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review Article

Heavy Metal Toxicity: Impact on Human Health: A Review

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ABSTRACT

The detrimental effects of heavy metals on human health are known as several health risks are associated with heavy metal toxicity. Rapid industrialization and enhanced use of metals in various industries resulted in the increased distribution of heavy metals in the environment. Industrial wastes in the form of liquid and gaseous effluents, as well as scrap in landfills are a major source of heavy metal pollution causing contamination of water bodies and the environment in general. These toxicants accumulate in the human body as individuals are exposed to them. The toxicity of heavy metals depends on various factors which include but not limited to amount of metal (dose), exposure duration, age, gender and health status of individuals. Heavy metals such as mercury, cadmium, arsenic, chromium, lead etc especially are of great concern for public health due to their acute toxicity. These metals are potent enough to induce multiple organ failure even at small concentrations. Studies have shown an association between heavy metals and carcinogenicity. In the present work, a comprehensive analysis of toxicity of eleven heavy metal namely, aluminium, antimony, arsenic, bismuth, cadmium, cobalt, iron, lead, mercury, tin and thallium has been reviewed along with their analytical aspects and management. Clinical features of metal toxicity with diagnosis techniques and treatment including hospitalization and post-hospitalization management are also elaborated.

Keywords | Heavy Metals, Metal Toxicity, Poisoning, Analytical Technique

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INTRODUCTION

Heavy metals are naturally occurring components of the earth's crust. Degradation of heavy metals is not possible. With increasing pollution, the concentration of heavy metals is rapidly increasing in the environment. Consequently, humans are exposed to these metal toxins through food, air and water. Some metals are essential for the human body due to their role in metabolism but at higher concentration these are toxic for human health. In the present review, 11 heavy metals are discussed, namely, Aluminium, Antimony, Arsenic, Bismuth, Cadmium, Cobalt, Iron, Lead, Mercury, Tin and Thallium.

Aluminum:

Aluminum is denoted by the symbol '*Al*' and has atomic number 13. Aluminium is a highly conductive, corrosion resistant, silvery-white metal and derived from bauxite ore. Aluminium poisoning can be caused by three ways which includes ingestion, inhalation and dermal contact. The total body burden of aluminium (in healthy individuals) is estimated to be 30 to 50 mg.[1]

Antimony Antimony is denoted by the symbol *'Sb'* and have atomic number 51. Antimony, a hard and gray lustrous metalloid is found in nature as the sulfide mineral, stibnite. Antimony trioxide exists in 4 valence states in which its trivalent state being most stable. Inorganic Antimony is more toxic than organic antimony. [2]

Arsenic

Arsenic is denoted by the symbol *'As'* and has atomic number 33. Arsenic is a toxic metalloid and found in different allotropic forms. There are three different metalloids of arsenic, each having different crystal structure. Arsenic is a natural component of the earth's crust and is widely distributed throughout the environment in the air, water and land. It is highly toxic in its inorganic form.[3]

4. Bismuth

Bismuth is denoted by the symbol '*Bi*' and has atomic number 83. Bismuth is a high-density, silvery, pink-tinged metal. Bismuth is brittle and due to its brittleness, it is usually mixed with other metals to make it useful. Its alloys with tin or cadmium have low melting points and are used in fire detectors, electric fuses, solders and extinguishers.[4]

5. Cadmium

Cadmium is denoted by *'Cd'* and having atomic number 48. It is soft, can be cut with a knife, malleable, ductile, bluish-white, divalent metal. Because of its unique physical, mechanical, and electrochemical properties, cadmium metal and other cadmium compounds such as cadmium sulphide, cadmium oxide and cadmium hydroxide are used in pigments, coatings, stabilizers, specialty alloys and electronic compounds, but it is mostly used in rechargeable nickel-cadmium batteries. Cadmium pigments are more stable than organic colouring agents at high temperatures and are not easily degradable by light.[5]

