IMPACT OF ELECTROPLATING ON THE METAL TOXICITY OF UTENSILS DUE TO LEECHING PROCESS

A THESIS

Submitted by

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IN

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APPROVAL SHEET

This Ph.D. thesis entitled “Impact of Electroplating on The Metal Toxicity of Utensils Due to Leeching Process” by Deepak Kumar Sharma is approved for the degree of Doctor of Philosophy in Forensic Science.

Examiners

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Place: Greater Noida

DECLARATION / CERTIFICATION

I, DEEPAK KUMAR SHARMA declare that the work in the thesis, entitled **"Impact of Electroplating on The Metal Toxicity of Utensils Due to Leeching Process"** was carried out by me in the Division of Forensic Science, School of Biomedical Sciences, Galgotias University, India. The information used for my literature review was fully acknowledged in the text and references. This thesis has not been presented in any scientific gathering, neither has it been presented for another degree at any University.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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DEDICATION

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LIST OF ABBREVIATIONS

Abbreviation	Full Form
µm	Micrometer
AAS	Atomic Absorption Spectrophotometer
ALAD	Amino Levulinic Acid Dehydratase
ATSDR	Agency for Toxic Substances and Disease Registry
BCSCRM	British Chemical Standard Certified Reference Material
BFD	Blackfoot Disease
CIS	Commonwealth of Independent States
CNS	Central Nervous System
CRM	Certified Reference Material
DL	Detection Limit
DNA	Deoxy Ribonucleic Acid
Dr.	Doctor
e.g.	For Example
EU	European Union
FAO	Food and Agriculture Organization
FDA	Food and Drug Administration
GFAP	Glial Fibrillary Acidic Protein
ICP MS	Inductively Coupled Plasma Mass Spectrometry
ICP OES	Inductively Coupled Plasma Optical emission spectroscopy
IQ	Intelligent Quotient
JECFA	Joint Expert Committee on Food Additives
Kg	Kilogram
MBP	Myelin Basic Protein
MDL	Method Detection Limit
MG	Microglobulin
Mg	Milligram

NAG	N-acetyl-D-glucosaminidase
NDMA Receptor	N-methyl-D-aspartate receptor
PAH	Polycyclic Aromatic Hydrocarbons
Ph.D.	Doctor in Philosophy
ppm	Parts Per Million
PVD	Peripheral Vascular Disease
QA	Quality Assurance
QC	Quality Control
RBC	Red Blood Cells
RBP	Retinol Binding Protein
RNA	Ribonucleic Acid
SS	Stainless-Steel
TDI	Tolerable Daily Intake
THQ	Target Hazard Quotients
US EPA	United States Environmental Protection Act
WHO	World Health Organization
XRF	X-Ray Fluorescence

LIST OF SYMBOLS

Symbol	Detail
μ	Micron
Al	Aluminium
As	Arsenic
Bi	Bismuth
Cd	Cadmium
Co	Cobalt
Fe	Iron
Hg	Mercury
Pb	Lead
Sn	Antimony
Sn	Tin
Th	Thallium

LIST OF PUBLICATIONS

S. No	Title of the Paper	Journal/Conference	Year
1.	Iron Poisoning with Analytical Aspects and its Management	International Journal of Medical Laboratory Research	2019
2.	Tin Toxicity with Analytical Aspects and its Management	International Journal of Forensic Science	2019
3.	Barium Poisoning with Analytical Aspects and its Management	International Journal of Advanced Research in Medicinal Chemistry	2020
4.	Magnesium Poisoning with Analytical Aspects and its Management	Indian Journal of Forensic and Community Medicine	2020
5.	Heavy Metal Toxicity: Impact on Human Health- A Review	Indian Journal of Forensic Medicine and Pathology	2021
6.	Metal Exposure from Utensils: Risk to Public Health- An Illustrative Review	Indian Journal of Forensic Medicine and Pathology	Accepted
7.	Migration of Metals from Utensils: An Assessment	Indian Journal of Forensic Medicine and Pathology	Accepted
8.	Critical review on metal based cosmetic products	Macromolecular Symposia	Accepted
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10.	Assessment of Heavy metal migration from utensils and it's Impact on family health: a study on potential health risks and prevention strategies	Environmental Geochemistry and Health	Submitted

ABSTRACT

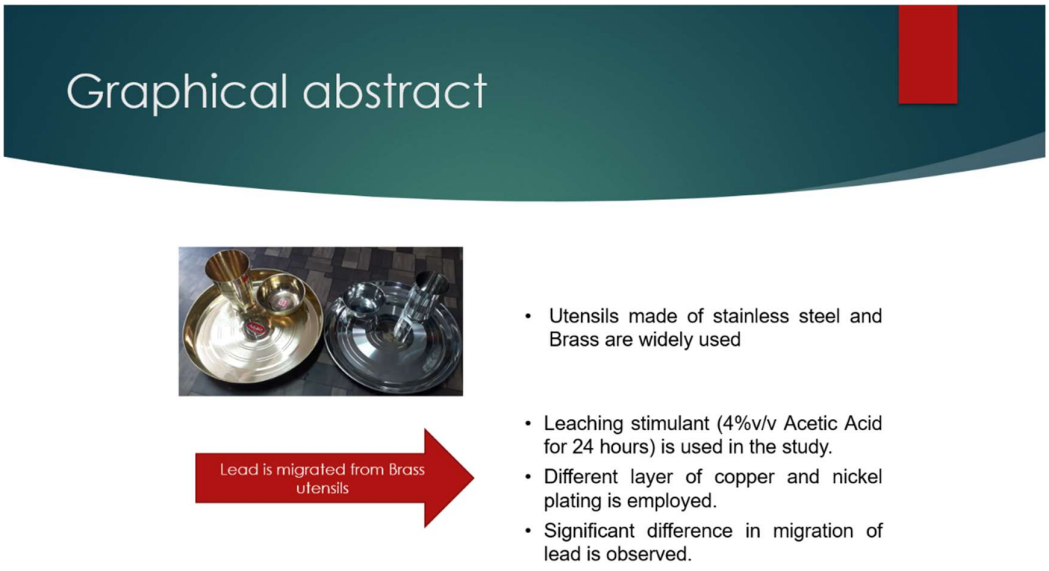


Figure 1: Graphical Abstract

Metal toxicity refers to the harmful effects that can occur when certain metals accumulate in the body and interfere with normal physiological processes. Some metals, like zinc and iron, are necessary nutrients that the body needs in little amounts to function properly, whereas other metals can be hazardous even in small levels.

Some of the most common metals associated with toxicity include lead, mercury, cadmium, arsenic, and aluminium. The neurological system, cardiovascular system, renal system, and reproductive system are just a few of the systems and organs in the body that these metals can impact. Depending on the type and amount of metal exposure, symptoms of toxicity may range from mild to severe and may include nausea, vomiting, diarrhoea, fatigue, cognitive impairment, organ damage, and even death.

Multiple pathways can lead to toxic metal exposure, including skin contact with metal-containing substances, consumption of tainted food or water, and inhalation of metal-containing dust or fumes. Some of the most common toxic metals include lead, mercury, cadmium, arsenic, and aluminium.

The effects of metal toxicity can vary depending on a person's age, sex, genetic makeup, and overall health status. For instance, lead exposure can have harmful effects such as

developmental delays and cognitive impairment on young children and pregnant women. Likewise, individuals with compromised immune systems or pre-existing medical conditions may be more susceptible to the harmful effects of metal exposure.

Chronic illnesses like cancer, heart disease, and neurological disorders are all made more likely by prolonged exposure to hazardous metals. Additionally, some metals, such as lead and mercury, can be particularly harmful to developing fetuses and young children, potentially leading to developmental delays, learning disabilities, and behavioural problems.

It is crucial to be aware of potential sources of metal exposure and to take precautions to reduce exposure as much as possible in order to prevent metal toxicity. This may involve avoiding certain foods or products that contain high levels of metals, using protective equipment in certain occupational or industrial settings, and practicing safe and responsible disposal of hazardous materials.

Preventing metal toxicity involves minimizing exposure to toxic metals, such as avoiding contact with contaminated materials and consuming a healthy diet that is low in metal contaminants. In cases where metal toxicity has already occurred, treatment may involve chelation therapy, which involves the use of medications to remove metal ions from the body.

Overall, metal toxicity is a serious health concern that can have significant impacts on individual and public health. By understanding the risks associated with metal exposure and taking steps to minimize exposure, we can help protect ourselves and others from the harmful effects of metal toxicity.

The purpose of this study is to look at any health concerns that might be brought on by using metal utensils when preparing food and cooking. The study explores the possibility of metal leaching into food during cooking and the potential toxic effects of ingesting these metals. A literature review is conducted to evaluate existing research on the topic and to identify knowledge gaps. The study also includes experimental research to measure the amount of metal leaching from commonly used metal utensils and to assess the potential toxicity of the leached metals. The findings suggest that metal leaching from utensils can occur and that ingesting metals such as lead, and cadmium

can have adverse health effects. The study provides recommendations for safe use of metal utensils and calls for further research on the topic to improve public health.

The research also evaluates the extent to which metal toxicity can impact human health, including its effects on the immune system, nervous system, and various organs. Additionally, the study explores potential solutions to mitigate the risks associated with metal utensils, such as electroplating. The findings of this thesis provide important insights into the potential health risks of metal utensils and offer practical recommendations to promote safe and healthy cooking and food storage practices.

CHAPTER 1:

INTRODUCTION

1. INTRODUCTION

There is a fair amount of awareness on issues such as air pollution, water pollution, and the dangers of home chemicals [1-3]. According to recent studies, certain kind of cookware might introduce harmful chemicals into the human system. Several materials are used to make pots, cups, and cookware. The chemicals from such materials may leach into the cooked meals [4]. Cooking may be done using cast iron, aluminium, copper, ceramic and enamel, glass, stainless steel, and other materials [5-8]. In India, the most often used cooking pots are brass, cast iron, and bronze. Most Indian marketplaces are characterised by the success and economic efficiency of these pans, as well as their simplicity of washing and distinctive surfaces that are tough to fracture, difficult to roost, and have a long lifetime.

The degradation of the environment is worsened by the heightened presence of metallic elements within the food chain [9]. Various factors can affect the presence of metals in food, including the types of cooking ingredients utilized, the cooking methods applied, and the storage and processing techniques employed. These factors have been shown to contribute to the elevation of trace metal levels in food [9-11]. Heavy metals are environmental toxins that may be responsible for adverse health effects [12]. In addition to the chemicals in the cooking equipment, liquidating meals may add considerable levels of trace metals to foods According to studies, cooking methods, food preparation, storage, and processing all raise the amount of metal in food [6, 8, 12]. Leaching of metals from domestic cookware may be harmful.

Heavy metals have been found to be humanly degraded as a consequence of industrial or residential pollution, and illnesses associated to these metals are likely to affect populations across the globe. Arsenic (As), Iron (Fe), Cadmium (Cd), Copper (Cu), and Nickel (Ni) are essential elements, but they can become highly toxic even at low concentrations. Aluminium (Al), beryllium (Be), and lead (Pb) lack biological significance [15-18].

Metal toxicity generally requires ingestion, but prolonged exposure to specific metals like cadmium and lead can result in severe toxicity even at low levels.

Individuals take metals via a number of routes, the most common of which are polluted air inhalation and food consumption [19-22].

As of June 1, 2020, the World Health Organization (WHO) has recognized arsenic (As) cadmium (Cd), mercury (Hg), and lead (Pb) and as among the top 10 chemicals presenting considerable public health concerns. This data originates from the WHO website and is depicted in Figure 2 [23].

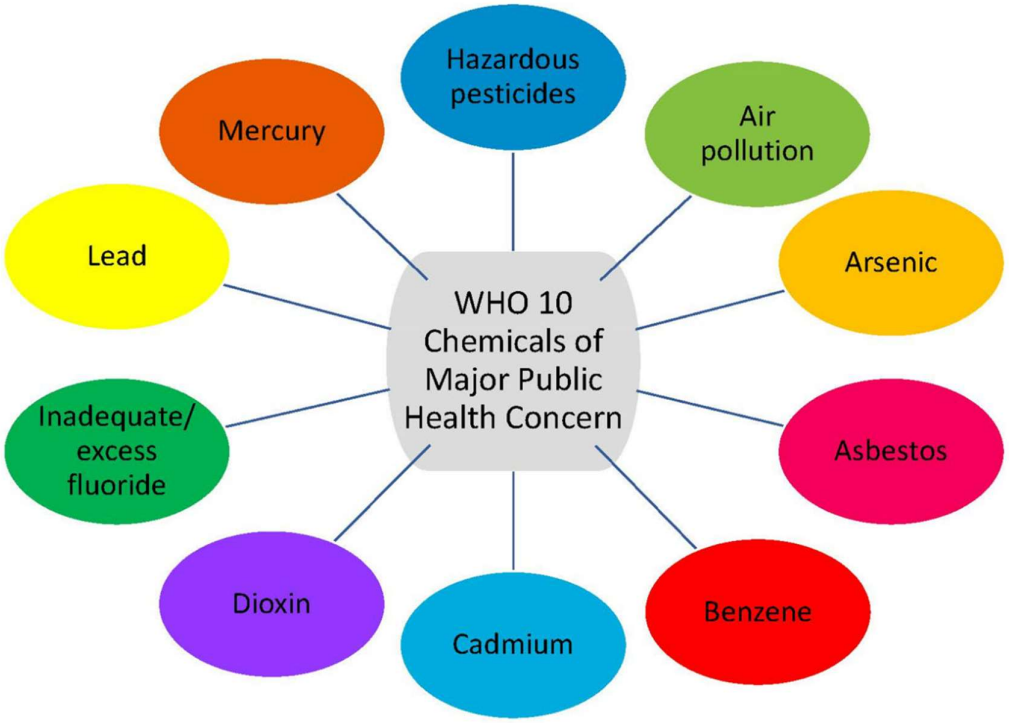


Figure 1.1: Ten chemicals of significant public health concern identified World Health Organization

1.1. BACKGROUND

Metals have both beneficial and negative effects [24]. Metals are found in our air, water and soil (and elements that combine metals and nonmetals called metalloids). Changing environments, industrial processing, agricultural processes, and contamination are all variables that affect food levels [25]. Breakfast cereals and baby formulations are often fortified with nutrients such as Fe [26].

