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Forensic Aspect of Metal Poisoning: A Review

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Abstract: ***Even though metals are oldest known toxins harmful to humans and their toxicity is still a topic that requires further investigation. This paper aims to provide an overview of metal toxicity on human health and their forensic significance. Metals form an important, but disparate, group of agricultural, household and industrial poisons that present many difficulties in their systematic chemical analysis. The toxicity of metallic poisons may be influenced by the chemical nature of the compound ingested and the route of administration. Certain heavy metals like Lead, Mercury, Cadmium, Copper, Arsenic, Iron, Chromium, Silver etc are naturally occurring elements, and are present in varying concentrations in all ecosystems and hold significance in cases of poisoning along with other metals like antimony, zinc, iron, barium etc. The wide range of metallic substances that might be involved in any case of suspected poisoning holds both the careful collection of appropriate specimens and also the selection of proper toxicological analytical procedures. Metal poisoning holds forensic relevance so as to ascertain the cause of it, acute or chronic exposure, manner of the poisoning as homicidal, suicidal or accidental, and hence the awareness and knowledge regarding the toxicity of metals on humans is important.***
Keywords: Metals, metal poisoning, forensic toxicology, fatal ose, fatal period.

I. INTRODUCTION

Toxicology deals with the science that embodies the knowledge of the sources, characters and properties of poison, the symptoms they produce, lethal effects and the remedial measures to be taken.

Forensic toxicology is the application of the principles and techniques of general toxicology for the purpose of criminal justice system. Metal poisoning is the development of unusual symptoms appearing in living organism after its contact with a toxic metal substance. Metals are considered as inorganic irritant poisons. Metal toxicity poses a real and substantial danger to human health and depends upon the chemical nature of the compound ingested and their route of administration. Heavy metals include Lead, Mercury, Cadmium, Copper, Arsenic, Iron, Chromium, Silver and the Platinum group elements and occur naturally in ecosystem. Potential exposures to metals include natural sources (e.g.: groundwater, metal ores), industrial wastes which are also dumped in rivers, contaminated food and herbal products like Lead in noodles, mercury in Sindoor etc. Pure metals (with exception of mercury and lead) are rarely toxic. Metallic salts possess poisonous properties of varying intensity. The signs and symptoms of acute poisoning may differ from those associated with chronic toxicity. Some metallic substances undergo extensive metabolism after ingestion. These factors have a significant influence on analytical investigations applied to biological materials and their interpretation. Many death cases are reported regularly which are investigated forensically to determine the cause and manner of death so as to establish them as the cases of homicidal, suicidal or accidental metal poisoning and to know whether poisoning resulted from acute, chronic or acute-on-chronic exposure. The toxicological details of few metals like symptoms, their fatal doses and period etc. are given as under:

Table 1
Metals and their toxicological effects

S.NO.	METAL	SYMPTOMS	FATAL DOSE	FATAL PERIOD	FORENSIC SIGNIFICANCE
1.	Arsenic	Weakness, anorexia, nausea, cold, cough, conjunctivitis, pigmentation in skin, hair, nails, fallout of hair, brittleness of nails, Mees lines (Aldrich-crossing the nails), tingling in hands and feet, headache, drowsiness, impairment of vision and mental activity, renal and hepatic damage, bone	120-200mg	1-2 days	Homicidal-as cheap, easy to obtain, colourless, odourless, tasteless, less quantity required to cause death, easy to add in food or drinks

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		marrow suppression with anaemia.[1, 2]			Suicidal - rare Accidental- admixture with food, drinking well water having arsenic, improper medicinal use, licking of paint having arsenic by children. [2]
2.	Antimony	Similar as arsenic	Antimony trichloride- 0.1-0.2 g	Usually within 24hrs	Accidental- occupational exposure, antimonials as a result of therapy (leishmaniasis and schistosomiasis.) Homicidal- common
3.	Barium	Vomiting, nausea, diarrhea, stiffness of muscles, dilation of pupils, paralysis of tongue and larynx, BP rises, pulse is irregular and heart may stop in systole.	About 1 g	Usually within 12hrs	Suicidal &homicidal- rare Accidental- common
4.	Copper	Metallic taste, salivation, abdominal pain, vomiting, collapse, diarrhea, stool (liquid, brown, not bloody), urine (inky in appearance, uraemia), jaundice, muscle cramps, breathing difficulty, renal failure, circulatory collapse, convulsions, coma precede death.	Copper sulphate -30g Copper sub acetate -15g	1-3 days	Cu used in fungicides, suicidal, homicidal-rare Accidental-children (swallow $CuSO_4$ attracted by its colour), added in vegetables to keep the green colour, Sometimes as abortifacient, rarely as cattle poison.
5.	Iron	1st stage(after ingestion) →Vomit, abdominal pain, acidosis, coma, 2nd stage →sets in 6-24hrs symptom free 3rd stage (24-48hrs) →jaundice, hypoglycaemia, shock, coma, renal failure.	20-30 g	24-30hrs	Accidental- overdose of iron tables in children
6.	Lead	Facial pallor, metallic taste, anorexia, constipation with blackish stools, lead colic(cramping pain in abdomen),lead line(blue black stain in gums near the junction with teeth),dead foetus/abortion/sterility in males and females, paralysis, wrist drop.	Absorbed lead- 0.5g Lead acetate- 20g Lead carbonate- 40g[2]	1-2 days Death within 2nd -3rd day.	Accidental-occupational hazard, children Chronic- cosmetics, fruit juices, Pb absorption from unremoved bullet in body(rare) Homicidal &suicidal - rare.[1]
7.	Mercury	Corrosive, burning sensation from mouth to stomach, Ptyalism (salivation), vomiting, loosening of teeth, bloody diarrhea, purgation with pain, swollen inflamed gums, urine with albumin and blood, discoloration of lens of eye(deposition of Hg), renal tubular necrosis, Uraemia, tremors, death.[2]	1-2g of $HgCl_2$	Death within few hrs but usually delayed for 3-5 days	Accidental- acute/chronic poisoning, disinfectants, medical & dental practice, industry, fireworks, introduced as

