and water by heavy metals is a global concern due to its ability to affect different biological systems . Heavy metal contamination can result in bioaccumulation and bio magnification in the food chain affecting human health . Metal contamination in aquatic and terrestrial ecosystems is a serious environmental problems. The incorporation of heavy metals into the food chain is one of the biggest concerns . The consumption of contaminated fish, fruits and vegetables is considered the main source of human exposure to heavy metals . [3]

The present paper deals with the study of the effects of heavy metals on health of human beings.

Sources of hazardous metals:

Environmental pollution from hazardous metals and minerals can arise from natural as well as anthropogenic sources. Natural sources are: seepage from rocks into water, volcanic activity, forest fires etc. Pollution also arises from partitioning of polluting

elements (which are concentrated in clay minerals with high absorption capacities), between sedimentary rocks and their precursor sediments and water. (sisir sen, personal communication). With rapid industrialization and consumerist life style, anthropogenic sources of environmental pollution have increased. The pollution occurs both at the level of industrial production as well as end use of the products and run-off.

Lead (pb) - lead acid batteries, paints, e-waste, smelting operations, coal- based thermal power plants, ceramics, bangle industry.[18]
Arsenic (as) - as geogenic/natural processes, smelting operations, thermal power plants, fuel burning .[24]
Cadmium (cd) - zinc smelting, waste batteries, e-waste, paint sludge, incinerations & fuel combustion .[19-23]
Mercury (hg) - chlor-alkali plants, thermal power plants, fluorescent lamps, hospital waste (damaged thermometers, barometers, sphygmomanometers), electrical appliances etc.[15,16,17]

Besides the industrial sources of lead, listed in table 1, lead exposure also occurs through gasoline additives, food can solder, ceramic glazes, drinking water system, cosmetics, folk remedies, and battery/plastic recycling industry1. According to some work done at the dpsar university, new delhi many brands of cosmetics like talcum powder, lipsticks, shampoos, 'kajal' and hair colours contain heavy metals. [27]

In recent years the use of energy-saving cfl bulbs has gone up enormously.

Each bulb contains 3-12 mg of mercury. With no system to recover these bulbs and safe disposal, these can prove to be a major health hazard.

The major heavy metal contaminated sites in india -

Lead

Ratlam, madhya pradesh , bandalamottu mines, andhra pradesh vadodara, gujarat , korba, chattisgarh

Mercury

Kodaikanal, tamil nadu , ganjam, orissa , singrauli, madhya pradesh

Arsenic

Tuticorin, tamil nadu west bengal , ballia and other districts

Apart from industries, roadways and automobiles contribute substantially to the environmental burden of heavy metals since particulate matter in traffic emissions include heavy metals like lead, cadmium and arsenic. Exposure to traffic emissions, especially diesel exhaust may enhance asthma, allergen responsiveness and inflammation, leading to atherosclerotic vascular disease. Role of metal per se in this pathology is however not clear.2, 3. With the use of unleaded petrol, the burden of lead has decreased.

Toxicity due to metals

In general, heavy metal toxicity can cause chronic, degenerative conditions. General symptoms include: headache, short-term memory loss, mental confusion, sense of unreality, distorted perception, pain in muscles and joints, and gastro-intestinal upsets, food intolerances, allergies, vision problems, chronic fatigue, fungal infections etc. Sometimes the symptoms are vague and difficult to diagnose.

Lead (Pb)

Absorption of pb from different sources is dependent on the amount of pb presented to portals per unit time and the physical and chemical state in which pb is presented. It is also influenced by factors such as age and physiological status. In adults, almost 20-30% and in children almost 50% lead is absorbed through the gi track. Depending on the particle size, lead can enter through lungs. While organic lead is well absorbed through the skin, inorganic lead is not. Since lead is chemically similar to calcium, body handles it like calcium. In the body lead is distributed throughout- bone, teeth, liver, lung, brain and spleen; bone being the major accumulator. Lead can cross blood brain barrier as well as placental barrier. Excretion occurs through urine and faeces. Dose and duration dependent genotoxic effects have been observed. Nutritional iron deficiency enhances Pb toxicity, raising concern that pregnant women and young children in whom iron deficiency anaemia is high, may be more susceptible to Pb toxicity. Pb absorption is increased considerably with fasting or in persons whose diet is deficient in calcium, iron, phosphorous or zinc . In general Pb is excreted very slowly from the body. Its biological half-life estimated at 10 years, facilitates accumulation in the body. Almost 90% lead is bound to red blood cells.