Age, stage of development, and the qualities of different metals all have a role in how a metal influences an individual's well-being. The most vulnerable groups include children and teens, the elderly, and the persons with medical conditions that were present before, all of whom may be affected adversely by metals in food. Due to children's smaller bodies and metabolism, they may be more susceptible to detrimental impacts of certain metals, which is why we're paying special attention to them in our efforts to reduce metal exposure. Concern should be expressed in particular over how heavy metals affect children's growth and development. Overdosing on health-promoting metals, on the other hand, may pose negative side effects. Because the body regulates Fe absorption to prevent inappropriate amounts, overconsumption of iron replacement pills might result in an iron deficiency. Symptoms might include severe vomiting, diarrhoea, stomach discomfort, nausea, and fatigue. As, Cd, Hg and Pb may affect the CNS (Central Nervous System), plasma, kidneys, lungs, and the liver [1,4,6,13,16,25].

Mortality has previously been linked to large dosages of As, Pb and Hg, there are no documented health risks [27].

Poisoning with toxic elements is a significant problem for the ecosystem [28]. Consumption of certain contaminated food may transfer toxic substances, and the hazard increases with the quantity consumed. Examples include marine species near the top of the food chain, where hazardous substances are present in greater abundance [29]. For the most part, this is due to the fact that marine organisms accumulate radioactive elements at a higher rate than terrestrial ones. Certain hazardous chemicals, for example Hg and its compound (methymercury), are neurotoxic to human beings. Mental retardation, blindness, and cerebral palsy have been linked to Hg intoxication

in humans [30-31]. There is evidence to show that Cd exposure may cause bone fractures and damage, also kidney damage, even at low levels of toxicity. The consumption of inorganic arsenic has been associated with a heightened risk of skin cancer and various skin conditions, including hyperkeratosis and alterations in skin coloration. Metals are prevalent throughout our food chain since most people's dietary sensitivities are not linked to a single food source. A diverse array of foods can contain these metals, putting people at risk of being exposed to them. One possible cause for worry is that modest quantities of hazardous metals in food, together with all of the other chemicals that are consumed [32-34].

Metals mainly enter the human body along with food. To determine how typical food processing methods affect the levels of hazardous components in food, researchers have performed several experiments. Other research shows that processing practices have a favourable influence on the decrease of hazardous components in foods, even though other trials demonstrate a negative impact of processing practices [35-36]. Rules and regulations for use of chemicals for lowering total quantity of radioactive elements in the foods have also been suggested. Such research focuses on chemical attachments of organic and inorganic kinds of each component (element) in diverse meals to minimize the presence of harmful components. The types of reactions that occur and the chemical groups and ligands that food products employ to attach to metals are often debated topics.

According to the Food and Drug Administration (FDA), currently, novel approaches exist to minimize the adverse impact of metals' toxicity. Emphasis is being given to As, Cd, Hg and Pb in meat, cosmetics, and nutritional supplements since these metals are predicted to have the greatest impact on the health of individuals. A large number of contaminants are being detected in the food that is collected from supermarkets all around the globe, including the heavy metals mentioned earlier. To understand more about how consumers are exposed to these toxins, these data are essential.

A number of regulations and procedures are being published to minimize exposure, including requiring or pushing industry activities to eliminate metals in products as well as advising consumers on how to limit the dangers caused by these metals. This study

aims to draw attention to the heavy metal contamination caused by exposure to cooked food.

1.2. IMPACT OF METAL TOXICITY ON HUMAN HEALTH

Toxic metals have a devastating effect on the body's critical biochemical processes in two ways. They interfere with the normal functioning of the heart, brain, kidney, bone, and liver, as well as the transport of vital mineral nutrients. In children who have been exposed to certain metals, cognitive impairment, memory loss, nervous system disturbance, and atypical behaviour like aggression and occurrences of anxiety, depression, and hyperactivity have all been reported. Higher concentrations of heavy metals can lead to lasting harm to both the brain and other organs in the body. Due to their higher food intake relative to adults, children are at a greater risk of ingesting metals through their diets [37].

Figure 3 depicts the potential pathways of heavy metal exposure and their impact on human health. A comprehensive explanation of their mode of operation is presented in the subsequent section [38].

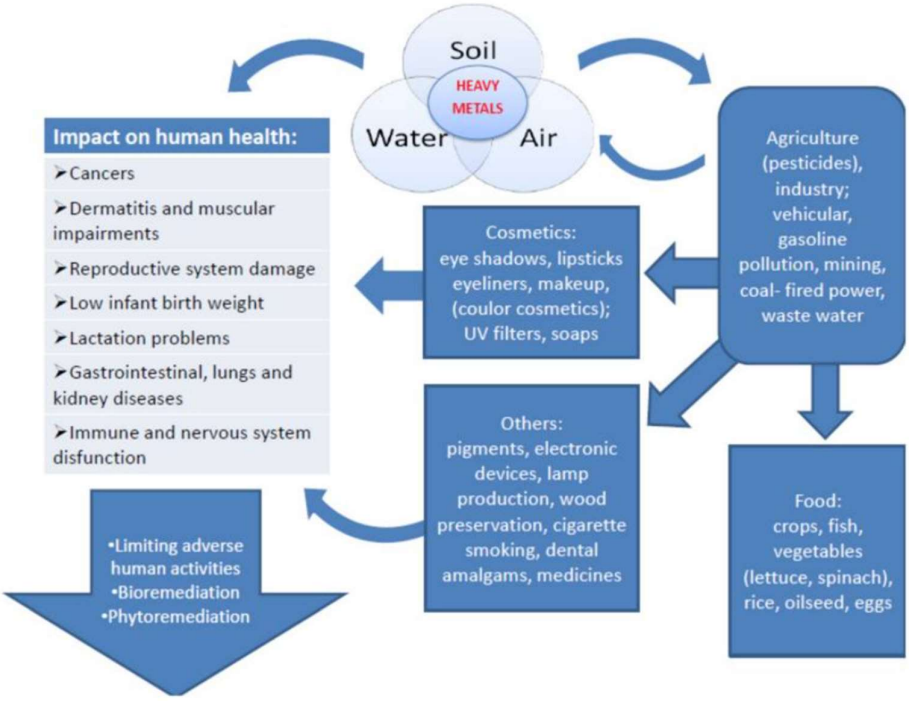


Figure 1.2: Aspects concerning toxic metals

1.2.1 ALUMINIUM TOXICITY

Aluminium, for example, has been shown to hinder the appropriate use of key elements such as calcium, zinc, and copper by acting as a chelator [39]. Alzheimer's disease is exacerbated by exposure to this metal [40-41]. Cooking acidic foods, such as tomatoes, releases metals into the meal, making Aluminium cookware particularly dangerous. Additionally, Al has been related to Alzheimer's, different dementias, and bone disease. Foetuses, newborns, and young children's developing bodies are more vulnerable to metal toxicity, which is why metals should be avoided throughout pregnancy and breastfeeding.

a) Respiratory effects

The impact of these effects is typically experienced by individuals employed in pot rooms, foundries, and welding settings, where they encounter aluminium fumes, dust, and powdered substances. Apart from aluminium, these individuals are susceptible to various harmful substances detrimental to their health, like polycyclic aromatic hydrocarbons (PAHs), carbon monoxide, hydrogen fluoride, chlorine, and sulphur dioxide. Wheezing, reduced lung function, dyspnea, and occupational asthma are some of the consequences. One of the most often observed negative consequences of exposure by inhalation is pulmonary fibrosis. There have also been reports of pulmonary alveolar proteinosis, interstitial pneumonia, granulomas, and pneumoconiosis caused by aluminium [42].

b) Cardiovascular effects

In the event that a substantial amount of aluminium powder is inhaled, hypertrophy and dilatation may be observed in the heart's various regions. Moreover, lung fibrosis and reduced pulmonary function can also be contributing factors to its occurrence. Aluminium poisoning has been associated with various cases of increased erythrocyte sedimentation rates and decreased RBC haemoglobin content. In rodent studies, researchers observed various alterations in cardiac tissue, including dose-dependent bioaccumulation, genomic DNA oxidation, micromineral imbalances, significant parenchymal loss, diffuse inflammatory infiltrates, increased collagen deposition,

reduced myocardial vascularization index, mitochondrial swelling, sarcomere disorganization, and cardiomyocyte fragmentation [42].

c) Effects on Bones

The majority of the aluminium in bodily tissues, approximately 54% of the total, is found in the skeleton, according to the International Commission on Radiological Protection. It is thought to be toxic to the body's major organs, including the bones, where it can result in osteomalacia, which leads to fracture-causing osteodystrophy, and softening the bones and decrease of bone mass. Aluminium exhibits a half-life of approximately 10 to 20 years, which allows it to be maintained in bones for a longer period of time. Aluminum accumulation in skeletal tissues occurs due to the movement of Al ions from citrate and transferrin into the bloodstream and then onto various bone surfaces. These surfaces include the internal endosteal surface, the outer periosteal surface, the surface of vascular channels, and the trabecular surface, which are found in dense bones. Dynamic bone disease is among the long-term consequences, impeding the natural bone regeneration process and leading to unexpected fractures. Additionally, it has been observed that aluminium binds to the proteins in secretory granules, disrupting the exocytosis process and impairing the release of secretory granules that carry parathyroid hormone, causing hypoparathyroidism [42].

d) Neurological Effects

According to certain research, aluminium ions that do not undergo redox reactions may produce oxidative alterations and trigger the creation of reactive oxygen species, which can result in a variety of neurological illnesses, most notably Alzheimer's disease. The buildup of aluminium can sometimes lead to an inflammatory reaction, causing the production and release of interleukins and other inflammatory cytokines [42].

e) Breast Cancer

Because there is limited and conflicting information, the association between aluminium and breast cancer cannot be conclusively established or disproved. It has been noted that breast tissue from women who have tumours may have somewhat greater aluminium contents than tissue from those who are healthy. However, the information on this is conflicting, making it impossible to make a scientifically sound

connection between aluminium-containing antiperspirants or deodorants and breast cancer at this time. Commercially accessible antiperspirants without aluminium [42].

Table 1 provides comprehensive information regarding various aspects of aluminium, including its sources, routes of exposure, poisoning mechanisms, toxicity impacts, onset and duration of toxicity, detection methods, normal and reference values, as well as critical data on fatal dose and fatal period.

Table 1.1: Aluminium Toxicity

Particular	Details		
About	Denoted by the symbol "Al"		
	Atomic number: 13		
	Highly conductive, corrosion resistant, silvery-white metal and derived from bauxite ore		
Source	Aerospace, Construction materials, Utensils manufacturer, Electrical Appliances, Packaging, and automobiles.		
	Paints and Pigments.		
	Fuel additives, propellants, and explosives.		
Routes of exposure	Environment Pollution (contaminated water and air)		
	Inhalation and transdermal absorption through cosmetics containing aluminium.		
	Medicines (e.g., Antacids)		
	Workers working in the industries like refining, mining, smelting, and those which make tools by grinding and cutting using metal or compounds of aluminium		
	Aluminium utensils for cooking purposes		
Poisoning	Ingestion		
	Inhalation		
	Dermal		
Impact of toxicity	lungs, CNS, and Bones		
Onset and duration of action	The symptoms of aluminium toxicity depend upon the duration and amount of exposure. However, it may take weeks to months for the symptoms to appear, depending upon the dose and compound of aluminium until one swallow the large amount all at once		
Detection of poisoning	Urine, blood, serum, bone, and other tissues		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	7 to 10 µg/l	> 60 µg/l
	Urine	< 7µg/l	30 to 100 µg/l
	Serum	1 to 3 µg/l	50 to 100 µg/l
Fatal Dose and Fatal Period	40 mg/kg of body weight, Few months		
Symptoms	Confusion, Muscle weakness, Seizures, Speech problems, Bone deformities & fractures, Shunted or slow growth in children, Asthma, lungs related problems, Bone disease, Anaemia, Impaired absorption of iron, neurodegenerative disease such as Alzheimer's disease, CNS related issues, Osteomalacia.		

1.2.2 ANTIMONY TOXICITY

a) Chronic effect of antimony

Extended contact with antimony, particularly in the presence of antimony trioxide or pentoxide dust, is thought to be linked to the emergence of pneumoconiosis. Other respiratory adverse effects associated with antimony exposure include chronic bronchitis, pleural adhesions, chronic coughing, and wheezing. GI problems and cardiovascular issues are some of the additional symptoms. Animal studies have documented effects of oral antimony consumption on the liver, gastrointestinal tract, central nervous system, and blood [44].

b) Acute effect

The skin and eyes are affected by acute impacts. Antimony spots are skin conditions that can result in rashes with pustules surrounding sweat and sebaceous glands. This dermatitis, which frequently affects those working in hot environments and in hot weather, can cause rashes that clear up in 3 to 14 days. Ocular conjunction is one of the impacts on the eyes, whereas gastrointestinal issues are caused by oral exposure. Animal studies have revealed effects on the heart, liver, and lungs [44].

c) Effect on cardiovascular system

Over a period of 8 months to 2 years, employees who were exposed to 2.15mg/m^3 of antimony trisulphide and phenol experienced cardiovascular effects, including elevated blood pressure and alterations in electrocardiography values, primarily affecting the T waves. Moreover, inhaling antimony trisulphide dust led to adverse effects on the myocardium and various related anomalies in electrocardiograms across different animal species. [44].

d) Effect on gastro-intestinal system

Regular exposure to airborne antimony compounds, such as antimony trichloride, antimony oxide, or antimony trisulfide, has been linked to gastrointestinal discomfort, including stomach pain, vomiting, ulcers, and diarrhoea.[44].

e) Reproductive effects

The impact on reproduction includes higher occurrences of spontaneous abortions and menstrual irregularities in females. Rats subjected to 209mg of antimony trioxide for 63 days in animal tests showed failure to conceive, as demonstrated by two thirds of the rats [44].

f) Gene toxicity and mutagenicity effect

In tests for non-mammalian gene toxicity, trivalent and pentavalent antimony compounds do not cause any toxicity; nevertheless, in systems involving mammals, Sb (+3) compounds cause toxicity while Sb (+5) compounds do not. Although antimony trisulfide and antimony trioxide have been found to produce lung tumours in rats, antimony has not been properly demonstrated to be carcinogenic to humans. The International Agency for Research on Cancer suggests that Antimony trioxide might have a potential link to human cancer [44].

Table 2 contains detailed information on cadmium, including its sources, routes of exposure, poisoning mechanisms, effects of toxicity, onset and persistence of symptoms, methods for detecting poisoning, normal and reference values, lethal dose, lethal time, and related symptoms.

