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A Review of Heavy Metal Toxicity, Effects and Methods for Estimating Heavy Metal Concentration in Water

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Abstract: ***Heavy metals are metal ions which acts as carcinogens and causes serious health issues as they produce free radicals and these free radicals cause damage to DNA which eventually leads to cancer. They are non-degradable in nature and responsible for contamination of various natural resources in environment mainly water contamination has become a major problem. Many metal ions such as cadmium, lead, arsenic, mercury are considered as toxic metals. The analysis of these metal ions is necessary and to detect these metal ions, several detection methods such as electrochemical biosensors, CNT's, silver nanoparticles have been developed. In this paper, the toxicity and health effects of several heavy metals and their role in causing of oxidative stress have been summarized. Also, various heavy metal detection methods have been listed.***
Keywords: Heavy metals, Toxicity, Effects, Methods, Detection

I. INTRODUCTION

Heavy metals have low density so they are low density compounds which are highly toxic in nature[1]. As these heavy metals are non-degradable in nature, so they pose high threat to both human health and environment. As they are non-degradable in nature they can accumulate in biosphere and through the food chain they enter living organisms and effects the health of the [1]. Heavy metal ions such as cadmium, arsenic, chromium, lead and mercury are considered as harmful chemical compounds even at lower concentrations[1]. The Agency of Toxic Substances and Disease Registry Priority List of Hazardous Substances made a list and ranked these metal ions in top 10 hazardous metals. Metal traces are important for carrying out metabolic cellular functions, its concentration limit range is important in effecting human health. If the concentration limit range of heavy metals lies below permissible limits, then it is considered to be safe but when it crosses beyond permissible limits, it leads to various cytological and physiological effects[1].The main sources for these heavy metals are chemical compounds used in cosmetic products, different kinds of radiations, industrial effluents etc. When heavy metals enters into human body through different sources, it effects cellular functions leading to metal toxicity. Some gets excreted through liver or kidney or spleen, but some metals gets accumulated in some excretory organs and leads to organ damage. Heavy metals are also leading to food contamination which is one of the main reasons for maintaining food safety issues.The major food contaminants includes pesticides, toxins along with heavy metal contamination. There are some traditional methods for the analysis of these heavy metals which includes Atomic Absorption Spectrometry (AAS),Atomic Fluorescence Spectrometry (AFS)[2].These methods can detect heavy metal contamination but limitations are complicated as they require pre-sampling steps, long detection time, involves expensive equipment and high operating equipment costs. Optical methods involves high cost and complexity in building equipment. Therefore, development of simple, low cost and reliable techniques are suitable for on-time detection. Electrochemical techniques can be easily used and suited for various in-field applications. These Electrochemical techniques have simple procedures and can be easily constructed on small circuits for monitoring contaminated samples.

Their adopted techniques are fast when compared to other spectroscopic related detection methods. Other detection methods have been developed with interfaces coated with enzymes, microorganisms, silver and gold nanoparticles, Carbon nanotubes [3].Among these, Nanomaterials has considered most promising as they have strong adsorption[2].Electro-chemical biosensor is an analytical method for electrochemical signal detection of biomolecules and has been widely used in the fields and of medicine, food testing and environmental testing. By coupling Electro chemical techniques with Nanomaterials enhanced the sensitivity and detection limitation[2]. This paper reviews different types of detection methods implied for various heavy metal ions detection in water samples.

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II. STANDARD LIMITS & SOURCES OF HEAVY METALS

Even though metal ions are important as they involve in cellular metabolic functions, their concentration range plays a major impact role on human health. If the concentration levels of metals lies below the toxicity range, then it is considered to be safe [1] but if the concentration range is above permissible limits then it can pose serious health effects[1]. Table1 is the list of heavy metal sources and standard permissible limits of different heavy metals given by World Health Organization (WHO) and Bureau of Indian Standards (BIS)[1, 2].

Table I
Represents Different Types Of Metals, Sources And Their Standard Limits

METALS	WHO Limits(mg/L)	BIS Limits(mg/L)	SOURCES
Lead	0.05	0.05	PVP spikes, agriculture, PVP lead paints, jewelry, lead batteries, Iron pipes[1,2].
Arsenic	0.05	0.05	Wooden electricity poles which treated with arsenic based preservatives, fertilizers, pesticides, oxidation of pyrite, arsenic pyrite[1,2].
Mercury	0.001	0.001	Combustion of coal, municipal waste incineration, volcanic emissions[1,2].
Zinc	5	5	Soldering, cosmetics and pigments[1,2].
Cadmium	0.005	0.01	Paints, pigments, Electro plated plates, batteries, plastics, synthetic rubber, photovoltaic cells[1,2].