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					contraceptives in vagina Homicidal &suicidal- rare.
8.	Thallium	Abdominal pain, vomiting, diarrhea, pain in muscles, joints and nerves, impaired vision, convulsions, loss of hair, loss of outer 3rd of eyebrows, Mees lines on nails, painful peripheral neuropathy, mental confusion with lethargy, death appears natural.	1g	24-36hrs	Homicidal- when used as a rodenticide Accidental- intoxication from therapeutic use as 'Depilatory' Chronic poisoning- industrial exposure.
9.	Zinc	Zinc sulphate - GI irritation, metallic taste, pain in abdomen, diarrhea, collapse may follow Zinc chloride - corrosive destroys mucous membrane of mouth, throat, oesophagus and stomach, severe vomiting, shock.	Zn sulphate- 15g Zn chloride (more toxic)- 400mg	Zn chloride- few hrs	Suicidal, homicidal or abortion Accidental- eating food cooked or stored in galvanised iron vessels.

A. General Mode Of Action

A major site of toxic action for metals is interaction with enzymes, resulting in either enzyme inhibition or activation. Two mechanisms are of actual importance-

1) Inhibition may occur as a consequence of interaction between the metal and sulfhydryl (-SH) groups on the enzyme, or

2) The metal may relocate an essential metal cofactor of the enzyme. [3]

Arsenic, certain chromium compounds, nickel, antimony etc. are known human carcinogens.

B. Isolation And Identification Of Metal Poisons

The wide range of metallic or anionic poisons that might be involved in any case of suspected poisoning means that great care is required in the collection of appropriate specimens and the selection of toxicological tests for their analysis.

Forensic Analytical Laboratories adopt several methods to isolate, identify and estimate the poison. Methods like dry ashing, wet digestion process etc are performed primarily on the suspected matrices for metal isolation, then several colour and microscopic tests (like Reinsch test) for different metals are performed for their identification. For confirming the presence of metal/s in a matrix, instruments like AAS, ICP, ICP-MS, X-Ray Fluorescence Spectroscopy etc. are used.

Atomic Absorption Spectroscopy (AAS) is the method of choice for precise quantitative determination of single elements in air, water, soil, paint and other matrices. Inductively Coupled Plasma Spectroscopy (ICP) provides the laboratory with the ability to analyse multiple inorganic elements/metals simultaneously in all types of matrices. Inductively coupled plasma-mass spectrometry (ICP-MS) has also been expanded rapidly as a choice for sensitive multi-element analysis, particularly in the investigation of suspected poisoning with 'heavy metals'. Forensic labs have added the capability to determine Hexavalent Chromium (Cr6+) also by UV-Visible Spectroscopy.

C. Illustrative Cases

1) *CASE 1:* In 1994, Zhu Ling, a 21-year-old student at Tsinghua University in Beijing, started suffering from unexplained medical problems. These included hair loss, blurred vision, and acute stomach pain. She eventually fell into a coma. Subsequent tests by doctors confirmed that Zhu had high levels of thallium in her body. Doctors were able to save her life. Unfortunately, the poisoning caused severe neurological damage in her. To this day, a large section of her body is paralyzed and she is unable to speak. [5]

2) *CASE 2:* An outbreak of apparent food-borne illness following a church gathering was promptly reported to the Maine Bureau of Health. Gastrointestinal symptoms among church attendees were initially attributed to consumption of leftover sandwiches that had been served the previous day. However, a rapid epidemiological and laboratory assessment revealed the etiology of illness, including the death of an elderly gentleman, was not food-borne in origin. A criminal investigation determined that deliberate ***arsenic*** contamination of the brewed coffee by one of the church members was the source of the outbreak. [6]

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3) *CASE 3:* Blanche Kiser Taylor Moore (born February 17, 1933) is an American convicted murderer from Alamance County, North Carolina. She was convicted of killing her boyfriend by slipping arsenic into his food, and is suspected of killing three other people and nearly killing another in the same manner [7]

II. CONCLUSION

Metals have been used during the course of much of human history to make utensils, machinery, mining and smelting. More recently metals have found a number of uses in industry, agriculture and medicine. These activities have increased the exposure not only to matter related to occupational worker but also to consumers of the numerous products.