6. Cobalt

Cobalt is denoted by *'Co'* and has atomic number 27. Cobalt is a rare element of the earth's crust, which is essential to mammals in the form of cyanocobalamin.[6] Cobalt is a ferromagnetic metal. Cobalt is the active centre of a group of coenzymes called cobalamins.[7]

7. Iron

Iron is denoted by the symbol *'Fe'* and has an atomic number 26. Iron plays an important role in the formation of different complexes with oxygen in haemoglobin and myoglobin (oxygen transporters). It is a very crucial component of different metalloproteins and plays a crucial role like oxygen sensing and transport, electron transfer and catalysis.[8]

8. Lead

Lead is denoted by the symbol *'Pb'* with the atomic number 204. Lead is bright and silvery when freshly cut, but rapidly fades in air and produces a dull luster. It is ductile, dense, very soft, and has poor electrical conductivity. [9,10,11]

9. Mercury

Mercury is denoted by the symbol '*Hg*' and has atomic number 80. Mercury is liquid at standard conditions of temperature and pressure. Mercury occurs in the form of elemental or metallic mercury, inorganic mercury and organic mercury.[12]

10. Tin

Tin is denoted by the symbol Sn, has an atomic number 50. Tin is a silvery metal that occurs in two stable oxidation states +2 and +4. Tin is used to preserve canned food and beverages. Common examples of organotin include agrochemicals, biocides, Polyvinyl chloride and some catalysts.[13]

11. Thalium

Thalium is denoted by Tl, has an atomic number 81. In its physical properties, it is a soft metal and resembles tin. It exhibits unipositive (Tl+1) and tripositive (Tl+3) valence states, of which the Tl+1 is more stable.1 The properties of Tl+1 resemble potassium and silver compounds, while Tl+3 resemble aluminium compounds.[14]

Thallium acetate and thallium sulphate are the chief salts of thallium having toxicological importance. Thallium salts being colourless, odourless and tasteless add to its potential to cause accidental ingestion, more so for homicidal intent.[15]

B. Sources of Heavy Metals

The Table 1 shown on page 47 gives a brief info on the most common sources of heavy metals and their usages.

Sl. No.	Name of the Metals	Source
1.	Aluminum	• Aerospace, Construction materials, Utensils manufacturer, Electrical Appliances, Packaging and automobiles. • Paints and Pigments. Fuel additives, propellants and explosives.
2.	Antimony	• Ores such as Valentinite (Sb203) and Stibnite (Sb2 S3) • Environment through waste incineration, metal processing mines and burning of coal.
3.	Arsenic	• Smelting industry (by-product of ores containing lead, gold, zinc, cobalt and nickel) • Pesticides • Paints and Dye industries
4.	Bismuth	• Sea Water (About 0.02 µg/litre Bi is present in Sea water). • Anthropogenic sources (copper, lead, silver and gold smelting, waste water and sewage sludge).
5.	Cadmium	• Environment, By-product of Zinc concentrates. • Batteries, Manures and Pesticides • Food such as liver, mushrooms, shellfish, mussels, cocoa powder and dried seaweed
6.	Cobalt	• Implants, Batteries (Lithium Cobalt Oxide), Coloring pigments and dyes. • Magnets
7.	Iron	• Supplementary Food and Drugs, Coloring pigments and dyes. • Toys and Sports Goods, and Cast Iron
8.	Lead	• Ores (Eg., Galena, Cerrussite and Anglesite • Batteries, metal products, Pipes and Solders and ammunition • Paints
9.	Mercury	• Fish and Shellfish (in the form of methylmercury which is highly toxic.a
10.	Tin	• Canned Foods and Beverages, Tin industries, Mining, Soil (due to weathering process) • Biocides, Antifouling paints
11.	Thallium	• Glass, Photoelectric cells, Rodenticides and Fungicides

Table 1 **Sources of Heavy Metals**

Human Exposure to Heavy Metals:

Sl. No.	Name of the Metals	Human Exposure
1.	Aluminum	• Environment Pollution, Inhalation and transdermal absorption through cosmetics containing aluminum. • Medicines (e.g., Antacids). • Workers in industries like refining, mining, smelting and those make tools by grinding and cutting using metal or compounds of aluminium. • Aluminum utensils for cooking purposes..
2.	Antimony	• Inhalation (exposure occurs during occupational activities while working with antimony compounds and inhaling antimony dust, or fumes)ds). • Ingestion (through contaminated vegetables) • Dermal exposure (occurs during working near antimony mines or antimony processing sites)
3.	Arsenic	• Smelting industry (by-product of ores containing lead, gold, zinc, cobalt and nickel) • Pesticides • Paints and Dye industries
4.	Bismuth	• Medicines • Cosmetics

Table 2 **Source of Heavy Metal Exposure**

Sl. No.	Name of the Metals	Human Exposure
5.	Cadminum	• Environment Pollution (contaminated food water) • Smoking • Occupational exposure (through inhalation of fine dust and fumes).
6.	Cobalt	• Environmental Pollution (Contaminated water, Air) • Prosthetics • Medicines (due to the overdose of vitamin B12 supplements). • Occupational exposure
7.	Iron	• Environmental Pollution (Contaminated water, Air). • Iron dust and fumes from welding, smelting, grinding • Medicines (excessive use of Iron supplements)
8.	Lead	• Environmental Pollution (Contaminated water, Air). • Occupational Exposure. • Paints, Ceramicwares, Cosmetics, Medicines, Pencils • Toys, Automobile Exhaust
9.	Mercury	• Environmental Pollution (Contaminated Food, water, Air). • Occupational exposure • Cosmetics
10.	Tin	• Consumption of canned Food and beverages. • Inhalation (Landfills or industries dealing with the manufacturing of tin products).
11.	Thallium	• Environmental Pollution (Contaminated Food as plants absorb thallium from thallium-treated soil, which further enters the food chain). • Inhalation of thallium oxides and salts • Absorption through skin.

Table 2 **Source of Heavy Metal Exposure (continued...)**

Pharmacokinetics of Heavy Metals

1. Aluminium

Absorption: About 0.1% to 0.6% of aluminium is absorbed through ingestion whereas absorption of less biovailable form such as aluminium hydroxide is as low as 0.1% and the rest is excreted in faeces.

After entering the bloodstream, it binds to various ligands and gets distributed in each organ system of the body with highest concentration in lungs and bones tissues.[18]

Distribution: In a healthy individual the total body burden of aluminium is approximately 30mg to 50mg. The level of aluminium in serum is 1 µg/l to 3µg/l. Half of the total body burden of aluminium is in bones, one fourth in lungs and rest in other tissues of the body. With the increase in age, the concentration of aluminium also increases in brain tissues and serum.[18]

Elimination: The unabsorbed aluminium gets eliminated from the body through excreta, whereas the absorbed aluminium gets eliminated through kidneys or urine. Extended exposure of Aluminium and its accumulation, the human body itself is not capable of eliminating aluminium and its compounds effectively from the body.[18]

2. Antimony

Absorption: Antimony compounds get absorbed through ingestion and inhalation. Gastrointestinal absorption being poor in man necessitates parenteral administration of pharmaceuticals of antimony2.

Distribution: Total body pool of antimony was estimated and observed that only 5 % of the ingested dose could be found in a patient who died of accidental antimony potassium tartrate ingestion, with high antimony concentrations found in the liver, gall bladder and gastrointestinal mucosa.[19]

Elimination: Reasand *et al*, 1980 demonstrated that about 80% to 90 % of the intramuscular dose of sodium stibogluconate is recovered in the urine within about 6 hour of administration. Kentner *et al,* 1995 estimated renal elimination half-life of about four days, upon occupational inhalation of antimony trioxide and stibine among[21] employees of a battery manufacturing plant.[20]

3. Arsenic

Absorption:

When ingested in dissolved form, inorganic arsenic is readily absorbed. About 80-90% of a single dose of arsenite As (III) or arsenate As(V) was absorbed from the gastrointestinal tract of humans and experimental animals.[21,22,23] A much lower degree of gastrointestinal absorption was reported for arsenic-contaminated soil[23], although the form of arsenic in the soil, as well as the type of soil, can be assumed to influence the degree of arsenic absorption. Also, arsenic compounds of low solubility (e.g., arsenic selenide)[24], arsenic trisulfide and lead arsenate[25] and gallium arsenide[26,27] are absorbed much less efficiently than is dissolved arsenic.