III.HEALTH EFFECTS OF HEAVY METALS

The Lead toxicity lowers energy levels of body and can cause several health effects as it penetrates through the protective tissue layer of Blood Brain Barrier tissues and thus causes Alzheimer's disease and senile dementia[4].It also causes many neuro-degenerative diseases, Kidney damage, Coma, IQ decrement, circulation failure, decreased bone growth, hyperirritability, multiple sclerosis, muscular dystrophy, behavioural issues and even leads to cancer[4]. The Cadmium toxicity leads to renal failure, hypertension, weight loss, pulmonary fibrosis, pulmonary lung cancer, lymphocytosis, atherosclerosis and osteoporosis. The Mercury toxicity shows its harmful effects on digestive system, lungs, kidneys, skin and eyes and can also lead to impaired neurologic development. The chromium toxicity shows its effects on reproductive system and thus leads to mutagenicity (cause of mutations), carcinogenicity, lung cancer, perforation of septum. The Zinc toxicity leads to respiratory disorders, leukocytes and can also increases cancer risk. The copper toxicity causes hyperactivity, allergies, anemia, autism, hemorrhaging, and cystic fibrosis and also leads to renal disorders[4]

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IV. TOXICITY MECHANISM OF HEAVY METALS ON CELLS

The heavy metals are non-degradable and found most prominently everywhere in nature. They enter human body through different sources and interfere in cellular functions of the body which leads to toxicity[1]. They sometimes acts as a pseudo elements inside the body and interfere with protein sites and causes malfunctioning of cells and thus ultimately leads to toxicity. These metals get excreted very slowly unlike other molecules[1]. Longer accumulation of these metals in excretory organs can cause organ damage and also leads to the changing in cellular functioning. Continuous long-term high exposure of heavy metals may even lead to cancer[1].

A. Example: Toxicity Mechanism of Lead Heavy Metal

Lead has ability to bind towards sulfhydryl groups and it also binds to certain enzymes like Aminolevulinc acid Dehydratase (ALAD) and Glutathione reductase(GR)[1].The inhibition of ALAD results in increase in the ALA level so heme production decreases[1]. Persons who are exposed to lead have MAD and lead levels in their Erythrocytes[1]. It also effects the Glutathione reductase through which these enzymes oxidizes hemoglobin and thus eventually lead to the increase ALA concentrations. Changes in ALAD activity leads to production of MAD(Mitochondria Associated Degradation)[1]. This MAD causes oxidative stress and produces ROS[1]. The higher concentrations of ALA also produces ROS which is gene toxin upon oxidation. This ROS also produces Nitric oxide and also produces peroxynitrite which damages lipids and DNA[1]. The mechanism of lead toxicity is shown in Fig.1.

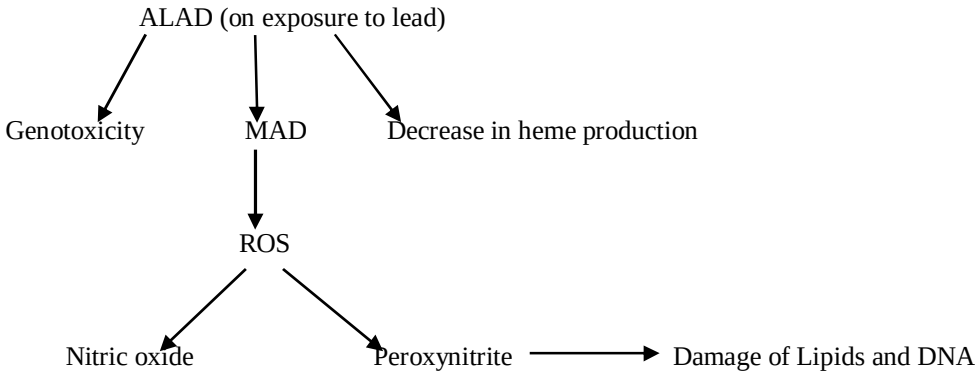

Fig. 1 Toxicity mechanism of lead

V. DETECTION METHODS

A. Enzyme Analysis

Heavy metals binds to the sulfhydryl or carbonyl functional groups that binds to the active site of the enzyme and leads to the change in structural and other properties of the enzyme[2].Thus the quantitative relationship of concentration of heavy metals and enzyme conformation is established. This technique has high sensitivity[2].

B. Immunoassay

This antibody immunoassay works on the basis of the principle of antibody and the antigen which specifically identifies and have and high affinity even at very low concentrations[2]. The color reaction labelled on secondary antibody and when this secondary antibody forms complex with primary antibody and antigen, it characterize and quantify heavy metals.This technique has quick detection, high sensitivity and selectivity[2].

C. Biosensor

Biosensors use biological compounds like enzymes, antibodies, DNA for detection and these are combined with electro chemical signal converters i.e., electrodes which converts biological signals into electrical signals[2].This technique has low detection limit, less response time, low manufacturing cost[2,6].

D. Test Strips

The test strips detects through the color reaction of the heavy metal ion with a color developer. This technique is very simple and cheap [2].

E. Electrochemical Sensors

Electrochemical sensors is a device that converts signals which are caused by chemical reactions into an electrical signal. It consists of electrodes which attains signals when there is a presence of heavy metals ions and these signals leads to the voltage difference which further leads to raises a current signal which can be measured[2,5,6].