For a metal to exert its toxicity, it must cross the membrane and enter the cell. These metals are toxic known to aggravate the health effects in human which leads to the anorexia, conjunctivitis, abdominal pain, convulsions, impaired vision, painful peripheral neuropathy, etc.

The severity of health effects is related to the type of metal and its chemical form, which is solely dependent on time and dose too and also on its mode of administration. Inhalation of vapours can cause acute toxicity, including rapid death.

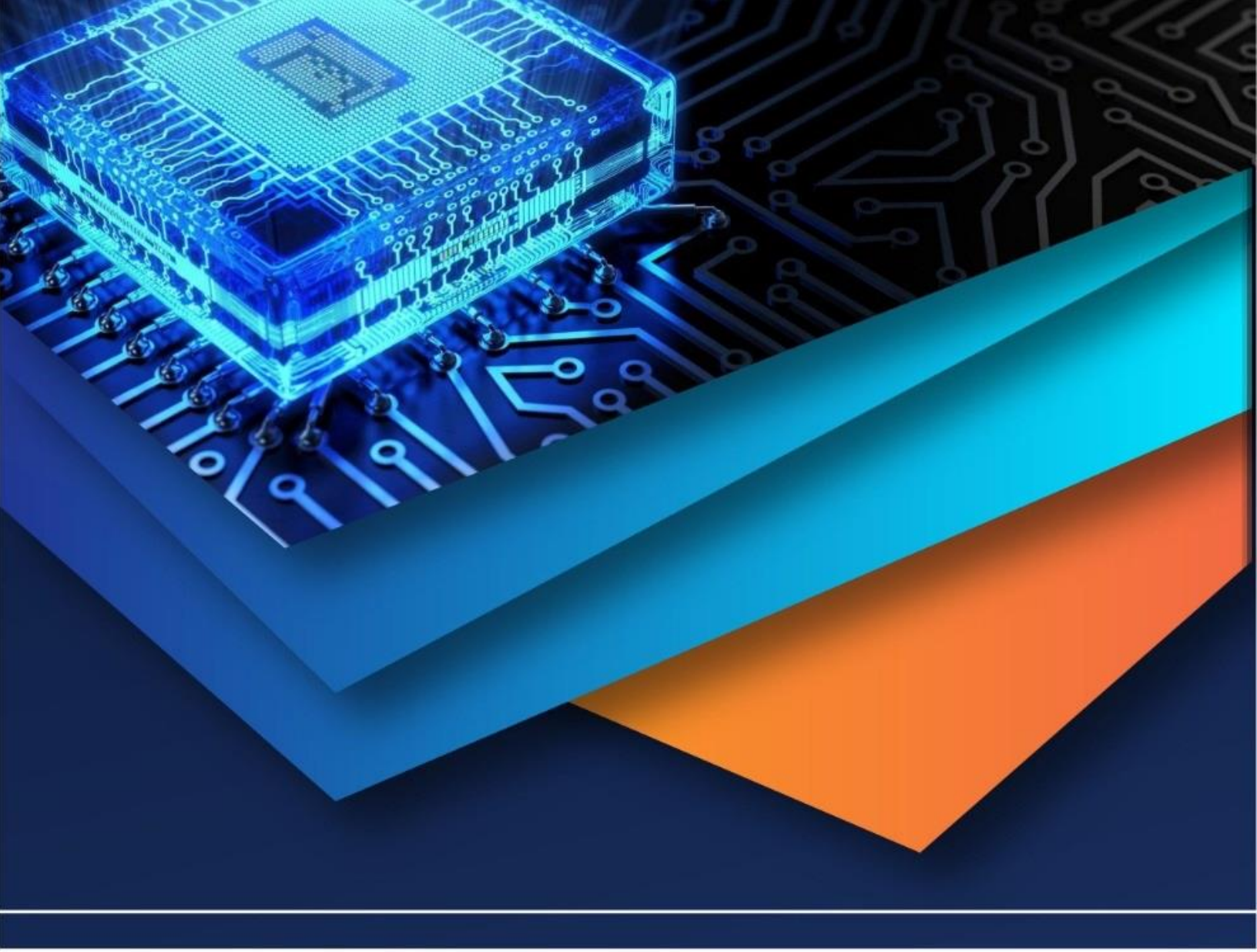
Metal poisoning upholds utmost forensic significance so as to ascertain the cause and its manner, to know whether the poisoning resulted from acute or chronic exposure, or the case is homicidal, suicidal or accidental.

Considerable advances in analytical techniques for measuring metals in biological fluids have been made since the early 1980s, particularly in electro thermal atomic absorption spectrometry, inductively coupled plasma-mass spectrometry (ICP-MS) and ICP coupled with atomic emission spectrometry (ICP-AES).

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