Distribution:

In the body, As (III) is mainly bound to SH groups. In particular, As (III) forms high-affinity bonds with vicinal thiols, as demonstrated with lipoic acid and DMSA.[28,29] A very stable complex appears to be formed between DMA and hemoglobin in the rat30. In vitro studies indicate the formation of mixed protein hemoglobin-GSH complex with As (III).[31]

Elimination

The major route of excretion of most arsenic compounds is via the urine. Following exposure to inorganic arsenic, the biological half-time is about 4 days. It is slightly shorter following exposure to As (V) than to As (III)32,33,21,34. In humans, about 78% of MMA and 75% of DMA were excreted in the urine within 4 days of ingestion of the dose34. Similar results were reported for mice in which the half-time of MMA and DMA was about 1 hr35. The 24-hr whole-body retention was about 2% of the dose.

With an average arsenic concentration in the skin of 0.18 mg/kg36 estimated that the daily loss of arsenic through desquamation was 0.1-0.2 µg in males with no known exposure to arsenic.

4. Bismuth

Absorption

About 0.2% of orally administered bismuth is absorbed systematically from the gastrointestinal tract.

Distribution

Bismuth accumulates in the kidney, bone (metaphysis), liver, spleen, heart and muscle. With a half-life of months to years, bismuth in bone is very slowly turned over.

Excretion

Bismuth is primarily excreted via the kidney as this organ contains the highest concentrations of bismuth.

5. Cadmium:

Absorption:

Cadmium has a long biological half-life from 17-30 years in man. After uptake from the lung or the gastrointestinal tract, cadmium is transported in blood plasma.

Distribution

Cadmium is widely distributed in the body, with the major portion of the body burden located in the liver and kidney.

Elimination

Most cadmium that is ingested or inhaled and transported to the gut via mucociliary clearance is excreted in the faeces.

6. Cobalt

Absorption

The cobalt enters into the body through food is absorbed at the small intestine, followed by absorption of metal into blood flow where it causes the binding with proteins and transport to various cells of the body resulting in accumulation in all organs mainly liver, pancreas, kidneys, heart and skeletal muscles7.

Distribution

As cobalt is a major component of vitamin B12, it is found in most body tissues like bone, hair, lungs, muscle, lymph nodes, brain, pancreas, liver (largest amount), urinary bladder etc. reflecting the exposure from all sources and routes.

Elimination

Long term clearance is directly related to the solubility of cobalt compounds, e.g., higher (cobalt (II) oxide) the solubility faster the clearance from lungs than the less soluble ones (cobalt (III) oxide).

7. Iron

Absorption

Iron absorption is a complex process that occurs in the proximal small bowel and consists of a series of steps. These include binding of the iron molecule to the brush border, uptake of bound iron into the intestinal mucosal cell, intracellular handling of iron, transcellular transport and passage of the iron from the cell into the portal circulation.

Distribution

Distribution of iron is very rapid. Entry of iron into tissues is an active process involving specific transferrin receptors and endocytosis.

Elimination

Excretion of iron after an overdose is insignificant as the body does not have any effective means of excreting it from the body8.

8. Lead

Absorption:

Lead is absorbed through mucous membranes in the mouth, nose, and eyes and through breaks in the skin. Tetra-ethyl lead passes through the skin37. Inorganic lead, found in food, paint and most lead-containing consumer products, are absorbed through inhalation and ingestion38.

Distribution:

The main body compartments that store lead are blood, soft tissues and bone; the half-life of lead is measured in weeks for blood, months for soft tissues and years for bone38.