General signs and symptoms of lead toxicity fatigue irritability lethargy paresthesis , myalgias abdominal pain, tremor headache ,vomiting , weight loss , constipation , loss of libido motor neuropathy , encephalopathy , cerebral edema , seizures ,coma , severe abdominal cramping epiphyseal lead lines in children (growth arrest) renal failure .[9,10,12,13,14]

Mercury (Hg)

Mercury occurs in three forms:

Elemental: liquid at room temperature, but volatizes readily. It is rapidly distributed in the body through vapour, but poorly absorbed through gi track.

Inorganic: Poorly absorbed through gi tract, but can be caustic. Dermal exposure results in toxicity.

Organic: lipid soluble. It is well absorbed via gi tract, lungs and skin. Can cross placenta and into breast milk.

Anaerobic organisms bio-transform the inorganic form to methyl mercury which gets bio-accumulated in food chain. It's the most toxic form of mercury.

Some of the symptoms of mercury poisoning are summarised. At high concentrations, vapour inhalation produces acute necrotizing bronchitis, pneumonitis, and death. Long term exposure affects central nervous system , insomnia, forgetfulness, anorexia, mild tremor late: progressive tremor and erythrism (red palms), emotional lability, and memory impairment salivation, excessive sweating, renal toxicity (proteinuria, or nephrotic syndrome) gastrointestinal ulceration or perforation and haemorrhage are rapidly produced, followed by circulatory collapse. Breakdown of mucosal barriers leads to increased absorption and distribution to kidneys (proximal tubular necrosis and anuria). Acrodynia (pink disease) usually from dermal exposure

maculopapular rash, swollen and painful extremities, peripheral neuropathy, hypertension, and renal tubular dysfunction. Signs progress from paresthesias to ataxia, followed by generalized weakness, visual and hearing impairment, tremor and muscle spasticity, and then coma and death. Teratogen with large chronic exposure asymptomatic mothers give birth to severely affected infants infants appear normal at birth, but psychomotor retardation, blindness, deafness, and seizures develop over time. Thus, exposure to inorganic and organic mercury is associated with genotoxicity, teratogenicity, and embryo toxicity. [4,5]

Cadmium (Cd)

Tobacco smoke is an important source of cadmium exposure. Smoking one pack a day, can imbibe 5-10 times the amount of cadmium obtainable through a regular diet. Food is a poor source of cadmium. It is transported in blood, bound to metallothionin. Urinary excretion is slow, biological half life can be up to 30 years. Highest concentration is found in kidney and liver. The problem of cadmium toxicity in india is not known. The disease itai itai is caused by cadmium contamination associated with a diet low in calcium and vitamin d. Cadmium affects lungs, kidneys, liver and skeletal system. It binds to sulfhydryl groups, displacing other metals from metalloenzymes, disrupting those enzymes. Cadmium competes with calcium for binding sites on regulatory proteins.

Arsenic (As)

Arsenic tends to accumulate in keratin- rich tissues like nails, hair and skin. Inorganic arsenic is converted to organic arsenic . This may represent a process of detoxification. 30-50% of inorganic arsenic is excreted in about 3 days through urine.

Symptoms of acute arsenic toxicity-

Bodily system affected symptoms or signs systemic thirst hypovolemia, hypotension gastrointestinal hematopoietic system pulmonary (primarily in inhalational exposures) liver garlic or metallic taste burning mucosa nausea and vomiting diarrhoea abdominal pain hematemesis hematochezia, melena rice-water stools haemolysis hematuria lymphopenia pancytopenia cough dyspnea chest pain pulmonary edema jaundice fatty degeneration central necrosis kidneys proteinuria hematuria acute renal failure.[11]

Chronic exposure can result in poisoning of the nervous system, liver damage, and peripheral vascular disease, leading to gangrene of the lower limbs. This condition is commonly known as `black foot disease'. Chronic exposure to as is also associated with leukaemia, kidney and bladder cancers, dermatitis, hyper pigmentation, and arsenical keratosis. Arsenic acts as a non-genotoxic carcinogen. However, it affects dna methylation and repair. [6,7]

Heavy metal poisoning (toxicity)[26]

Heavy metal poisoning (toxicity) is the result of exposure to heavy metals like lead, mercury and arsenic. Heavy metals bind to parts of your cells that prevent your organs from doing their job. Symptoms of heavy metal poisoning can be life threatening and they can cause irreversible damage.

What is heavy metal poisoning?

Heavy metal poisoning occurs when microscopic molecules of metals accumulate within your body after exposure. Heavy metals attach to your cells and prevent them from performing their functions, which causes symptoms that could be life threatening without treatment.

Several metals can be toxic to your body. The most common toxic metals are: lead , mercury , arsenic , cadmium , thallium , etc.