Table 1.2: Antimony Toxicity

Particular	Details		
About	Denoted by the symbol "Sb"		
	Atomic Number: 51		
	A hard, grey lustrous metalloid is found in nature as the sulphide mineral, stibnite		
Source	Ores such as Valentinite (Sb_2O_3) and Stibnite (Sb_2S_3)		
	Environment through waste incineration,		
	metal processing mines and burning of coal.		
Routes of exposure	Exposure occurs during occupational activities while working with antimony compounds and inhaling antimony dust, or fumes)		
	Ingestion through contaminated vegetables		
	Dermal exposure occurs during working near antimony mines or antimony processing sites)		
Poisoning	Ingestion		
	Inhalation		
Impact of toxicity	Interfering with cellular metabolism		
Onset and duration of action	Antimony in the lungs enters the bloodstream after several days or weeks depending on the nature of its compound. Even a small amount of antimony that is taken orally enters the bloodstream only after a few hours.		
Detection of poisoning	Urine, blood, serum		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	0.7-2 µg/l	9mg/l
	Urine	0.06-0.01 µg/l	0.26-0.39 µg/l
	Serum	<0.066 µg/g	0.088 µg/g
Fatal Dose and Fatal Period	The fatal dose of antimony is 90 to180 mg in terms of tartarum, while 8 to 12 ml in terms of trichloride. The fatal period is around 24 h.		
Symptoms	Upon moderate ingestion, symptoms are usually seen after 30 min to 2 h, which includes nausea, vomiting, metallic taste, abdominal pain, or diarrhoea. A garlic odour too can be felt on the breath.		

1.2.3 ARSENIC TOXICITY

Arsenic and its compounds are well-known carcinogens for humans and are utilized in various industries like mining, insecticide, pharmaceuticals, glass, and microelectronics. The sources of arsenic exposure are both natural and man-made, contributing to environmental contamination. While inhalation is the primary route of exposure in workplaces, drinking water pollution is the major cause of severe environmental exposure globally. This contamination of drinking water presents a significant public health risk, as high concentrations of arsenic have been observed in some countries, leading to both acute and chronic exposure. As a consequence, arsenic exposure gives rise to a wide array of health issues, including anaemia, leukopenia, eosinophilia, diabetes, hearing loss, portal fibrosis, hematologic disorders, and various types of cancers. These health problems have led to standardized mortality rates being observed in numerous populations. To mitigate these risks, efforts to reduce arsenic exposure from both occupational and environmental sources are essential for safeguarding public health [45].

Prolonged consumption of arsenic-contaminated drinking water is definitively linked to an elevated cancer risk in various organs, including the skin, lungs, bladder, and kidneys, alongside skin conditions like hyperkeratosis and pigmentation alterations. Several studies with various study approaches have proven these effects. For each of these end objectives, exposure-response correlations and high risks have been noted. Taiwan has conducted the most extensive research on the consequences, although other countries have also provided significant data. Consuming water containing 50g/litre of arsenic has been linked to higher chances of developing bladder and lung cancer, along with various skin issues related to arsenic exposure [45].

It has been proven that occupational arsenic exposure, particularly by inhalation, causes lung cancer. High hazards and exposure-response linkages have been identified. Risks have been found to increase at cumulative exposure levels of 0.75mg/m^3 per year, or after 15 years of contact to workroom air with a 50g/m^3 concentration. In two of the three major smelter cohorts, tobacco smoking has been examined. It was discovered that tobacco usage interacts with arsenic to raise lung cancer risk, rather than being the direct source of the higher risk [45-46].

According to a substantial body of data, arsenic has the potential to negatively affect multiple cell types and lead to various outcomes in both exposed individuals and cancer patients, although a few conflicting studies exist. Results for point mutations are primarily unfavourable. Consuming substantial amounts of soluble inorganic arsenic leads to gastrointestinal issues, circulatory and neurological system abnormalities, and ultimately, death. Survivors of such exposure may undergo bone marrow depression, hemolysis, hepatomegaly, melanosis, polyneuropathy, and encephalopathy after receiving treatment [46].

Blackfoot disease (BFD) is a severe type of peripheral vascular disease (PVD) characterized by gangrenous changes, and it has been associated with prolonged arsenic exposure in Taiwan. The findings in Taiwan could be influenced by additional contributing factors since this condition has not been reported in other regions of the world. However, research conducted in a number of nations provide solid proof that different types of PVD are brought on by arsenic exposure [45].

Less certain conclusions may be drawn about the association between arsenic exposure and other health outcomes. The strongest evidence supports the link between hypertension and cardiovascular illness. However, the evidence is less robust for cerebrovascular disease, long-term neurological effects, and non-lung, bladder, kidney, and skin-related cancers. It is also suggestive for diabetes and reproductive consequences [45-46].

With regard to arsenic, its sources, routes of exposure, poisoning mechanisms, effects of toxicity, the onset and duration of symptoms, methods for poisoning detection, normal and reference values, the lethal dose, the fatal time, and related symptoms, detailed information is described in Table 3.

Table 1.3: Arsenic Toxicity

Particular	Details		
About	Denoted by the symbol "As" Atomic Number: 33 A toxic metalloid and found in different allotropic forms		
Source	Smelting industry (by-product of ores containing lead, gold, zinc, cobalt, and nickel) Pesticides Paints and dye industries		
Routes of exposure	Environment (contaminated Food, Water and Air) Inhalation (exposure occurs during occupational activities)		
Poisoning	Ingestion		
Impact of toxicity	causes acute irritation		
Onset and duration of action	The time elapsing between the intake of the poison and the appearance of the symptoms varies according to whether the arsenic is taken more or less soluble form and whether the stomach at the times contains food or is empty.		
Detection of poisoning	Urine, blood, serum		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	<1 µg/l	>50 µg/l
	Urine	<100 µg/l	>5000 µg/day
	Serum	≤1000 µg/l	>1000 µg/l
Fatal Dose and Fatal Period	The fatal dose of arsenic in an adult is usually stated as 120-200 mg and 2mg/kg body wt. in children.		
Symptoms	The symptoms of acute arsenic poisoning appear within half an hour, but it may be delayed in those cases where arsenic enters the system by routes other than mouth. Acute arsenic Poisoning from ingestion results in increased permeability of small blood vessels and inflammation and necrosis of the intestinal mucosa; manufacturing as haemorrhagic gastroenteritis, fluid loss and hypotension. Patient initially complains of dizziness, depression and nausea followed by severe paint and constriction in the throat and stomach which increases on pressure. Increased salivation and stomatitis are present. Intense thirst and severe vomiting are constant symptoms.		

1.2.4 BISMUTH TOXICITY

There is a condition known as bismuth poisoning, which mostly damages the kidney, liver, and bladder, however the damage is typically not severe. Exposure to the corresponding organs can potentially cause skin and respiratory discomfort. Large amounts injected into closed cavities and applied extensively to burns may result in serious and occasionally deadly poisoning. When gingivitis first occurs, it is recommended that bismuth administration be stopped because otherwise, a significant ulceration stomatitis is likely to develop. Other toxic effects may manifest, including a generalised bodily ache, presence of albumin or other protein compounds in the urine, diarrhoea, skin rashes, and occasionally severe exodermatitis [47].

Industrial bismuth poisoning has not been documented, but the medicinal uses of the substance have contributed significantly to our understanding of its toxicity. Most bismuth salts are very weakly soluble and poorly absorbed when inhaled or consumed. The kidney, liver, and bladder are the primary organs affected by bismuth toxicity. Exposure to the corresponding organs can potentially cause skin and respiratory discomfort. The main exposure pathways involve inhaling/ingesting dust and fumes. Following extended inhalation of bismuth, mental changes, nervousness, blood alterations, lymphocytosis, and bone marrow depression are noted [47].

a) Acute

Skin/Eye contact: Skin or eyes may irritate the local area, but no tissue harm would result. The skin does not absorb it. Asthma: Asthma may irritate the upper respiratory tract when inhaled. Sneezing, coughing, and shortness of breath are some of its signs. Abdominal cramps, disturbed sleep, nausea, exhaustion, headache, vomiting, weight loss, anaemia, and pain in the legs, arms, and joints are all side effects of intense exposure [47].

Ingestion: Similar symptoms to those experienced after inhalation include vomiting, increased salivation, diarrhoea, enlargement of the buccal mucosa, weakness, and pyorrhea. Other health consequences, such as a metallic taste in the mouth, constipation, or bloody diarrhoea, may also be anticipated [47].

b) Chronic

Chronic health problems from bismuth overexposure could occur over time. Skin responses, weight loss, exhaustion, sleep difficulties, and depression are some symptoms of poisoning. In severe circumstances, bismuth accumulation in the gums can also result in a bluish or brownish colouring of the gums. Anaemia, digestive issues, and central nervous system harm are further potential side effects [47].

In-depth information about bismuth, including its sources, routes of exposure, poisoning mechanisms, effects of toxicity, onset and persistence of symptoms, methods for detecting poisoning, normal and reference values, lethal dose, lethal time, and related symptoms, is provided in Table 4.

Table 1.4: Bismuth Toxicity

Particular	Details		
About	Denoted by the symbol "Bi" Atomic Number: 83 A high-density, silvery, pink-tinged metal		
Source	Sea Water (About 0.02 µg/litre Bi is present in Sea water). Anthropogenic sources of bismuth include copper, lead, silver and gold smelting, Wastewater and sewage sludge.		
Routes of exposure	Medicines Cosmetics		
Poisoning	Ingestion		
Impact of toxicity	Induce synthesis of metallothionein		
Onset and duration of action	The symptoms occur over 26 hours after exposure however in case of lower dose, symptoms may occur over 8 days.		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	<0.05µg/ml	0.05-0.1µg/ml
	Urine	0-20 mmol/l	400 mmol/l
Fatal Dose and Fatal Period	The fatal dose of bismuth is 524mg orally every 0.1-to-1-hour up to a maximum of 8 doses/day (4192mg/day). Probable oral lethal dose in humans is 0.5 -5g/kg. The time to peak conc. is typically within one hour. The distribution half-life is approximately 1 to 4 hours, and the elimination half-life is 5 to 11 days. Urinary bismuth is detectable 3 months after the last dose.		
Symptoms	Clinical appearance of symptoms depend on the form of bismuth and dose intake Bismuth may lower the blood sugar levels so people with diabetes or hypoglycemia, and those taking drugs must be administered supplements or herbs that increase blood sugar.		

1.2.5 CADMIUM TOXICITY

a) Cardio-vascular system

The cardiovascular system is not significantly impacted by inhalation exposure. According to certain research, people exposed to cadmium had decreased rates of cardiovascular disease mortality [48-50].

b) Gastrointestinal system

The major symptoms are discomfort or tenderness in the epigastrium, which is sometimes accompanied by nausea and mild constipation [50].

c) Haematological system

Following gastrointestinal exposure to cadmium, reduced iron absorption from the diet is the main cause of cadmium-induced anaemia. Depending on the method and quantity, cadmium inhalation might result in varying amounts of gastrointestinal exposure [49-50].

d) Musculoskeletal system

Osteoporosis, osteomalacia, and calcium deficiency can all be caused by prolonged job exposure to high levels of cadmium. Effects on bone often appear only after renal injury and are most likely a side effect of the subsequent alterations in the metabolism of calcium, phosphorus, and vitamin D [48-50].

e) Hepatic

The primary effects of cadmium consumption on the liver. Both the liver and the kidney can become accumulated with cadmium. The liver's capacity to produce additional metallothionein, a substance that binds with cadmium and decreases the levels of free cadmium ions, could potentially relate to the liver's ability to withstand the detrimental impacts of cadmium exposure [50].

f) Renal

Due to cadmium exposure via inhalation, the kidney becomes the principal target of toxicity, leading to proteinuria and a decrease in glomerular filtration rate. An initial sign of kidney impairment is tubular dysfunction, marked by elevated levels of intracellular enzymes such as N-acetyl-glucosaminidase (NAG) and low-molecular-weight proteins like retinol binding protein, human complex-forming glycoprotein (pHC), and β2-microglobulin in the urine. High-molecular-weight proteins like albumin are found in larger concentrations in the urine at increasing exposure levels [50].

Chronically high cadmium exposure can harm glomeruli and lower glomerular filtration rate (GFR) through causing glomerular damage. Kidney injury causes disruptions in calcium metabolism, which leads to an increase in the occurrence of kidney stones in cadmium workers. The harm to the kidneys is typically irreversible after exposure ends. The initial level of retinol binding protein is the primary determinant of tubular proteinuria reversibility, while urine cadmium levels and the duration since exposure cessation do not exhibit any statistically significant influence [50].

g) Central nervous system

Although cadmium seldom crosses the blood–brain barrier, persistent exposure can cause a variety of CNS symptoms, including olfactory impairment [50].

The detailed information in Table 5 on cadmium includes its sources, modes of exposure, mechanisms of poisoning, effects of toxicity, onset and persistence of symptoms, methods for poisoning detection, normal and reference values, lethal dose, lethal time, and related symptoms.

Table 1.5: Cadmium Toxicity

Particular	Details
About	Denoted by the symbol "Cd" Atomic Number: 48 Soft, can be cut with a knife, malleable, ductile, bluish-white, divalent metal
Source	Environment (from natural sources and processes e.g., erosion and abrasion of rocks and soils, forest fires, volcanic eruptions and in water). By-product of zinc concentrates Batteries Manures and pesticides Food such as liver, mushrooms, shellfish, mussels, cocoa powder, and dried seaweed.
Routes of exposure	Environmental Pollution (Contaminated Food, water) Smoking Occupational exposure (through inhalation of fine dust and fumes)
Poisoning	Ingestion Inhalation
Impact of toxicity	Stimulates production of inflammatory cytokines and down-regulates the protective function of nitric oxide formation.
Onset and duration of action	The onset of symptoms may be delayed for two to four hours after exposure. Biological half-time of cadmium is extremely long. In human kidney half-life ranges between 6 and 38 years and in human liver between 4 and 19 years.
Detection of poisoning	Blood

Normal and Reference Value	Matrix	Normal	Toxic
	Blood	<1µg/L	>1µg/L

Fatal Dose and Fatal Period	An exposure of 2,500 minutes X mg/m^3 of cadmium in air would be fatal. Ingestion of >100 mg of its soluble salt can be lethal. Time to death after cadmium iodide ingestion is 7 days and, 33 hours after ingestion of the cadmium chloride.
Symptoms	Overexposure may cause fatigue, headaches, nausea, vomiting, abdominal cramps, diarrhoea, and fever. In addition, progressive loss of lung function (emphysema), abnormal buildup of fluid within the lungs (pulmonary edema), and breathlessness (dyspnea) may also be present. In some cases, affected individuals may exhibit increased salivation; yellowing of the teeth; an unusually rapid heartbeat (tachycardia); low levels of iron within the red blood cells (anaemia); bluish discoloration (cyanosis) of the skin and mucous membranes due to insufficient oxygen supply to these tissues; and/or an impaired sense of smell (anosmia).