Elimination:

Lead is excreted from the body very slowly, mainly through urine. Small amounts of lead are also eliminated through the faeces and very small amounts through hair, nails, and sweat.

9. Mercury

Absorption

Exposure to mercury occurs through ingestion, inhalation and occasionally by skin contacts.

Distribution

Non-occupational exposure occurs through air, food, drinking water and dental amalgams.

Elimination

Approximately 7-14 % of inhaled mercury vapour mercury is exhaled within a week after exposure. 80% excreted through faeces and urine.

10. Tin

Absorption

It is observed, with an increase in the dosage of tin in the body the gastrointestinal absorption decreases. Although there is very poor absorption of tin in the body, some compounds such as dibutyltin and trimethyltin were detected in post-mortem blood and liver suggesting their absorption in the body39.

Distribution

After absorption in the intestine, tin reaches various body parts via blood. Less than 17 mg of tin is found in the human body, and various experimental studies suggested the highest concentration of tin in kidneys and liver.

Elimination

Most of the ingested inorganic tin remains unabsorbed and is readily excreted in urine and faeces and a small amount in bile.

11. Thallium

Absorption

Thallium oxides and salts are rapidly absorbed from mucous membranes of the respiratory tract, mouth and lungs as well as through skin40.

Distribution

After oral ingestion of a thallium salt, its peak blood level reaches within 2 hours and its occurrence in urine within 4 hours.

Elimination

The excretion of parenterally administered thallous ions continues for 3 months in urine and 35 days in faeces; however, the quantity of thallium decreases with time.[41]

Sl. No.	Name of Metals	Matrix	Levels	
			Normal	Toxic
1	Aluminum	Blood Urine Serum	7 to 10 µg/l < 7µg/l 1 to 3 µg/l	> 60 µg/l 30 to 100 µg/l 50 to 100 µg/l
2	Antimony	Blood Urine Serum	0.7-2 µg/l 0.06-0.01 µg/l <0.066 µg/g	9mg/l 0.26-0.39 µg/l 0.088 µg/g
3	Arsenic	Blood Urine Serum	<1 µg/l <100 µg/l ≤1000 µg/l	>50 µg/l >5000 µg/day >1000 µg/l
4	Bismuth	Blood Urine Serum	<0.05µg/ml 0-20 mmol/l 1 to 3 µg/l	0.05-0.1µg/ml 400 mmol/l 50 to 100 µg/l
5	Cadmium	–	>1µg/l	>1µg/l
6	Cobalt	Blood Urine Serum	0.08 to 0.50 0.3 to 0.7 µg/L 60 µg/L	µg/L 5 µg/L 1- 5.1 µg/L >60 µg/L
7	Iron	Blood Urine	500-2000µg/l 65µg/g	>3500 µg/l >65 µg/g
8	Lead	Blood Urine 0.667µg/L	1.5µg/dl >25 µg/dl	>20µg/dl
9	Mercury	Blood-Plasma/Serum Urine < 10µg/L	1.5 - 2.0 µg/L < 20µg/L	50-200 µg/L
10	Tin	Blood Urine	< 0.005 µg /mL 1 – 20 µg/L	> 0.009 µg/ml > 30 µg/ml
11	Thallium	Blood/Urine	<5 µg /mL	10-15mg/kg

Table 3 Normal and Toxic Levels of Heavy Metal in Biological Samples

Diagnostic Investigation of Heavy Metals:

Aluminium
The diagnosis of aluminium toxicity depends upon the combination of both the clinical history of patient and the laboratory findings.

Antimony
The antimony concentration in blood is indicative of any recent exposure of it and is most useful in the diagnosis of acute antimony poisoning.

Arsenic
The urine test is the most reliable test for arsenic exposure. Tests on hair and fingernails can measure exposure to high levels of arsenic over the part 6 to 12 months.

Bismuth
Without a clear history of exposure of bismuth, it is very difficult to make diagnosis of bismuth toxicity.