VI. CONCLUSION

This review represents the heavy metals toxicity and its health effects in humans. It also represents the basic setup which is necessary for electrochemical sensing and analysis of heavy metal ions. At lower concentrations of these heavy metals have higher binding affinity towards DNA and these bindings or interactions would eventually leads to mutations and also causes certain neurological diseases, cancer. As they are non-degradable in nature, when they enter into the body gets accumulated inside the organ tissues and causes organ failure. So the analysis check of these heavy metals is needed. Many traditional detection methods such as Atomic Absorption Spectrometry(AAS),Mass Spectrometry are widely used but they are time taking to provide results. Various less time taking detection methods are also present such as enzyme analysis, Immunoassay, Electrochemical biosensor, test strips are for the detection of these heavy metals. Electro chemical sensors combing with nanoparticles are playing major role in heavy metal detection but, even though good results are obtained, there are certain challenges which are involved, they are, identification of metal ions in biological fluid samples such as urine, blood etc. Overcoming the challenge of chemical fouling, inability to sense the metal ions in complex forms as mostly they exists in complex forms. Mostly these electrochemical techniques lags behind because of the problems like low stability.

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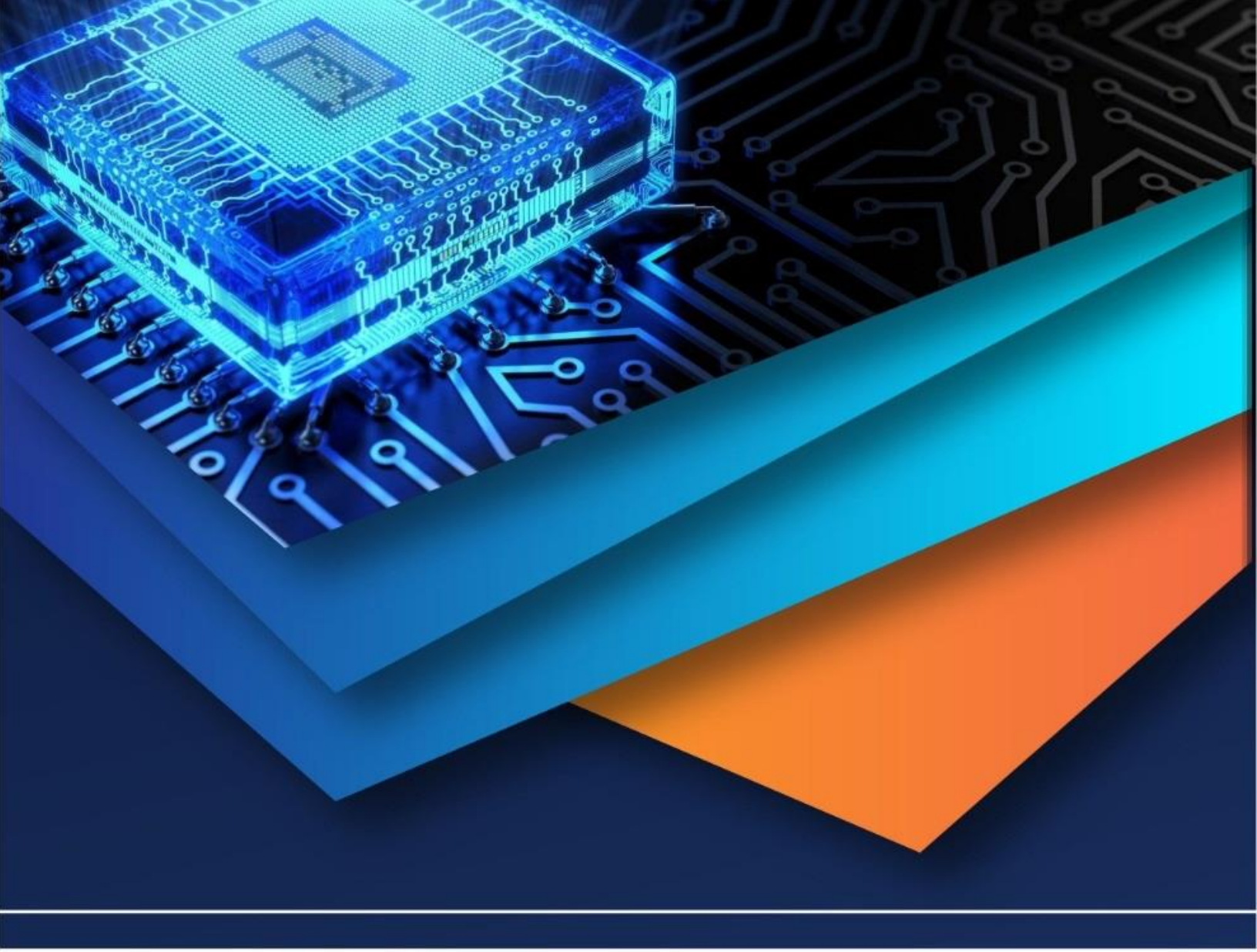

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