1.2.6 COBALT TOXICITY

Cobalt poisoning can have a number of impacts, including cardiovascular problems, neurological problems, blood system problems, immune system problems, skin problems, eye problems, gastrointestinal problems, and problems with the reproductive system [51-54].

a) Cardiovascular

Over an extended period, regular consumption of beer containing cobalt sulphate as a stabilizer, with an average intake ranging from 0.04mgCo/kg/day to 0.140mgCo/kg/day, may lead to cardiomyopathy in beer enthusiasts. Cobalt builds up in the heart tissues, causing cardiomyopathy. Carotid body chemoreceptors imitate hypoxia as a result of this buildup. GI symptoms are among the first symptoms of this illness, which later lead to heart issues. Apart from these impacts, it leads to heart failure, an enlarged left ventricle, pericardial effusion, cardiogenic shock, and pathological changes in the myocardium, such as enlarged muscle fibers and increased interstitial tissue growth [51-53].

b) Haematological effects

Since cobalt acts at least twice in the biosynthetic route, these consequences result from the cessation of heme synthesis in vivo. Cobalt protoporphyrin is generated in place of heme. Heme oxygenase is induced by cobalt, which may result in the oxidation of heme in numerous organs. Heme-containing proteins are also affected by cobalt, which may cause an increase in EPO (erythropoietin) [51-53].

c) Neurological

Cobalt buildup causes the creation of free radicals, which subsequently causes neurodegeneration. The visual cortex 8 will undergo structural alterations as a result of prolonged exposure. Additionally, it causes changed mental status, convulsions, vertigo, and memory loss [54].

d) Hepatic effects

Liver issues occur when cobalt levels exceed or equal 0.014 mg/kg/day. The mentioned factors associated with the condition involve elevated levels of blood bilirubin and central hepatic necrosis, alongside markers such as creatinine phosphokinase, aspartate

transaminase, lactate dehydrogenase, alanine transaminase, isocratic dehydrogenase, aldolase, and ornithine carbamyl transferase. Measures to reduce similarity are applied to the best extent possible. [51-53].

Cobalt, its sources, routes of exposure, poisoning mechanisms, the effects of toxicity, the onset and duration of symptoms, methods for detecting poisoning, normal and reference values, the fatal dose, the fatal time, and accompanying symptoms are all covered in detail in Table 6.

Table 1.6: Cobalt Toxicity

Particular	Details		
About	Denoted by the symbol "Co" Atomic Number: 27 A ferromagnetic metal		
Source	Implants. Batteries (Lithium cobalt oxide). Colouring pigments and dyes (as cobalt blue). Magnets.		
Routes of exposure	Environmental Pollution (Contaminated water, Air) Prosthetics Medicines (due to the overdose of vitamin B12 supplements). Occupational exposure (workers working in refining, mining, smelting, tools making by grinding and cutting using cobalt metal or compounds of cobalt).		
Poisoning	Ingestion		
Impact of toxicity	Causes inhibition of major enzymes of mitochondrial oxidative phosphorylation, inhibition of thyroid iodinase and direct cytotoxicity. Organs which are exposed to the toxicity of cobalt includes liver, lungs, pancreas, cardiovascular system and kidneys		
Onset and duration of action	The symptoms of cobalt toxicity depend upon the duration and amount of exposure. However, it may take weeks to months for the symptoms to appear, depending upon the dose and compound of cobalt until one swallow large amount at once.		
Detection of poisoning	Urine, blood, serum		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	0.08 to 0.50 µg/L	5 µg/L
	Urine	0.3 to 0.7 µg/L	1- 5.1 µg/L
	Serum	60 µg/L	>60 µg/L
Fatal Dose and Fatal Period	Intake of 250mg/Kg to 300mg/Kg will results in the symptoms of cobalt toxicity. More than 300mg/Kg of body weight will lead to severe poisoning within few weeks of intake56.		
Symptoms	Symptoms or clinical appearances depends on the type, time of exposure and amount of dose. The most threatening toxicity occurs due to breathing of high doses of cobalt, which generally occurs to people residing in industrial areas. It may lead to chronic lung problems like asthma, shortness of breath etc. Nausea, Vomiting, Diarrhoea, Allergic dermatitis, Blood in faeces, Heavy breathing are the symptoms of acute cobalt poisoning. However, chronic cobalt poisoning may cause Cardiomyopathy (enlarged and floppy heart, difficulty in pumping blood), Deafness, Thyroid problems, Vision problems, Ringing in ears, Nerve problems.		

1.2.7 IRON TOXICITY

There are two types of iron toxicity: corrosive and cellular. A direct caustic lesion to the gastrointestinal mucosa brought on by ingested iron can result in nausea, vomiting, abdominal pain, and diarrhoea. Hypovolemia can be brought on by significant fluid and blood loss. Hematemesis, perforation, and peritonitis can result from haemorrhagic necrosis of the gastrointestinal mucosa. Iron disrupts cellular metabolism in the heart, liver, and central nervous system. Cells can contain free iron, which gathers in the mitochondria. As a result, oxidative phosphorylation is disrupted, lipid peroxidation is catalysed, free radicals are produced, and cell death results [55-59].

a) Central Nervous System

According to Fenton chemistry, the buildup of iron in cells contributes significantly to the onset of neurodegeneration by encouraging the production of free radicals. In the presence of hydrogen peroxide (H_2O_2) resulting from oxidative stress, a chemical reaction occurs that generates hydroxide radicals and converts ferrous iron (Fe^{2+}) to ferric iron (Fe^{3+}). Neurotoxicity arises due to a reduction in cellular antioxidants, which hinders their ability to neutralize hydroxide radicals. Excessive iron exposure is a contributing factor to neurodegenerative conditions like Parkinson's and Alzheimer's disease, as it leads to elevated levels of oxidative stress in the brain [55-59].

b) Cardiovascular system

The primary cause of cardiomyocyte damage is believed to be the iron-induced creation of harmful reactive oxygen species. This initiates a pathological sequence leading to apoptosis, fibrosis, and eventually heart failure [55-59].

c) Reproductive system

Women who have excessive iron levels may experience ovarian dysfunction syndrome, which can lead to reduced ovarian reserve and lower chances of spontaneous pregnancy due to suboptimal hormonal stimulation response. Moreover, an increased intake of iron can negatively impact male fertility, resulting in faulty spermatogenesis, reduced libido, and oxidative damage to the testicular tissue and sperm cells [55-59].

The more details about Iron, its sources, routes of exposure, poisoning mechanisms, the effects of toxicity, the onset and duration of symptoms, poisoning detection techniques,

normal and reference values, the fatal dose, the fatal period, and accompanying symptoms are mentioned in table 7.

Table 1.7: Iron Toxicity

Particular	Details		
About	Denoted by the symbol "Fe" Atomic Number: 26 Very crucial component of different metalloproteins and plays a crucial role like oxygen sensing and transport, electron transfer and catalysis		
Source	Supplementary Foods/ Drug Toys and Sports goods Cast Iron		
Routes of exposure	Environmental Pollution (Contaminated water, Air) Iron dust and fumes from welding, smelting, grinding Medicines (excessive use of Iron supplement)		
Poisoning	Ingestion Inhalation		
Impact of toxicity	Gastrointestinal epithelium, cardiovascular system, and liver		
Onset and duration of action	Symptoms of iron poisoning are evident mostly after 6 hours of administration through oral route.		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	500-2000µg/l	>3500 µg/l
	Urine	65µg/g	>65 µg/g
Fatal Dose and Fatal Period	Ingestion of 20 mg/kg to 60 mg/kg results in moderate symptoms. Ingestion of more than 60 mg/kg can cause severe toxicity and lead to morbidity and mortality within 6 hours of ingestion.		
Symptoms	Clinical appearances/systems in case of iron poisoning depend upon different forms of iron and the number of doses taken. The patient may feel nausea, vomiting, Gastrointestinal bleeding led to hematemesis or bloody diarrhoea, local corrosion leads to the formation of gastric antral and pyloric strictures due to acute iron poisonings. In case of chronic iron poisoning, Myocardial dysfunction, Heart failure, Lactic acidosis, Cardiogenic shock leads to hypoperfusion, Hepatic necrosis, Abnormalities in coagulations and inhibitory effects on clotting factors may happen.		

1.2.8 LEAD TOXICITY

The central nervous system, renal system, cardiovascular system, and reproductive system are the key organ systems that lead negatively affects. Because of its lipid solubility, lead in its organic state poses a greater risk compared to its inorganic form [60-69].

a) Central Nervous System

Lead affects the central and peripheral neurological systems, particularly the motor nerves [65]. Children are more affected by peripheral nervous system impacts than adults are by central nervous system effects [66]. Hippocampus cells are harmed by lead [67]. Lead blocks NMDA receptors, which prevents the release of neurotransmitters, primarily glutamate (essential for many processes, including learning). Additionally, it disrupts the organisation of ion channels and the development of synapses in the cerebral cortex [68]. It leads to a reduction in neuron count and hinders neuronal development, resulting in the degeneration of nerve cell axons and the loss of their protective myelin coatings.

Children's blood lead levels have been linked to declines in intellect, short-term memory, fine motor abilities, nonverbal reasoning, attention, reading and math aptitude, emotional control, and social engagement [66]. Research suggests that there is a correlation between lower IQ and behavioral problems such as aggression, and blood lead levels below 10g/dL. Developmental problems are a possibility when blood lead levels are above 10g/dL. Children's IQs drop by roughly 2-4 points for every 1g/dL increase in blood lead levels between 5 and 35g/dL. Neuropsychiatric conditions like attention deficit hyperactivity disorder and antisocial behaviour are also linked to lead exposure in young children [66].

MRI scans of lead-exposed adults' brains reveal reduced volume, particularly in the prefrontal cortex [70]. Adults with high blood lead levels also have lower cognitive function and psychological symptoms such anxiety and depression [71-72]. Blood lead levels ranging from 20 to 50g/dL were found to be associated with neuro-cognitive impairments among a considerable number of inorganic lead workers in Korea [73]. According to research, a rise in blood lead levels from 50 to 100g/dL has been linked to a persistent and perhaps irreversible impairment of CNS function [74].

Children who have been exposed to tetra ethyl lead are more likely to develop lead encephalopathy. It shows symptoms including nausea, agitation, headaches, sleeplessness, hallucinations, convulsions, coma, and death. Typically, it is irreversible [75].

Peripheral nervous system involvement occurs late in the poisoning process, and in adults more so. The nerve deteriorates, and the muscles that are innervated shrink. It primarily affects muscles that are prone to tiredness. Wrist drop results from primarily using the wrist extensors. In addition, the deltoid, biceps, and anterior tibial muscles all contribute to foot drop. Occasionally, the intrinsic muscles in the hands, feet, and eyes are also affected.

b) Renal System

Any amount of blood lead might result in kidney damage. Lead's toxic effects result in nephropathy and may affect proximal tubule function, which can induce Fanconi syndrome. Lead poisoning prevents urate excretion and increases the risk of developing gout. "Saturnine gout" is the name given to this ailment [76].

c) Cardiovascular System

Because lead exposure causes vascular constriction, high blood pressure is linked to it. Heart rate variability, persistent arteriolar degeneration, coronary heart disease, and stroke mortality are also associated with it [77]. On days when ozone and fine particle concentrations are greater in the air, individuals who have encountered elevated levels of lead may face a heightened vulnerability to cardiac autonomic dysfunction.

Initially microcytic and hypochromic, lead-induced anaemia frequently becomes normochromic and normocytic in the chronic stage. Basophilic stippling in red blood cells is caused by RNA and ribosome accumulation. Because 5 pyramidine neucleotidase is inhibited, the cells are unable to dispose of the byproducts of RNA breakdown, which leads to a buildup of ribosomes [78].

d) Reproductive System

Both the male and female reproductive systems are impacted by lead. Men's sperm counts decline above 40g/dL, and changes to sperm volume, motility, and morphology take place. Elevated blood lead levels during pregnancy can potentially lead to

miscarriages occurring between the third and sixth months of gestation. Moreover, it may result in adverse outcomes such as low birth weight, preterm birth, and developmental challenges in children. The placenta is permeable to lead. When lead from the mother's bones is mobilised due to metabolic processes, a foetus gets poisoned even while it is still inside the mother. Breast milk is another excretion site. In general, blood lead levels in mothers and newborns are comparable. Increased calcium consumption during pregnancy may assist to reduce this occurrence [60,62, 64,66,69,72,75].

In-depth information about lead, its sources, routes of exposure, poisoning mechanisms, effects of toxicity, onset and persistence of symptoms, methods for detecting poisoning, normal and reference values, lethal dose, lethal time, and related symptoms is provided in Table 8.

Table 1.8: Lead Toxicity

Particular	Details		
About	Denoted by the symbol "Pb" Atomic Number: 82 Ductile, dense, very soft, and has poor electrical conductivity		
Source	Ores (e.g., Galena (PbS), Cerussite ($PbCO_3$) and Anglesite (PbSO4) Batteries, metal products (pipes and solder) and ammunition. Paints		
Routes of exposure	Environmental Pollution (Contaminated water, Air) Occupational exposure (Auto repair works, battery making, glass manufacture, mining, plastics manufacture, ship building or ship breaking, smelting & refining, steel, welding & cutting, plumbing, pottery, printing, rubber industry, soldering (electronics)) Paints, Ceramicware, Cosmetics, Medicines, Pencils, Toys		
Poisoning	Ingestion Inhalation Dermal		
Impact of toxicity	Interferes with the activity of enzymes, delta-aminolevulinic acid dehydratase (ALAD), and ferrochelatase of heme synthesis. ALAD converts delta- aminolevulinic acid to porphobilinogen. Lead interference with ALAD leads to accumulation of aminolevulinic acid, which is harmful to neurons		
Onset and duration of action	The time elapsing between the intake of lead and appearance of symptoms varies depending on individual and duration of lead exposure.		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	1.5µg/dl	>20µg/dl
	Urine	0.667µg/L	>25µg/dl
Fatal Dose and Fatal Period	The average lethal dose is said to be 10g/70kg for most lead salts, while it is 20g/70kg for Lead acetate (Pillay, 2005) and 100mg/kg for tetraethyl lead. Fatal period is variable. The large amount of lead can be fatal in 1-2 days while small amounts, taken for a long period, may not be detrimental.		
Symptoms	Acute lead poisoning is rare. Only symptoms are metallic taste, dry throat, abdominal pain, nausea, vomiting, peripheral circulatory collapse, paraesthesias, depression, coma and death. In children, there may be cerebellar ataxia. Exposure to highly concentrated lead fumes can produce metal fume fever, an influenza-like reaction characterized by an acute self-limited neutrophilic alveolitis.		