How does someone get heavy metal poisoning

Heavy metal poisoning occurs when metals get into your body. This can happen if you're exposed to a large amount of metal including:

Heavy metals form naturally within the earth's crust. We interact with small amounts of heavy metals every day .this can happen if you're exposed to a large amount of metal including:

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- Eating a lot of food that contains metals (fish).
- Drinking water from older water supply systems.
- Working with metals on the job.
- Taking medications or supplements with high amounts of metallic elements.
- Handling metals or products made with a large amount of metal (like paint or pesticides) without using personal protective equipment.
- Heavy metals can enter your body by:
- Absorbing into your skin.
- Breathing in or inhaling tiny metal molecules.
- Eating or drinking (ingesting) the metal from food or water.
- Heavy metal poisoning can affect anyone who has exposure to heavy metals. This most often affects people who:
- Drink water from pipes made of older metals (lead).
- Work with metals.
- Take more than the prescribed dosage of medicine or supplements that contain metal.
- Live in an environment with high air or water pollution.
- Eat a lot of foods that contain metal.
- Consume a non-edible product made with metal (paint).
- Children are at a higher risk of heavy metal poisoning because their bodies are still developing and they are more sensitive to the harmful effects of heavy metals.

- Exposure to heavy metals can be dangerous to your health. While we use and interact with metals every day, certain heavy metals are toxic because the molecules that make up the metal damage or negatively interact with the cells in your body that are essential to keep your organs functioning.

Effects of heavy metals on health of human

Heavy metals have harmful effects on human health, and exposure to these metals has been increased by industrial and anthropogenic activities and modern industrialization. Contamination of water and air by toxic metals is an environmental concern and hundreds of millions of people are being affected around the world. Food contamination with heavy metals is another concern for human and animal health.

The industrial activities have caused massive increases in human exposure to heavy metals. Mercury, lead, chromium, cadmium, and arsenic have been the most common heavy metals that induced human poisonings. Bioaccumulation of these heavy metals leads to a diversity of toxic effects on a variety of body tissues and organs. Heavy metals disrupt cellular events including growth, proliferation, differentiation, damage-repairing processes, and apoptosis. Some toxic metals including chromium, cadmium, and arsenic cause genomic instability. Defects in dna repair following the induction of oxidative stress and dna damage by the three metals have been considered as the cause of their carcinogenicity. Several acute and chronic toxic effects of heavy metals affect different body organs. Gastrointestinal and kidney dysfunction, nervous system disorders, skin lesions, vascular damage, immune system dysfunction, birth defects, and cancer are examples of the complications of heavy metals toxic effects.

Toxic effects of some heavy metals are following –

Mercury (Hg) :

Mercury (Hg) is found in air, water, and soil and exists in three forms: elemental or metallic mercury (Hg0), inorganic mercury (Hg+, Hg2+), and organic mercury . Elemental mercury is liquid at room temperature and can be readily evaporated to produce vapor. Mercury vapor is more hazardous than the liquid form. Organic mercury compounds such as methyl mercury (me-Hg) or ethyl mercury (et-Hg) are more toxic than the inorganic compounds.some skin lightening creams and some soaps are mercury polluted. Mercury chloride (Hgcl2) is one of the active ingredients of skin brightening creams which are used to remove freckles and spots of the skin due to excessive accumulation of melanin.

Microorganisms in marine environments perform natural biomethylation reactions to produce me-Hg. Me-Hg enters the food chain of aquatic animals and eventually enters the human body through the consumption of fish cooking fish does not diminish its hg content . Chronic hg toxicity caused neurological damage including ataxia, muscle weakness, numb limbs, disturbance in speech, chewing, and swallowing, and brisk and increased tendon reflex among the patients exposed to massive amounts of me-hg.

Lead (Pb)

Lead is a harmful environmental pollutant which has high toxic effects to many body organs. Even though pb can be absorbed from the skin, it is mostly absorbed from respiratory and digestive systems. Pb exposure can induce neurological, respiratory, urinary, and cardiovascular disorders due to immune-modulation, oxidative, and inflammatory mechanisms.exposure to Pb can produce alteration in physiological functions of the body and is associated with many diseases Pb is highly toxic which has adverse effects on the neurological, biological, and cognitive functions in the bodies.