Cadmium
In healthy, unexposed persons, β2-microglobulin levels average about 200μg/g creatinine. Excretion increases with age and cadmium exposure. In cadmium workers, urine levels greater than 300μg/g creatinine indicate possible early kidney disease.

Cobalt
The diagnosis relies upon the combination of both the clinical history of patient and the laboratory findings.

Iron
Testing for serum iron concentration is crucial for confirming iron toxicity. The serum iron concentration should be repeated after 4-6 hours after the initial determination. Abdominal radiographic examination can be useful to identify iron. Laboratory tests should include serum electrolytes, blood urea nitrogen (BUN), aniline and aspartate aminotransferases and bilirubin8.

Lead
It has been suggested that all children should be screened for blood lead levels before the age of 1 year and if possible, at yearly intervals thereafter until they are 6 years old.

Mercury
Faecal metal tests helps determine if mercury eliminated is in normal range or not.

Tin
The physical examination is equally important; where forced vital capacity (FVC) posteroanterior chest roentgenogram, and forced expiratory volume per sec (FEV1) is performed.

Thallium
Thallium is radio-opaque; therefore, an abdominal radiograph should be obtained especially in the cases of acute thallium poisoning by ingestion.

G. Management of Heavy Metals Toxicity:

Aluminium
Hospital Management starts with complete and thorough examination of the patient which includes serum level of aluminium, hepatic function, whole blood test, renal function test and coagulation profile. In case of swelling and inflammation in lungs, blood, urine tests, ECG and X- rays are performed.

Antimony
Hospital management involves supportive and symptomatic measures as per the patient's conditions. Upon ingestion of an antimony compound, gastric lavage could be considered if presentation is within the first hour. The administration of 50 g activated charcoal within first hour of substantial ingestion could adsorb antimony.

Arsenic
In case of accidental arsenic ingestion, immediately 5 charcoal tablets should be given, and then 5 more every 15 minutes until reaching Health Care provider or emergency room of the nearest hospital.

Bismuth
Ingestion of single and small amount of bismuth are unlikely to cause systemic toxicity. Ingestion of acute overdose or large amount of bismuth should be evaluated in hospital.

Cadmium
When inhaled, take the person to fresh air, rest in a half upright position. If indicated provide artificial respiration and referred for medical attention.

Cobalt
Hospital Management starts with complete and thorough examination of the patient which includes serum level of cobalt, hepatic function, whole blood test, and renal function test and coagulation profile. In case of swelling and inflammation in lungs, blood, urine tests, ECG and X- rays are performed.

Iron
Intravenous access should be established and

normal saline should be administered (0.9%) at an initial dose of 20 ml/kg followed by continuous infusion. Management includes thorough investigations such as serum iron levels, renal function test, electrolytes, complete haemogram, coagulation profile, liver function test and Arterial Blood Gas analysis of severely poisoned patients.

Lead

Garlic can be used for detoxification in cases of chronic lead poisoning. It also has prophylactic effect.

Mercury

In suspected mercury poisoning, remove mercury from body, intake of vitamin C foods, green leafy vegetables and cilantro should be increased. Cilantrois is one of the best herbs to detox mercury.

Tin

Ingestion of a very small amount of tin or its compound is unlikely to cause any systemic toxicity, Intake of a large amounts of tin in any form should be evaluated in the hospital.

Thallium

The decontamination should be done at the earliest by giving gastric lavage after the medical attendant wearing protective clothing.