1.2.9 MERCURY TOXICITY

The central nervous system and the renal system are the two organ systems that are most negatively impacted by mercury intoxication. Additionally impacted are mucous membranes. In contrast to vaporised mercury and mercury (II) compounds, metallic mercury and mercury (I) compounds are poisonous. Occupational exposure to mercury vapor and the presence of mercury in amalgam dental fillings or its release during their removal can lead to elevated levels of mercury in both blood and plasma [79-85]. The following are some general impacts of mercury poisoning on humans:

• Peripheral vision impairment

• Coordination issues

• Speech, hearing, and walking impairment

• Cognitive problems and alterations in nerve responses.

• Muscle atrophy.

• Insomnia.

• Headaches

• Emotional alterations

• Sensational disturbances

a) Central Nervous System

Both elemental and methyl mercury pose dangers to both the central and peripheral nervous systems. Complete brain damage results from mercury exposure at high levels. Anger, weariness, behavioural changes, headaches, hearing and cognitive impairment, dysarthria, lack of coordination, hallucinations, and death are the consequences. neurological signs such the Erethism and Hatter's Shake tremor. Intentional tremor that first affects the wrists, tongue, and then the legs characterise the Hatters Shake tremor. While erethism alters personality through shyness, impatience, memory loss, and insomnia. Symptoms of mercury exposure include ataxia, slurred speech, constricted visual fields, sensory disturbance, blindness, deafness, involuntary movements, mental retardation, coma, and death [79-80,83].

b) Renal System

Elemental mercury has been found to target the kidneys, and long-term exposures have been noted. Tubular dysfunction can also brought on by prolonged occupational exposure [79-80,83].

c) Cardiovascular

Mercury toxicity affects the cardiovascular system by causing hypertension and endothelial function problems. Cardiotoxicity is caused by inorganic mercury. Frequent fish consumption causes an increase. Atherosclerotic disease development and mercury levels are related [81].

d) Reproductive system

Both the male and female reproductive systems are impacted by mercury. It causes sperm motility, viability, malfunction, and DNA breakage in spermatozoa in males. Women commonly experience irregular menstrual cycles. Mercury vapour exposure in dental assistants has been linked to lower fertility. Developmental abnormalities and cerebral palsy were present in the offspring of women who had consumed methyl mercury [83,85].

On Mercury, its sources, routes of exposure, poisoning mechanisms, the effects of toxicity, the onset and duration of symptoms, methods for poisoning detection, normal and reference values, the lethal dose, the fatal time, and accompanying symptoms, detailed information is provided in Table 9.

Table 1.9: Mercury Toxicity

Particular	Details		
About	Denoted by the symbol "Hg" Atomic Number: 80 Quicksilver, liquid at standard conditions of temperature and pressure		
Source	Fish and shellfish (in the form of methylmercury which is highly toxic). Dental fillings Fluorescent light bulbs. Preservatives, Medicines, Batteries		
Routes of exposure	Environmental Pollution (Contaminated Food, water, Air) Occupational exposure (amalgam makers, barometer makers, chemical laboratory workers, Chlor-alkali petrochemical workers, dentists, fluorescent lamp markers, gold and silver extractors, insecticide makers, Hg miner workers and thermometer makers) Cosmetics		
Poisoning	Ingestion Inhalation Dermal		
Impact of toxicity	Malfunctioning of nervous system, kidney, cardiovascular and reproductive system		
Onset and duration of action	The symptoms appear in a day to weeks after exposure however higher the dose, symptoms may occur the earlier.		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood-plasma/ Serum	1.5 - 2.0 µg/L	50-200 µg/L
	Urine	< 10 µg/L	> 20 µg/L
Fatal Dose and Fatal Period	The fatal dose of mercury is 1-2 grams in terms of sublimate. For an adult it ranges between 14-57 mg/kg. Organic form of mercury constitutes 20-60 mg/kg to be toxic. Death may occur within few hours but is usually delayed for 3-5 days.		
Symptoms	Clinical appearance/systems in case of mercury poison will depend on different form of mercury and doses taken. In case of acute poisoning the symptoms are choking sensation in throat, difficulty in breathing, corroded and swollen tongue greyish white in colour, burning sensation in mouth to abdomen followed by nausea and vomiting, scanty urine containing blood. Chronic mercury poisoning symptoms are diarrhoea & vomiting, digestive disturbances & nausea, foul breath, swollen & painful salivary glands with inflamed gums, nephritis, brownish blue line at the junction of gums and teeth, brownish reflex formed on the anterior lens of both eyes.		

1.2.10 TIN TOXICITY

According to studies, tin in its metallic state is not very harmful because the body has a difficult time absorbing it. Acute ingestion of tin-containing inorganic compounds, however, can have certain negative side effects, including nausea, vomiting, skin and eye irritation, and different gastrointestinal problems. It is well known that tin's organic compounds, such as $(CH_3)_3Sn$ (trimethyltin) and $(C_2H_5)_3Sn$ (triethyltin), can affect an animal's neurological system and immunological system. Most studies examining the impact of tin and its compounds on human health have primarily been conducted on animals, resulting in a limited availability of experimental data [86-91].

a) Respiratory effects

Long-term stannic oxide dust exposure is known to cause stannosis in people because it deposits in the lungs. It is well known that butyltin oxide irritates the upper respiratory tract, resulting in symptoms including chest pain and tightness. With continued exposure, breathing problems and coughing may develop. In several species, including rats and rabbits, inflammatory alterations such as bronchitis, lung edoema, and hyperemia have been seen [89].

b) Gastrointestinal effects

Trimethyltin chloride and tributyltin oxide are believed to cause severe nausea, vomiting, and diarrhoea, as well as substernal and epigastric burning, according to studies. Even two to three months after exposure, constant pain and burning may still exist [86,89].

c) Renal effects

Numerous animal experiments show proximal tubule deterioration and significant levels of tin in the urine. Additional necropsy investigations pointed to collecting tubules and glomeruli injury. Along with significant renal tubular epithelial edoema, there was also significant kidney congestion [89-90].

d) Neurological effects

Numerous studies demonstrate that chronic exposure to organotin chemicals in humans causes neurobehavioral alterations, with typical side effects including headache, memory loss, hearing loss, cognitive impairment, and neuropsychiatric behaviour. In some severe cases, epileptic seizures have also been reported. In certain cases, myelin degradation and brain and spinal cord swelling are visible [89-91].

e) Reproductive effects

Pregnancy rates may be decreased by acute and intermediate exposure to chemicals like tributyltin bromide and dibutyltin dibromide, according to experimental research on rats. The female reproductive system also showed some damage, but these changes appeared to be reversible after the exposure was reduced [90-91].

Table 10 contains thorough information on tin, including its sources, routes of exposure, mechanisms of poisoning, effects of toxicity, the onset and duration of symptoms, methods for poisoning detection, normal and reference values, the lethal dose, the fatal time, and associated symptoms.

Table 1.10: Tin Toxicity

Particular	Details		
About	Denoted by the symbol "Sn" Atomic Number: 50 Silvery metal		
Source	Canned food and beverages Tin industries, Mining, Soil (due to weathering process) Biocide, Antifouling Paints		
Routes of exposure	Consumption of canned Food and beverages Inhalation (Near landfills or industries dealing with the manufacturing of tin products).		
Poisoning	Ingestion		
Impact of toxicity	Cause genotoxicity by damaging the DNA and causing chromosomal aberrations		
Onset and duration of action	In the case of tin poisoning appearance of symptoms depends upon the dose of exposure. The occurrence of symptoms appears depending upon the form of the tin compound and its mode of exposure.		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood	< 0.005 µg/mL	> 0.009 µg/ml
	Urine	1 – 20 µg/L	> 30 µg/ml
Fatal Dose and Fatal Period	The fatal dosage of tin varies greatly depending upon the compound of tin and its mode of exposure. According to the World Health Organization, the intake of 200mg/kg in salt is fatal in humans (9. Feng G, Lu X, Lu Q, 2010). The fatal period varies a lot depending upon several factors, in general, it can be estimated as an incubation period of 15 minutes to 14 hours. Triphenyltin acetate if consumed orally in dosage 260 mg/kg is fatal in humans. Triethyltin if consumed about 90 mg/day for 7-8 days is highly toxic and lethal.		
Symptoms	Clinical appearances and symptoms in case of tin poisoning depends upon the amount of substance, form of tin (organic/inorganic), mode of exposure and duration of the exposure. Acute tins toxicity causes gastrointestinal (Nausea, Abdominal pain and burning, vomiting, diarrhoea, irritation in oesophagus) and systemic effects (lacrimation & severe conjunctivitis, upper respiratory tract irritation, irritants to the skin and mucous membranes, headache, subacute lesions). Chronic tin toxicity symptoms are Proximal tubule degeneration, Congestion of kidney and swelling of renal tubules, Memory loss, Cognitive dysfunction, Epileptic seizures.		

1.2.11 THALLIUM TOXICITY

a) Acute thallium poisoning

When thallium salt is consumed, symptoms take a rather lengthy time to manifest. Within 12 to 24 hours, digestive disorders such as appetite loss, nausea, vomiting, abdominal pain, diarrhoea, or constipation start to occur. Neurological symptoms such as hallucinations, convulsions, delirium, muscle weakness, and tingling sensations in the limbs may manifest after more than five days. The lower extremities' extraordinary sensitivity to touch is one of the distinguishing characteristics. It's possible to experience vasomotor problems including puffiness in the lips, cheeks, and eyelids [92-101].

b) Chronic thallium poisoning

The signs and symptoms of ongoing intoxication are milder. Some eye abnormalities can include retrobulbar neuritis resulting in impaired vision, color vision problems, and, in rare cases, ophthalmoplegia, ptosis, strabismus, and optic atrophy. Neural symptoms may manifest as ascending paralysis, psychosis, insomnia, anxiety, limb discomfort, and weakness. Cardiac symptoms may involve angina, arrhythmias, tachycardia, and hypertension. Digestive and hepatorenal symptoms could include colitis, severe hemorrhagic gastroenteritis, albuminuria, haematuria, and fatty infiltration of the liver [92,95,97-101].

Keratinization of the epithelium, horizontal cross lines/ white bands on fingernails (Mee's lines); petechiae, scaly erythema, ecchymosis and are the additional signs and symptoms. After 10 days of ingesting thallium salts, hair loss begins in large tufts and finishes in 30 days with complete baldness. Alopecia typically only affects the outer two thirds of the brows. Usually, facial hair and axillary hair are unharmed [92,95,97-101].

In-depth information is given in Table 11 on thallium, its sources, routes of exposure, poisoning mechanisms, the consequences of toxicity, the onset and duration of symptoms, methods for poisoning detection, normal and reference values, the lethal dose, the fatal time, and associated symptoms.

Table 1.11: Thallium Toxicity

Particular	Details		
About	Denoted by the symbol "Th" Atomic Number: 81 A soft metal and resembles tin		
Source	Glass Photoelectric cells Rodenticides and Fungicides.		
Routes of exposure	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.		
Poisoning	Ingestion Inhalation Dermal		
Impact of toxicity	Interference with K^+ based biological processes		
Onset and duration of action	Symptoms and signs are milder in chronic intoxication. The eye findings include retrobulbar neuritis with reduction in vision, disturbed colour vision and occasionally ophthalmoplegia, ptosis, strabismus, and optic atrophy		
Detection of poisoning	Urine, blood		
Normal and Reference Value	**Matrix**	**Normal**	**Toxic**
	Blood-plasma/ Serum	< 5 µg/mL	10-15mg/kg
	Urine	< 5 µg/mL	10-15mg/kg
Fatal Dose and Fatal Period	Generally accepted limit of thallium content in arable soil is 1 mg/kg. World-wide limit of thallium content for crops is 0.03-0.3 mg/kg (dry mass) and for land plants is 0.8-1 mg/kg (dry mass). The estimated lethal dose of thallium salt in human is 10-15 mg/kg body weight. The documented minimum lethal dose of thallium is 0.8 g. The fatal period ranges between 5-7 days. In acute poisoning, death may result within 48 hours.		
Symptoms	Following the ingestion of thallium salt, symptoms appear after a relatively long latent period. Gastrointestinal disturbances begin within 12-24 hours, which includes loss of appetite, nausea, vomiting, abdominal pain, diarrhoea, or constipation. Neurological symptoms may take more than 5 days to develop, which includes hallucinations, convulsions, delirium, muscular weakness, and tingling pain in the extremities. One of the characteristic features is the extreme sensitivity of the lower extremities to touch. The vasomotor disturbances such as puffiness of eyelids, cheeks and lips may occur. Symptoms and signs are milder in chronic intoxication.		

1.3. MECHANISM OF TOXICITY

1.3.1 Aluminium

The mechanism comprises focusing on the body's primary organs, including the lungs, central nervous system, and bones. In biological systems of the body, it is known to rival with cations, remarkably magnesium for the binding of transferrin and citrate. Through its irreversible binding to nuclear components, it may have an impact on calcium availability via influencing secondary messenger systems. It might prevent the synthesis of neuronal microtubules. Because it prevents dietary phosphorus from being absorbed, it damages bones and results in rickets and osteomalacia [42].

1.3.2 Antimony:

Compounds containing antimony are slowly absorbed by the digestive system. It is supplied to the liver, bones, kidney, and other highly vascularized organs when consumed or taken orally. Antimony poisoning is caused via a mechanism involving the distribution of thiol proteins that bind to sulphydryl groups. It has been discovered to interact with the erythrocyte membrane, impairing the normal function of haemoglobin. Antimony is thought to be hazardous because it combines with a number of enzymes, which act as cells' organic catalysts and interfere with metabolism [44].

1.3.3 Arsenic

All arsenic compounds have both immediate and long-distance impacts. Early on, the toxin only has a localised effect and induces severe irritability. The poison's remote action of depressing the nervous system is added with the poison's absorption. An arsenic or arsenic-containing compound's toxicity is influenced by its valence state, organic or inorganic form, and physical characteristics like absorption and elimination. Arsenic, whether organic or inorganic, is thought to be more harmful. Sub-acute poisoning happens when little quantities are eaten or given sporadically over time, whereas acute poisoning can be brought on by ingesting a big dose at once and is enough to trigger dramatic symptoms [46].

1.3.4 Bismuth

When bismuth nephrotoxicity is described following exposure to medications containing this element, negative health effects are seen. Intranuclear inclusion bodies are created by bismuth in renal proximal tubule cells, and X-ray microanalysis has demonstrated that these inclusion bodies consist of bismuth. Additionally, it has been demonstrated to stimulate the production of metallothionein i.e. metal-binding protein. The interaction of bismuth with the renal tubule cell membrane has been observed to cause necrosis rather than apoptosis to kill cells, which is the most plausible mechanism. However, it was also discovered that several genes' regulation had changed [47].

1.3.5 Cadmium

Cadmium exacerbates oxygen stress by catalyzing the generation of reactive oxygen species, leading to reduced levels of glutathione and protein-bound sulfhydryl groups, while also elevating lipid peroxidation. Moreover, it hinders the protective impact of nitric oxide synthesis and promotes the creation of inflammatory cytokines [48].