Cadmium (Cd)

Cadmium (Cd), although rare, occurs naturally in soil and minerals such as sulfide, sulfate, carbonate, chloride, and hydroxide salts as well as in water. High levels of cd in water, air, and soil can occur following industrial activities which could be a substantial human exposure to cd. Moreover, the ingestion of contaminated food will cause major exposure to Cd. Cd exposure may also occur through smoking, which is capable of elevating blood and urine cd concentrations. Presence of Cd in contaminated water could disturb the necessary mechanisms in the body, occupational exposure to cd may occur in alloy, battery, and glass production and in electroplating industries. Acute or chronic inhalation of cd in industrial areas might lead to renal tubular dysfunction and lung injuries. Cd blood concentration in smokers is almost twice higher than that of nonsmokers.

Cd plays a key role in cardiovascular diseases caused by smoking such as peripheral artery disease and coronary heart disease.

Cd may give rise to the occurrence of the kidney, lungs, pancreas, breast, prostate, and gi cancers

Arsenic (As)

Arsenic as a harmful heavy metal is one of the main risk factors for the public health. Sources of as exposure are occupational or via the contaminated food and water. As is present as a contaminant in food, water, and environment. Arsenic exists in the forms of metalloid (As0), inorganic (As3+ and As5+), organic, and arsine (Ash3). The order of increasing toxicity of as compounds is defined as organic Arsenicals < As0 < inorganic species (As5+ < As3+) < Arsine .

Other routes of exposure are from the skin contact and by inhalation. Acute and chronic as toxicity is related to the dysfunctions of numerous vital enzymes.

Human studies on the association between as-contaminated drinking water and adverse pregnancy outcomes have shown that as can easily cross the placenta, particularly during early gestation, leading to spontaneous abortion, stillbirth, preterm birth, and low birth weight

Liver cancers hepatocellular carcinoma and angiosarcoma have been associated with as poisoning **. 25**

How to avoid the contamination of heavy metals?

Traces of heavy metals can be found throughout nature. Heavy metals are particularly a concern to pregnant and breastfeeding women since they can pass through both the placenta and breastmilk. Other ways we may be in contact with such harmful substances are unfortunately through our diet, the surface of our skin, and our body's mucous membranes. Substances such as Lead, Arsenic,

Cadmium or Mercury may also reach our body through the elevated concentrations in water or air resulting from industrial processes and environmental pollution.
Human activity has led to an increase in heavy metals in the environment. As a result, the risks of heavy metal exposure for humans, as well as all land and sea animals, have also increased.

Although we can hardly escape heavy metals in our everyday life, there are a few ways to deliberately avoid exposure to these harmful substances:

- **Consume wild mushrooms with caution -** mushrooms store heavy metals that accumulate in the soil, especially in industrial areas. It is therefore advisable to remove the outer peel of such mushrooms (the so-called pileipellis) before cooking or consumption.
- **Avoid cosmetics containing aluminium, such as deodorants -** heavy metals like lead, cadmium, mercury and aluminium etc. Can easily be found in makeup products, skincare products, and nail polishes. These unsuspecting products can make the average woman easily exposed to heavy metals on a daily basis. Deodorant with aluminium salt can enter the body through injured skin (e.g. After shaving) and contribute to the development of serious diseases such as breast cancer. So, we should avoid use of these types of cosmetics.
- **Ceramic dental fillings instead of amalgam -** although dental fillings made from heavy-metal amalgam offer certain benefits, such as antibacterial effects, they also have serious drawbacks, since the amalgam will slowly dissolve with time. Instead, invest in dental fillings made from plastic or ceramic in the future.
- **Give preference to organic foods -** since the use of chemical-synthetic pesticides is banned in organic farming, the resulting food items contain more antioxidants and fewer heavy metals than conventional products. Always wash fruits and vegetables with fresh water before going to use these.
- **Avoid excessive amounts of seafood –** some species of fish tend to live relatively long, which means that they accumulate more mercury than other species throughout their lives. Consume such seafood only occasionally as part of a balanced diet.
- ***Use water filters* -** water pipes, especially in older buildings, are also frequently made of lead or copper. Do filter water from the tap before drinking in all cases to avoid excessive intake of these harmful substances into your body.

CONCLUSION

The heavy metals enter the body from different ways including drinking water, air, food, or occasionally dermal exposure. Following absorption, heavy metals are retained, and they accumulate in the human body. Bioaccumulation of toxic metals leads to a diversity of toxic effects on a variety of body tissues and organs. Metal toxicity can have acute or chronic manifestations. Heavy metals disrupt cellular events including growth, proliferation, differentiation, damage-repairing processes, and apoptosis. Toxic metals can also promote epigenetic alterations which can influence gene expression.
Developing specific biomarkers for monitoring heavy metals will be a major achievement in the field. Future research will benefit from the evaluation of new targets as protective procedures against organ toxicity induced by heavy metals.

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