RESULTS AND CONCLUSION

Heavy metals show toxic effects in case of acute and chronic exposure in humans. Individuals working in industries dealing with heavy metals, mines, paints and other sources of toxins should be given special attention. Routine testing of blood, renal function test, urine albumin and other tests to monitor levels of heavy metals in the human body should be conducted to ensure early treatment. The use of canned food and beverages should be regulated. Any symptom, whether mild or severe, should not be neglected. Immediate medical help should be provided for treatment of exposed individuals. IJFMP

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REFERENCES

1. **Krewski D, Yokel RA, et al.** *Toxicol Environ Health B Crit Rev. 2007;10 Suppl1():1-269.*
2. **Jaiswal AK, Giri NG, et al.** *Analytical aspects and Management of Antimony poisoning – A review. J Pharm Adv Res, 2019;2(1):452-457.*
3. **Jaiswal A. K., Sharma K., et al.** *Analytical Aspects with Brief Overview of Arsenic Poisoning. Journal of Indian Academy of Forensic Medicine 2012;34(3),248-254.*
4. **Jaiswal AK, Solanki S, et al.** *Bismuth poisoning with analytical aspects and its management. Int. J. Med. Lab. Res. 2019,4(1):47-54.*
5. **SikaryAsit Kumar, Jaiswal A. K., et al.** *Cadmium poisoning with analytical aspects and its management. International Journal of Current Pharmaceutical & Clinical Research 2015, Vol 5(1):25-32.*
6. **Dijkman M., Vries M.S, Meulenbelt J.** *Cobalt Poisoning by Metal-on-Metal Hip Prosthesis. Ned TijdschrGeneeskd 2012;156:A4983.*
7. **Jaiswal AK, Kumar R, et al.,** *Cobalt toxicity/poisoning with analytical aspects and its management. Int. J. Med. Lab. Res. 2019,4(3):21-28.*
8. **Jaiswal AK, Shubhangi N, et al.,** *Iron poisoning with analytical aspects and its management. Int. J. Med. Lab. Res. 2019,4(2):33-40.*
9. **Polyanskiy NG, Fillipova NA.** *Analytical Chemistry of the Elements: Lead. 1986:18.*
10. **Thurmer K, Williams E, et al.,** *Autocatalytic oxidation of lead crystallite surfaces. Science. 2002;297:2033–35.*
11. **Tetreault J, Sirosis J, et al.,** *Studies of Lead Corrosion in Acetic Acid Environments. Studies in Conservation. 1998; 43(1),17–32.*
12. **Jaiswal AK, Nandgopal Giri, et al.,** *Mercury poisoning – a review. UJMDS 2018,06 (02):1-6.1*

11. **Tetreault J, Sirosis J, et al.,** *Studies of Lead Corrosion in Acetic Acid Environments. Studies in Conservation. 1998; 43(1),17–32.*
12. **Jaiswal AK, Nandgopal Giri, et al.,** *Mercury poisoning – a review. UJMDS 2018,06 (02):1-6.*
13. **Jaiswal A. K., BishtKiran,et al.,** *Tin toxicity with analytical aspects and its management. International Journal of Forensic Science 2019,02(02):78-83.*