There is some evidence that cadmium is genotoxic to animals and in vitro cultured cells, but there is less proof that it is genotoxic to humans. In cultured mammalian cells, cadmium results in mutations, DNA strand breakage, chromosomal damage, cell transformation, and impairment of the DNA repair mechanism. Signal transmission and gene expression are affected by cadmium [49].

Animals are susceptible to cancer when exposed to cadmium metal and its compounds, including cadmium chloride, oxide, sulphate, and sulphide. Increased rates of lung, prostate, and testicular cancer in animals have been reported. According to epidemiological research, personnel subjected to cadmium and its compounds have a marginally increased relative chance of developing lung cancer [50].

Cadmium sulphide compounds are less hazardous than the substantially more soluble cadmium carbonate compounds, cadmium oxide fume, cadmium chloride and in acute exposures. This discrepancy is mostly caused by the more soluble chemicals' longer lung absorption and retention periods. Muco-ciliary action removes less soluble

pigments. The toxicity, however, does not always link with solubility, and cadmium oxide may be more soluble in biological fluids than in water [49-50].

1.3.6 Cobalt

Once cobalt enters the bloodstream, it forms complexes with blood plasma proteins and spreads to various tissues, leading to the generation of harmful reactive oxygen species that can inflict damage on the body's organs. The oxidant species that cause lipid peroxidation can be produced in significant amounts by some hard metal particles. One notable aspect of it is its ability to generate free radicals, known for their potential to harm DNA. The calcium channels may be blocked by soluble cobalt. In rare instances, it results in the inhibition of thyroid iodinase, key mitochondrial oxidative phosphorylation enzymes, and direct cytotoxicity. Cobalt toxicity can affect the liver, lungs, pancreas, cardiovascular system, and kidneys, among other organs [53].

1.3.7 Iron

In aerobic environments, iron possesses the ability to generate oxygen free radicals, which can lead to cellular harm through the excessive production of reactive oxygen species, including superoxide and hydroxyl ions. Several organs, including the liver, cardiovascular system, and gastrointestinal epithelium, are exposed to elevated levels of iron. These increased iron concentrations are associated with five recognized clinical phases: Gastrointestinal Toxicity, Relative Stability, Circulatory Shock and Acidosis, Hepatotoxicity, and Gastrointestinal Scarring [59].

1.3.8 Lead

According to research, lead plays no physiological role in the body. Lead's primary toxicological mechanism involves interfering with the activity of several enzymes by attaching to sulfhydryl groups. As cofactors for numerous enzymes, it interacts with and displaces important metals. Lead interacts with a number of important metals, including calcium, zinc, and iron [60-63].

The key enzymes that are affected are ferrochelatase of heme production and delta-aminolevulinic acid dehydratase (ALAD). Delta- aminolevulinic acid is changed into porphobilinogen via ALAD. Aminolevulinic acid builds up as a result of lead interference with ALAD, which is bad for neurons. Protoporphyrin and Fe2+ are

brought together by ferrochelatase to produce heme. Due to its interference, anaemia develops and zinc protoporphyrin is produced [60,65,67].

Lead generates reactive free radicals that harm cell membranes and DNA. Additionally, it disrupts the transcription of DNA and the function of several enzymes involved in vitamin D production and cell membrane integrity. According to some research, this mechanism may shorten RBC lifespan and produce anaemia by damaging them. Lead poses a threat to the developing immune system, leading to an excessive production of inflammatory proteins, which increases the likelihood of childhood asthma. Moreover, it negatively impacts immune cell activity, specifically polymorphonuclear leukocytes. Collagen formation is disrupted by lead, affecting blood vessel permeability, and it interferes with the metabolism of bones and teeth. Additionally, this toxic element promotes intracellular accumulation and hinders the regular calcium metabolism in cells [68-75].

1.3.9 Mercury

Adverse health effects are observed when mercury binds to protein. Malfunctioning of nervous system, kidney, cardiovascular and reproductive system are observed. Cysteine contains sulfhydryl groups Usually mercury binds to sulfhydryl groups within proteins in the body and forms crosslinks or disulfide bridges. Methyl mercury exposure leads to elevated levels of antibodies targeting myelin basic protein (MBP), an essential component in neuron myelination. Similar effects are observed for glial fibrillary acidic protein (GFAP), crucial for the central nervous system (CNS). Consequently, this exposure contributes to the degradation of neural myelin and leads to a decline in CNS function. Mercury binds to sulphydryl groups and inactivates key enzymes involved in preventing oxidative damage. Alkyl are lipophilic there by binds to lipid rich tissues usually neurons [79-81,93].

1.3.10 Tin

Only a few research have suggested that alkylcobalamines can be used to bioalkylate tin via reductive Cobalt-Carbon bond cleavage. Despite the fact that there is no current direct experimental study on the subject. It has been demonstrated that some tin salts, such as stannous chloride, are genotoxic because they alter chromosomal structure and

damage DNA. Reactive oxygen species are known to be created when stannous ions decrease hydrogen peroxide [89].

1.3.11 Thallium

Basically, interference with K^+ based cellular processes is what causes thallium toxicity. The interference arises due to the closely matched ionic radii of K^+ and Tl^+ ions, measuring 1.33 and 1.44 angstroms, respectively. Research has shown that Tl^+ can effectively substitute physiological K^+ in activating several monovalent cation-activated enzymes. Notably, Tl^+ has been observed to activate enzymes like the ATPase enzyme in the Na^+-K^+ exchange pump and aldehyde dehydrogenase. When compared to K^+, Tl^+ interacts with ribosomes more effectively. Muscle fibres cannot discriminate between Tl^+ and K^+ in low Tl^+ concentrations [96-97].

A high thallous ion concentration in the blood causes the erythrocytes to agglutinate, lyse, and collect within them. Hypoacidity, fatty degeneration, inflammation, and swelling in both central and peripheral nerve tissue are among the various organs impacted by Thallium exposure. In non-fatal cases, Thallium can accumulate in hair follicles and nails. [97].

1.4. TOXIC METALS IN FOOD

Researchers report that foods sourced from contaminated locations may have greater quantities of toxic elements, mostly heavy metals from the periodic table. Depending on the route of exposure, any meal may get contaminated with a variety of harmful components. Vegetables, maize, and other commodities cultivated in specific regions of the nation are contaminated by high amounts of arsenic in waterways. From the many places where polluted water has been utilised to irrigate the crops, arsenic levels in rice, wheat, and vegetables have been found to be increased. Polluted coastal waters are often home to aquatic animals that have high concentrations of toxic substances such as arsenic and mercury. Furthermore, certain foods are more susceptible to contamination because of their matrix qualities and chemical makeup [102-103].

Each trace element has an impact on the food chain, whether it's on land or in the water. Although Hg is seldom found in the chain of terrestrial food. it is common in aquatic ones. Fish and shellfish are the primary sources of inorganic Hg poisoning in males, whereas vegetable meals often only create minute amounts of the element. Microorganisms in the aquatic environment, such as those found in fish and shellfish, are the primary source of methylmercury contamination [105]. Methylmercury to total Hg ratios in herbivorous fish is around 70% while in carnivorous fish is around 100% [106]. Predatory fish, particularly long-lived species like tuna, spur fish, sharks, whales, and dolphins, have been shown to have Hg concentrations up to 6g/g. Plant foods and vegetables often yield only trace amounts of Hg in dietary surveys from different nations [107-109]. For instance, no detectable Hg levels were found in beans sample, rice, potatoes, and olive oils obtained from Spanish resident markets. This element's bioavailability in soil and its ability to permeate plants is generally quite low because of its strong affinity for human compounds [110-111].

Due to its natural occurrence in water, arsenic, being a metalloid, constitutes a significant cause of arsenic poisoning among individuals [112]. Food and water contaminated with arsenic are most dangerous if they contain Inorganic arsenic. Produced crops and vegetables, as well as arsenic tainted water used in the irrigation of plants and food preparation, contain a significant level of arsenic. In terrestrial foods, arsenic levels are generally modest, with most tests reporting dry matter of less than

0.05 g/g as per European Commission. The exception to this rule is for rice, which typically holds between 0.03 and 1 g/g [113]. Inorganic arson is the most common species in plants (including rice) and drinking water. Inorganic arsenic accounted for around 90% of the total arsenic in rice [114-115]. Rice from India (West Bengal), Spain, and Sweden contains arsenic at high levels (up to 0.55g/g) [115-118]. Comparatively speaking, arsenic contamination in rice and other carbohydrates is disproportionately high.

Arsenic found in a variety of hazardous organic and inorganic plants, is often found in considerable concentrations in marine bodies. Over fifty compounds of arsenic have been discovered in marine creatures, the majority of which are common seafood species. This is one of the most important arsenic derivatives. It is significant (like dimethylarsinate [DMA]) or noteworthy because it's abundant (like algae-like arsenosugars) or toxic (like inorganic arsenic) [119]. A considerable number of arsenic compounds present in seafood are trimethylated and possess a structure akin to trimethylamine. There is less or no organic arsenic in fish than in inorganic forms (arsenobetane, arsenocholine, dimethysinic acid, monomethylarsonic acid and tetramethyl arsonic ion). Aquatic species have the most naturally occurring and abundant organo-As chemical, arsenobetain, which is both nontoxic and easily eliminated from the human body. In water-dwelling animals, arsenic concentrations may reach dangerously high levels, however most samples tested within the safe range of 5–100g/g dry matter [119]. Arsenic (inorganic) concentrations in fish and other marine foods are typically modest (0.1mg/kg) in comparison to the high total arsenic concentrations identified in the dietary studies conducted on seafood samples. As a result, seafood has no effect on the body's absorption of inorganic arsenic. Each little element has a significant impact on the whole food chain, whether it's on land or in the sea. Hg, for example, is not an important element in terrestrial food chains but is often found in aquatic creatures. Fish and shellfish are the principal sources of Hg exposure for humans, despite the fact that plant meals normally contain only negligible amounts of inorganic Hg. Aquatic microorganisms in organic methylmercury are the primary source of Hg contamination in fish and sea-food. Carnivorous peppers and herbivorous peppers were found to have methylmercury to total Hg ratios of 70% to 100% [120]. As high as six micrograms per gramme of Hg has been found in long-lived fish species

such as tuna, swordfish, sharks, whales and dolphins. Vegetable and veg tests often yield trace amounts of Hg, according to a variety of dietary surveys from throughout the world [108-109, 122]. No detectable Hg levels were found in samples of these foods procured from Spain's local markets [122]. Because of its strong affinity for humic chemicals, the material's bioavailability in soil and its ability to permeate plants are typically relatively limited [123-124].

Water is a crucial trigger for human arsenic. Inorganic form of arsenic is dangerous form observed in water and food. As a result of the enhanced arsenic concentration in cooked food and fresh produce, irrigation and food processing water have been polluted with arsenic [112]. Most samples contain a dry matter of less than 0.05g/g of arsenic in terrestrial food, which is typical (European Commission). Rice is an exception, since it typically contains between 0.03 and 1g/g [113]. Arsenic in drinking water and in inorganic foods (such as rice) are the most common contaminants. In comparison to other radioactive elements, rice and other grains are the most heavily contaminated.

Arsenic may be found in a variety of hazardous plants in marine environments, including inorganic and organic arsenic. Most seafood-producing marine species have more than 50 arsenic compounds. Some of the arsenic compounds are vital to life. DMA metabolites, for example, are substantial, whereas arsenosugars derived from algae. Inorganic arsenic is well-known for their toxicity or high concentrations of the metabolite [119]. With trimethylamine-like structures, a large number of arsenic species observed in fish may be classified as trimethyled arsenic. Compared to arsenic in fish, bio arsenic forms in fish are less hazardous and/or nearly nonoxidized (arsenobetaine, arsenocholine, dimethyllarsinic acid, monomethyl alpha, trimethylarsin oxides, and tetramethyl arsonium ion). Most commonly and profuse organo-arsenic chemical in aquatic animals is arsenobetain, which is non-toxic to humans and rapidly eliminated in their urine [119,125]. Compared to most samples, where arsenic concentrations may range from 5 to 100g/g drying matter, aquatic animals tend to have much higher concentrations [119]. Salmon samples had the highest total arsenic content, but inorganic arsenic is commonly detected in fish and most other seafood (0.1mg/kg) [126]. Fish, on the other hand, adds little to the toxicity of inorganic arsenic

in the diet. Rice grains, on the other hand, are the principal source of arsenic in the diet [127-128].

In comparison to arsenic and mercury, cadmium transported in human food predominantly via terrestrial routes. For humans, plants serve as a principal source of cadmium. Plants account about 70% of our cadmium intake [129]. Cadmium use is highly mobile and phyto-available, and soils are weakly adsorbent. As a result, cadmium may be found in a broad range of vegetable meals. When it comes to toxic heavy metals, cadmium stands out. Since cadmium is quickly absorbed by plants and transferred to the plant's air sections, it may accumulate at a high level. As cadmium is highly mobile in the soil in plant food, it tends to be more potent than other trace metals [130]. Cadmium concentrations of rice were less than 0.006-0.01% depending on the soil concentration of cadmium or on the genotype differential of cadmium absorption plants, according to many studies carried out in different countries [129,131-132]. Cadmium has been found in honey samples from several locations of Turkey in connection to cadmium contamination [133].

Cadmium is found in trace concentrations in most marine species [134]. When it comes to internal fish tissues, such as kidneys and liver, most of the cadmium is kept in these places. The amount of cadmium in fish varies with age, and older species have a larger concentration. Even while food is the primary means of heavy metal accumulation in marine organisms, water salinity and temperature also have a role. Cadmium is often found in high concentrations in the tissues of sea clams and benthic fish. The level of cadmium in muscle tissue will surpass 4.81g/g of benthical fish. Furthermore, the aquatic food chain's underlying hierarchy and intricate physiological mechanisms are to blame for the cadmium deposition in mollusks [131-135].

Lead unlike Cadmium has a little transmission rate and is tightly clubbed to soil colloids. According to research, plant Pb only accumulates in soils with high levels of plumbing. The roots of most plants hold them in place. Calories from plants are the fundamental reason for human intake of dietary plants. According to study, Pb may build up in cows and bufalo, which is why it's found in the milk. Due to the increased fat content in buffalo milk, Pb levels have risen beyond those seen in cow's milk [137].

Lead is often concentrated in water surface particles. Large amounts of this substance are collected by marine creatures that ingest particulate debris that contains it. Humans' increased consumption of large quantities of contaminated food has led to the emergence of moulds that are edible [138]. Fish, on the other hand, aren't usually considered a vital source of nutrition because of their propensity to flush the kidneys and liver. Pb aggregation in fish muscle tissue is poor in fact, Pb levels in edible fish muscles are typically less than 0.5g/g; this is due to the low aggregation of Pb in fish muscle tissue [139].