REFERENCES

14. **Douglas KT, Bunni MA, Baindur SR.** *Thallium in biochemistry. Int J Biochem 1990;22:429-438.*
15. **Hasan H.** *The Boron Elements: Boron, Aluminum, Gallium, Indium, Thallium. USA: Rosen Publishing Group, 2009.*
16. **Kumar Rajesh, SikaryAsit Kumar, et al.,** *Lead poisoning, analytical aspects and its management. International Journal of Biological & Pharmaceutical Research 2014;5(12):893-903.*
17. **Jaiswal A. K., Sharma Deepshika, et al.,** *Thallium poisoning: Analytical aspects with brief overview. Journal of South India Medicolegal Association 2012;(4):68-75.*
18. **Jaiswal AK, Thakur A, Mehta K, Nayyer S, Ali Z.** *Aluminium Poisoning with Analytical aspects and its Management. J Pharm Adv Res, 2020;3(3):804-810.*
19. **Lauwers, et al.** *Antimony and its inorganic compounds. Colorado: Micromedex, Inc., 1990.*
20. **Kentner, M., Leinemann, M., Schaller, K. H., Weltle, D., & Lehnert, G.** *(1995). External and internal antimony exposure in starter battery production. International archives of occupational and environmental health, 67(2), 119-123.*
21. **Pomroy C., Charbonneau S. M., McCullough R. S., & Tam G. K. H.** *Human retention studies with 74As. Toxicology and Applied Pharmacology 1980;53(3):550-556.*
22. **Vahter M., Norin H.** *Metabolism of 74As-labeled trivalent and pentavalent inorganic arsenic in mice. Environmental Research 1980;21(2):446-457.*
23. **Freeman G. B., Schoof R. A., Ruby M. V., Davis A. O., Dill J. A., Liao S. C. et al.** *Bioavailability of arsenic in soil and house dust impacted by smelter activities following oral administration in cynomolgus monkeys. Fundamental and Applied Toxicology 1995;28(2):215-222.*
24. **Mappes, R. Versuchezurausscheidung von arsenimurin.** *International Archives of Occupational and Environmental Health 1977;40(4):267-272.*
25. **Marafante, E., & Vahter, M.** *Solubility, retention, and metabolism of intratracheally and orally administered inorganic arsenic compounds in the hamster. Environmental Research 1987;42(1):72-82.*
26. **Webb D. R., Sipes I. G., Carter D. E.** *In vitro solubility and in vivo toxicity of gallium arsenide. Toxicology and applied pharmacology 1984;76(1):96-104.*
27. **Yamauchi H., Takahashi K., Yamamura Y.** *Metabolism and excretion of orally and intraperitoneally administered gallium arsenide in the hamster. Toxicology 1986;40(3):237-246.*
28. **Cullen W. R., Reimer, K. J.** *Arsenic speciation in the environment. Chemical reviews, 1989;89(4):713-764.*
29. **Delnomdedieu M., Basti M. M., et al.,** *Transfer of arsenite from glutathione to dithiols: a model of interaction. Chemical research in toxicology 1993;6(5):598-602.*
30. **Lerman S., Clarkson, T. W.** *The metabolism of arsenite and arsenate by the rat. Toxicological Sciences 1983;3(4):309-314.*
31. **Winski S. L., Carter D. E.** *Interactions of rat red blood cell sulfhydryls with arsenate and arsenite. Journal of Toxicology and Environmental Health, Part A Current Issues 1995;46(3):379-397.*
32. **Yamauchi H., Yamamura Y.** *Dynamic change of inorganic arsenic and methylarsenic compounds in human urine after oral intake as arsenic trioxide. Industrial health 1979;17(2):79-83.*
33. **Tam G. K. H., Charbonneau S. M., et al.,** *Metabolism of inorganic arsenic (74As) in humans following oral ingestion. Toxicology and applied pharmacology 1979;50(2):319-322.*
34. **Buchet J. P., Lauwerys R.** *Study of inorganic arsenic methylation by rat liver in vitro: relevance for the interpretation of observations in man. Archives of toxicology 1985;57(2):125-129.*
35. **Kenyon M. F. H. E. M.** *Dose-dependent effects on the disposition of monomethylarsonic acid and dimethylarsinic acid in the mouse after intravenous administration. Journal of Toxicology and Environmental Health Part A 1998;53(2):95-112.*
36. **Molin L., Wester P. O.** *The estimated daily loss of trace elements from normal skin by desquamation. Scandinavian journal of clinical and laboratory investigation 1976;36(7):679-682.*
37. **Patrick L.** *Lead Toxicity, a review of the literature. Part I: Exposure, Evaluation, and treatment. Alternative medicine review 2006;11(1).*
38. **Karri S. K., Saper R. B., Kales S. N.** *Lead encephalopathy due to traditional medicines. Current drug safety 2008;3(1):54-59.*
39. **Ohhira S, Matsui H.** *Metabolism of a tetraphenyltin compound in rats after a single oral dose. J ApplToxicol 2003;23:31-35.*
40. **Heim M, Wapperlhorst O, Markert B.** *Thallium terrestrial environments: occurrence and effects. Ecotoxicology 2002;1:369-377.*
41. **Polson CJ, Green MA, Lee MR.** *Clinical Toxicology. Philadelphia: Lippincott 1983.*