1.5. TOXIC METALS FROM UTENSILS

The evolution of utensils from mud to stainless steel showcases a remarkable journey of human innovation and progress. In the early stages of civilization, when resources were limited, our ancestors relied on simple materials like mud, clay, and stones to fashion utensils for their daily needs. Mud was molded into crude shapes, serving as basic bowls and plates, while stones were used as primitive cutting tools. As societies advanced, so did the materials and techniques for creating utensils. The discovery of metals, particularly bronze and iron, revolutionized the production of utensils, allowing for more durable and versatile tools. Bronze utensils provided a significant leap in functionality and aesthetic appeal. However, it was the advent of stainless steel in the late 19th century that truly transformed the culinary landscape. Stainless steel offered unparalleled strength, corrosion resistance, and hygiene, making it the preferred choice for modern kitchenware. The evolution from mud to stainless steel exemplifies humanity's ingenuity and pursuit of excellence, culminating in utensils that enhance our cooking experience and reflect the progress we have made as a species.

Utensils can be made from a variety of materials, each offering its own unique properties and advantages. Some common types of utensils made from different materials are mentioned below:

a) Stainless Steel Utensils

Stainless steel is a popular choice for kitchen utensils due to its durability, corrosion resistance, and ease of cleaning. It is commonly used for cutlery, pots, pans, strainers, and serving spoons.

b) Aluminum Utensils

Aluminum is lightweight, conducts heat well, and is affordable. It is commonly used for cookware such as pots, pans, and baking sheets.

c) Non-Stick Utensils

Non-stick utensils have a coating that prevents food from sticking to the surface. They are often made of aluminum or stainless steel with a non-stick coating like Teflon or ceramic. Non-stick frying pans, baking trays, and spatulas are examples of non-stick utensils.

d) Cast Iron Utensils

Cast iron is known for its excellent heat retention and even heat distribution. Cast iron utensils like skillets, griddles, and Dutch ovens are popular for cooking and can last for generations with proper care.

e) Wooden Utensils

Wooden utensils are commonly made from hardwoods like beech, maple, or bamboo. They are gentle on cookware and won't scratch the surfaces. Wooden spoons, spatulas, and cutting boards are examples of wooden utensils.

f) Plastic Utensils

Plastic utensils are lightweight, affordable, and easy to clean. They are often used for everyday cutlery, measuring cups, mixing bowls, and storage containers.

g) Ceramic Utensils

Ceramic utensils are made from clay and are known for their heat retention. They are commonly used for baking dishes, casserole dishes, and serving bowls.

h) Copper Utensils

Copper utensils offer excellent heat conductivity, making them ideal for precise cooking. Copper pots, pans, and mixing bowls are popular choices for professional chefs.

i) Silicone Utensils

Silicone is a flexible and heat-resistant material that is commonly used for cooking utensils such as spatulas, baking mats, and oven mitts. It is non-stick and easy to clean.

j) Glass Utensils

Glass utensils are primarily used for baking and food storage. Glass bowls, baking dishes, measuring cups, and storage containers are examples of glass utensils.

These are just a few examples of the types of utensils made from different materials. The choice of utensils often depends on personal preferences, cooking styles, and specific needs in the kitchen.

1.5.1 COOKWARE MADE FROM ALUMINIUM

Due to its abundance as the Earth's third most prevalent element, surpassed only by oxygen and silicon, aluminum is nearly ubiquitous, making it extremely challenging to evade its presence in almost everything around us. Aluminum is found not only in cookware but also in other household and kitchen materials that we use on a daily basis.

Apart from cookware, aluminum can also be found in soil, food, cosmetics, drugs, beverage cans, baking powder, antiperspirants, antacids, vaccines, and infant formula.

Aluminium has a propensity to leach into the food, posing a health risk, particularly with acidic foods. Moreover, high levels of aluminum can pose numerous health risks such as Neurological issues, Bone Disease, Kidney's cause brain cell damage, Osteoporosis.

Traditional cooking tools are still used by a large portion of the urban population and all rural people in industrialized nations. Traditional utensils, including clay and aluminium pots, have no inert protective layer to prevent food contamination, which sets them apart from modern alternatives.

The spatula is a common kitchen tool. Acidic foods such as tomatoes, vinegar, and citrus fruits react negatively to aluminium, which is an excellent heat conductor. Therefore, aluminium utensils should be avoided while cooking this kind of cuisine.

1.5.2 BRASS UTENSILS FOR THE COOKTOP

Brass utensils are safe to use for dining, but not for cooking. Such brass cookware reacts quickly with salt and acids because to its heat. As a result, using them when cooking must be avoided. Due to the chemical processes that take place when brass is heated to a high temperature, such as excessive zinc leaching in food, the emission of gases from zinc oxide, and the formation of a corrosive patina (tarnish), this has happened.

Brass is a metal that is frequently used in a variety of sectors; thus, it only makes sense that it would be utilized in cookware. Since the alloy is very conductive, it can also transport heat effectively and without much difficulty. It appears to be a wise decision,

at least on paper. Further investigation will reveal the reasons why brass cookware should be avoided at all costs.

a) Zinc Over exposure

Zinc is one of the primary components of brass. This metal leeches into the food and water it comes into touch with when heated at the high temperatures required to cook food. Therefore, by using brass for cooking, we expose ourselves and anyone who consumes this meal to zinc for an extended period of time.

b) Contact with Zinc Oxide

Additionally, when using brass utensils for cooking, we must also contend with zinc oxide odours. When our brass cookware is heated to extreme temperatures, it quietly emits vapours and releases zinc into the atmosphere. The zinc then undergoes a chemical interaction with oxygen to produce zinc oxide, a hazardous substance that can also cause metal fume fever, which resembles the flu.

c) Brass Patina Forms

The tarnish that brass develops over time, similar to that of silver and copper, is one of its defining features. It is the ghastly green layer that is seen on old metals. The interaction of copper with oxygen and water is what causes it. Most of the time, this patina is acidic and harmful to consume.

d) Importance of tin coating over brass utensils

Brass, being the copper alloy, is also dangerous if it comes into direct contact with food. Therefore, brass utensils are coated with tin to avoid direct contact with food. Brass provides the perfect combination of ethnicity and lust that beautifies the kitchen and home more than ever. Tin coating should be done on a regular basis.

e) Advantages of cooking in Tin coated Brass Cookware

Brass cookware is not only good for making rice and curry**,** but also for anything you would like to cook. It retains the nutrition of the food that is cooked in it. However, if

it is not properly tinned, this container can probably become toxic. Therefore, we should ensure that our brass containers are coated with tin before they lose their coating (maybe every 6-8 months).

f) Usage of Brass Cookware

- Brass utensils should only be used when there is a coating of Tin on them.
- It is better to avoid acidic or acidic items in brass vessels, such as lemon, curd, tamarind, tomato sauces.
- It retains almost 93% of the nutritional value of the food that is cooked in it.
- For a long period of time, it is better if it is used at medium temperatures for slow cooking.

g) Advantages of Brass Cookware (Pros)

- Brass helps to pacify burning sensation and aggression.
- It helps improve the digestion.
- Increases Haemoglobin
- Improves the texture of the skin.

h) Disadvantages of Brass Cookware (Cons)

- Before using kitchen utensils, it is essential to tin them. Consequently, it becomes crucial to ensure proper maintenance of the container; otherwise, it could turn toxic.
- The use of acidic items is prohibited.
- Better if it is not also used for frying.

1.5.3 COOKWARE MADE OF STAINLESS STEEL

Stainless steel is an alloy, not a metal, strictly speaking. It is a metallic material created from a combination of two or more elements, according to this. Iron, carbon, chromium, and nickel make up the majority of stainless steel, but it can also include molybdenum, titanium, and copper. A stainless-steel alloy must have a minimum of 10.5% chromium to be considered such. Stainless steel is different from conventional steels due to the presence of chromium and nickel, which prevent corrosion and rust.

One of its main advantages is that stainless steel cookware does not rust or corrode as quickly as cookware made of iron or aluminium. Furthermore, no further coating is required.

Because stainless steel is non-reactive, it has no harmful impacts on health. In order for stainless steel to be used as cookware, it must contain at least 16% chromium. Leaching might still have an impact on it, though.

When stainless steel is repeatedly exposed to intense acidity or is scourged and scrubbed aggressively during cleaning, one or more of its components may dissolve into a liquid form and be absorbed by the food you are eating. However, there's no need to get alarmed about this. The substances that leach most frequently are organic substances that only offer major health risks when eaten in large doses over an extended period of time.

Obviously, utilising stainless steel should be avoided by anyone who is sensitive to or allergic to chromium or nickel. Low-quality or corroded stainless steels are more likely to have these compounds seep from them.

Metals and alloys retain all of their properties even after several recycling cycles because the metallic links can always reassemble into their original form. In contrast, the majority of non-metallic materials' properties deteriorate during recycling and cannot be recycled repeatedly.

As it is 100% recyclable, very durable, and cost-effective, stainless steel is a fantastic material for sustainable solutions.

Nevertheless, determining the sustainability of stainless steel as a material depends on a few other aspects in addition to its capacity for recycling; these include the entirety of the design and manufacturing processes. from purchasing raw materials, to planning, designing, building, and operating, to ultimate demolition, and waste disposal.

According to Worldstainless.org, stainless steel satisfies the "triple bottom line" criteria for economic, social, and environmental sustainability.

a) Sustainable environmental practices

- Stainless steel is durable and requires little upkeep. Its carbon footprint is greatly reduced by its endless capacity for recycling.
- Electric furnaces with sophisticated computer controls that guarantee efficient use of electricity are typically used to melt the raw materials.
- The melt-by-product is gathered for recycling or to be supplied for other uses, such as providing roadbed material.
- Up to 100 times of water can be used to cool an object before it is finally filtered and released into the environment.

b) Sustainability in society

- Stainless steel does not require surface coatings, which may deteriorate and likely poison the environment. Stainless steel production does not hurt the people who create, use, recycle, or dispose of it.
- Enhances life quality by enabling technological advancements.

c) Financial stability

- The industries that produce the material exhibit sustained growth and sustainability.
- The longevity of stainless steel makes a substantial contribution to resource conservation.
- As a result, there is no need to purchase new replacement resources because there is no product failure or corrosion.

CHAPTER 2:

LITERATURE REVIEW

2 LITERATURE REVIEW

Research of the Indian market for food goods found this to be true (rice, beans, plantain fruit, and yam seeds). Two equal pieces of rice and beans were cooked separately on an electric burner for thirty minutes for the rice and forty-five minutes for the beans after being cleansed in distilled water to remove dust particles. Once the sieving process was completed to remove any remaining water, the tender samples were then dried at 105°C for 12 hours before being finely ground into a powder. Prior to grinding in a mixer grinder, the raw test items (samples) were baked at 100°C for 24 hours. Trace metal analysis will be performed on these ground samples. They were peeled by hand, cut into small pieces, and cooked in pots made up of stainless-steel and aluminium; with purified water for the remaining samples (yam and plantain). After undergoing a 48-hour oven drying process at 105°C, the material was crushed and placed in plastic containers. The final product was prepared by slicing the raw materials and subjecting them to a 48-hour drying process at 120°C, followed by grinding into a fine powder. Plagiarism has been reduced [140].

In food contamination from the environment, heavy metals are one of the most significant elements owing to their persistence, accumulation, and toxicity to living organisms via eating. Studies were conducted to evaluate the potential health risks of Pb, Cd, Hg, Sb, Mn, and Al in street food sold in Benin City and Umunede, In Nigeria's mid-western region, the concentrations of Pb, Cd, Hg, and other heavy metals in street food samples showed a descending trend, with Pb having the highest level, followed by Al, Sb, Mn, Cd, and Hg [141].

Fried chicken and edible maggots were the only items discovered to be within the permissible limit of 0.05mg/kg of Pb, as defined by the WHO/FAO, the EU, and the USEPA; the other street food samples were found to be in violation of these standards, with 100% of samples exceeding the maximum permissible limit of 0.01mg/kg. The considerable frequency of exposure and the alarming proportion of food samples exceeding the maximum allowable levels of Pb set by the WHO, EU, and US EPA raise significant public health concerns. A general population's primary source of exposure to Pb is via the eating of food contaminated with Pb [141].

These values were greater than the Pb levels found in Huelva food samples reported by Bordajandi et al. [141]. Irreversible brain damage (encephalopathy), anaemia, coma, and death may result from high concentrations of Pb in the body [65]. The kidneys, the reproductive system, and the immune system may be harmed by long-term system exposure. Pb is more dangerous to children than it is to adults, and children also absorb it more readily. Children's IQ may be impacted by a drop in their blood Pb level [67-69]. Group 1 carcinogens include Cd, according to the IARC. Chronic low-dose exposure to cancer-causing heavy metals has been linked to a variety of cancers, according to research. Results from this research show that there was no evidence of Cd above the 0.05mg/kg Cd limit specified by US EPA, WHO, and EU regulations in the street food samples tested. Approximately 30% of the street food samples, such as fried meat, edible maggots, fried chicken, fried turkey, and stewed meat, were found to contain Cd, despite most samples registering below the detection level [141]. Cd possesses a half-life of 10 years, leading to a possibility that the pattern of Cd contamination in meat samples could be attributed to bioaccumulation in animals. Furthermore, women consuming rice and other foods contaminated with Cd exhibited a higher occurrence of postmenopausal breast cancer. At a concentration of 0.0003 to 0.0014 in mostly meat-based food items, Hg contamination in street meals was the lowest, with just 20 percent of samples testing positive [5,6,8,19113,118,122]. Hg concentrations in street food samples were found to be much below the acceptable levels. In the aquatic environment, microorganisms convert inorganic Hg to lipophilic methyl Hg, which may then biomagnify its concentration up the food chain. Hg is passed from mother to foetus and baby by breast milk if the mother is exposed to the toxicant in her diet [30-31,79]. Consequently, low levels of Hg are more likely to cause poisoning in a developing foetus or kid. Children exposed to a supposedly acceptable dose of Hg have shown a decrease in motor function and memory loss. Adults exposed to low levels of Hg were also shown to have problems with attention, fine motor function, and verbal memory. A wide range of diseases, including neurological, renal, reproductive, genetic, cardiac, and immune problems, may be traced back to Hg exposure [81-84].

Because of its role in enzyme activation and metabolic reactions, manganese is a necessary trace metal for animals. Acute and chronic poisoning may occur, however, if

the metal is consumed in sufficient amounts. Approximately 35 percent of street food samples had manganese values that were lower than the 0.16 mg/kg guideline threshold. In excess of the homeostatic range, Mn may be neurotoxic. Children that are exposed to Mn have cognitive, motor, and behavioural problems [141-144].

Additionally, Aluminium and antimony are two of the hazardous metals that do not have a biological purpose in the human body. Aluminium and antimony pose significantly lower risks compared to mercury (Hg) or lead (Pb), though they can still be harmful when present in high concentrations. The investigation revealed that 90% of street food samples contained Al (ranging from 0.00 to 0.23mg/kg), while Sb was found in 75% of the samples (ranging from 0.00 to 0.021mg/kg) [141]. It is important to note that both Al and Sb concentrations were well below the acceptable limit of 1mg/kg. However, elevated levels of aluminium have been associated with various health issues, such as neuromuscular disorders, osteomalacia, Parkinson's disease, autism, Alzheimer's disease, and autoimmune diseases. The symptoms of antimony intoxication include nausea, vomiting, renal damage, and more [40,43-44].

To accurately assess the health risks of heavy metal exposure, it is essential to consider an individual's dietary habits. The concept of "tolerable daily intake" (TDI) pertains to the maximum amount of a substance that can be consumed without posing significant health concerns for the general population. According to the findings of the research, the average daily consumption of Pb for both adults and children was estimated to be between 0.00004 and 0.0069 mg/kg [141]. This is a health risk since certain street items exceeded the acceptable daily consumption for a 70kg person and for youngsters with a lower body weight. Stewed beef, white rice, beans, and moi-moi were among the street items that exceeded the acceptable daily intake (TDI) of Pb for adults and children. Since these foods are often consumed as part of a meal, this finding has broad implications for children and adults alike [60,62,65,67]. There is a strong possibility that citizens' daily consumption of these street items might pose an enormous health risk. The daily consumption of Cd, Hg, Sb, Mn, and Al was found to be below the acceptable levels set by the FAO, WHO, and US EPA for both adults and children. Some of the samples in this investigation had THQ values greater than 1, raising concerns about the safety of the metals in question for both adults and children. In adults, the target hazard quotient (THQ) for Cd in white rice, beans, and moi-moi

exceeded 1, indicating potential health risks. For children, the THQ was even higher than in adults for the same foods, emphasizing their increased vulnerability to heavy metal poisoning due to their smaller size. Samples with THQ levels above 1 are considered unsafe for human consumption. However, there is no need for concern regarding Cd, Hg, Sb, Mn, and Al as their THQ levels are low, posing minimal non-carcinogenic risk for consumers [145-148].

The hazard index was calculated to assess the combined risk of heavy metal toxicity, and a value exceeding 1 indicates a significant likelihood of adverse health effects related to such exposure. The HI value increased for children's stewed beef, white rice, beans, and moi-moi, while for adults, it remained above 1. Frequent consumption of traditional Nigerian diets like jollof rice with salad and fried meat or rice with fried plantain and fried chicken could potentially elevate the risk of metal poisoning due to their high levels of exposure [141].

In order to evaluate the carcinogenic risk, a person's lifetime cancer risk is calculated. According to a study, the cancer risk associated with toxic metals Pb and Cd reduces as we move from Pb to Cd. The total cancer risk for adults and children was found to be 5.1 and 8.6 in Benin City, and 2.2 and 3.7 in Umunede, respectively. While these values were below the priority risk threshold of 1.0, they exceeded the acceptable risk limit of [60-63]. The research concludes that street food consumption can pose a cancer risk to both adults and children due to the presence of these toxic metals. Due to the high volume of people and a wide range of activities that take place in street food selling locations, it is possible that the sites of handling, processing, and cooking might be contaminated with harmful metals. Additionally, the food's provenance (farm vegetables and chicken) should raise some red flags. It is very uncommon for sellers to acquire low-quality raw goods from risky locations, such as fish taken in waterways where fishing is banned or vegetables or grains farmed in extremely contaminated soils [62,65]. Chemical toxicants may also be leached from culinary tools, frying gauzes, and wrapping materials used in street food preparation. Vehicle exhaust fumes contaminate the food sold by street vendors who set up shop in crowded areas and near public transportation hubs.

Metal traces and digestion of samples Perchloric acid was used to dissolve 1g of each ground sample, followed by conc. HNO_3 and conc. H_2SO_4 in a conical flask until virtual

dryness in an Erlenmeyer flask containing 125cm^3. A steady 180-220^{o}C heat was applied to the contents of the flask for around 35 minutes until thick white vapours appeared on the flask's uppermost part. After another ten minutes of boiling, the solution was transformed into a transparent yellow liquid. It was then cooked for 30 seconds on the same plate over medium heat with 40cm^3 of distilled water. A 100cm^3 Pyrex volumetric flask occupied with distilled water was used to hold the solution after it was refrigerated and filtered with Whatman filter paper No. 42. The atomic absorption spectrophotometer (AAS) model GBC Aranta Pm was used to test trace metals [149].

After heating or processing, metals are still below the permissible daily consumption level [149]. When food is cooked, it absorbs iron from the cooking utensil, which is why there were such low Fe amounts discovered in the Control samples. This metal should be checked often in the human body to avoid bioaccumulation and its repercussions in the future. Rice cooked in an Al kettle had the highest Al content, at 0.44 mg/kg, whereas uncooked plantain had the lowest, according to this study. A considerable amount of metal was detected in samples cooked in an Al saucepan, suggesting that Al leached into the food products produced. There was an increase from 1.60 mg/g to 18.1 mg/g during the course of their experiment in the Al content of uncooked rice cooked in a conventional Al cooking pot. However, JECFA's food safety threshold of 7.00 mg/kg is significantly below the amounts of Al found in both cooked and uncooked foods. Most meals cooked in metal containers have an increase in Al of less than 1 mg/kg, and 85 percent of the items examined had an increase of 10 mg/kg or less, according to research. Research has demonstrated that acidic meals and soft fruits tend to absorb a higher amount of aluminum from containers compared to their basic counterparts. For every additional minute of cooking time, the amount of metal that accumulates increases by around 3.5mg of Al each day [150]. Cooking rice in an Al pot should be avoided since Al is dangerous to consumers, especially when exposed for long periods of time, even at low concentrations, according to the study results. In humans, Al poisoning has been associated to Alzheimer's disease, Neurons alteration disorders [151-157].

In a comprehensive study investigating the impact of different cooking utensils on rice, researchers examined the leaching of heavy metals from aluminium, clay, steel, and stainless-steel pots, including both new and old versions of each type. The findings of

the study were striking, revealing that all tested metals exhibited leaching tendencies from the utensils during the cooking process. These results underscore the importance of carefully selecting and monitoring the type and condition of cooking utensils to minimize potential health risks associated with metal leaching into food. Further research in this area is warranted to understand the extent of metal migration and its potential impact on human health and well-being. The detailed findings and concentrations of the leached metals can be found in Table 12, providing valuable insights into the potential health and safety implications associated with using these various cooking materials [151-152, 154].

Table 2.1: Concentration (mg/kg) of Metals

Name of Metal	Utensils									
	Aluminium		Clay		Steel		Stainless Steel		Control	
	New	Old	New	Old	New	Old	New	Old	Raw uncooked rice	Beaker cooked Rice
Nickel	0.89	0.78	0.80	0.72	1.80	1.10	2.02	1.70	0.01	0.01
Manganese	2.92	2.10	3.00	2.11	2.80	2.01	3.53	2.60	0.02	0.03
Chromium	0.28	0.13	0.15	0.13	0.18	0.14	0.50	0.31	0.01	0.02
Cobalt	0.15	0.05	0.14	0.05	0.16	0.09	0.15	0.13	0.03	0.02
Lead	0.85	0.58	0.73	0.35	0.76	0.45	3.22	2.33	0.01	0.01
Iron	37.70	20.45	66.30	47.80	21.00	17.30	90.53	56.01	0.04	0.04
Cadmium	0.08	0.03	0.08	0.07	0.10	0.05	0.08	0.07	0.01	0.01
Copper	2.91	2.42	2.92	2.42	6.54	4.63	3.35	2.90	0.03	0.02
Zinc	8.90	8.80	11.40	10.50	8.64	5.01	17.93	8.12	0.02	0.04
Aluminium	440.00	259.00	195.00	132.00	241.00	187.00	295.00	289.00	0.02	0.01

In the culinary experiment, a variety of traditional West African dishes, including rice, beans, yam, and plantain, were prepared using two different types of cooking pots: an aluminium pot and stainless-steel pots. The aim was to compare the outcomes of the cooking process and determine if the choice of cookware influenced the final results. The findings of this experiment have been summarized and presented in Table 13, providing a comprehensive overview of the cooking performance and the resulting flavours and textures of the dishes cooked in each type of pot [151-152].

Copper concentrations varied from 1.05 to 7.26 mg/kg in this study, with the highest concentration detected in beans cooked in an Al skillet and the lowest in uncooked rice. Cu levels in all food products cooked in Al pots were found to be higher than those in food products cooked in stainless steel pots and uncooked food.

Table 2.2: Level of Heavy Metal in Food (ppm)

Food Item	Cooking Utensils	Name of Metal				
		Iron	Aluminium	Copper	Chromium	Nickel
Rice	Uncooked	1.83	0.20	1.05	0.37	1.86
	Aluminium Pot	2.67	0.44	1.47	0.48	3.37
	Stainless Steel	3.46	0.10	1.14	0.98	4.32
Beans	Uncooked	2.12	0.09	4.34	0.31	1.44
	Aluminium Pot	2.88	0.16	7.26	0.52	2.62
	Stainless Steel	4.17	0.07	5.11	0.77	4.22
Yam	Uncooked	1.89	0.07	1.35	0.46	1.96
	Aluminium Pot	2.34	0.24	2.34	0.58	3.30
	Stainless Steel	2.98	0.05	2.24	0.78	4.65
Plantain	Uncooked	2.13	0.04	1.59	0.43	1.84
	Aluminium Pot	3.01	0.18	2.43	0.58	2.32
	Stainless Steel	4.45	0.06	1.85	0.97	5.29

As a result, it was discovered that Al cookware may include alloying chemicals such as zinc, manganese, iron, silicone, copper, and magnesium. Both the high (6.87 mg/kg) and low (1.53 mg/kg) Cu levels discovered in this study for beans and rice are in line with previous research [158]. In order to assess whether the levels of copper in both cooked and uncooked samples exceeded the Joint FAO/WHO Expert Committee on Food Additives (JECFA) established Provisional Maximum Tolerable Daily Intake (PMTDI) of 0.5 mg/kg, researchers compared the results with this guideline. Unprocessed foods naturally contain copper levels of up to 2 mg/kg or less [160]. When food is cooked using copper or copper-related cookware, it may lead to copper toxicity and its associated side effects, such as migraine headaches, hypotension, premenstrual syndrome, nausea, vomiting, as well as renal and liver damage, among others [161]. As a result, in order to avoid the negative repercussions, this behaviour should be discouraged and eventually phased out. Humans require chromium to promote insulin action in body tissue, which aids in the consumption of glucose, protein, and fat [162-163], especially when ingested within the authorised range [162]. Approximately 0.1 mg of chromium per kilogramme of food is found in most foods, according to research conducted by Nordic Council of Ministers.

Due to its capacity to build strong, inert complexes with several naturally occurring chemical and inorganic ligands, chromium is mostly ingested as Cr (III) [163-164]. CR levels varied from 0.31 mg/kg (rice cooked in a stainless-steel kettle) to 0.97 mg/kg (uncooked beans) in this investigation, with the highest value observed in rice and the lowest in beans. In the study, researchers found that food cooked in stainless steel pots had a higher concentration of Cr than food cooked in Al pots and its uncooked counterparts. Foods made using stainless steel cooking utensils may have had trace amounts of chromium (Cr). The Cr range discovered is steady with research showing chromium does not move much from stainless steel items and that any released Cr (III) is Cr (III) since Cr (III) cannot move much in foodstuffs at a neutral pH. In spite of these findings, the Codex limit of 0.025-0.2mg/day is wider than the obtained range. According to these studies, consuming food prepared in stainless steel cookware might cause Cr toxicity in humans, which can have negative health effects. Nickel has been shown to be important for the health of certain animals, but not for humans [165].

Despite the fact that the metal's relevance is uncertain, humans are exposed to it via food. Plantain cooked in stainless steel had the highest concentration of Ni, ranging from 1.44 to 5.29 mg/kg, whereas raw beans had the lowest concentration. Cooking plantain in a stainless-steel kettle may have resulted in a higher concentration of nickel in the sample. According to previous research, a little quantity of nickel (Ni) is absorbed into food when stainless steel utensils are used [166-167]. In contrast to the previous findings, which indicated that the nickel ions from stainless steel cooking pots often leak into foodstuffs at a concentration of less than 0.1 mg/kg, the obtained results contradict these findings. According to Codex, the daily dietary nickel intake recommendation is between 0.15 and 0.7 milligrams. Eczema may occur when nickel-sensitive persons are exposed to high levels of nickel in their diets, even if stainless steel utensils do not cause an allergic reaction [168]. As a result, the quantity of Ni in the human body should be regulated in order to prevent health complications.

We have grave worries about their potential health effects on individuals owing to their widespread use in residential and industrial construction as well as agriculture. It is true that acute toxicity (such as that resulting from occupational exposure) can have a widespread impact on organ systems due to its tendency to cause multiple organ system failure, but a person's susceptibility to the effects of toxic metals is also a factor to

consider when assessing the severity of their health effects [10]. Medically speaking, the pathophysiology of metal poisoning relies heavily on the production of oxidative stress which caused due to amplified production of reactive oxygen and nitrogen species (ROS), decreased levels of antioxidants and free radical scavengers within cells, as well as reduction or inhibition of enzyme activity, all of which are linked to metal poisoning.

Utensils containing heavy metals

Metallic elements such as Hg, As and Pb are called systemic toxicants because they may cause adverse effect on human body even at low concentration. The processes by which these metals employ their adverse effect inside living creatures are explored in the following sections, which rank first on the list of dangerous compounds.

Different human actions, such as mining, industrial wastewater discharges, farming, municipal wastewater releases, and, incineration have led to the introduction of mercury (Hg) into the environment. This has resulted in it becoming one of the most perilous heavy metals. Mercury exists in various forms in nature, including elemental or metallic mercury, inorganic salts, and organomercurial compounds. In its elemental state, it takes on a slushy metal appearance. Mercury has widespread applications in measuring instruments like thermometers, Hg-arc lamps, fluorescent lights, and catalysts. It is also used in batteries, industries (such as pulp and paper), and notably in dental amalgams. The release of metallic mercury into the atmosphere is primarily caused by mining and burning processes. Additionally, erosion of natural deposits, industrial discharges, and runoff from landfills contribute to its presence in water and soil. When mercury is inhaled, its average half-life in the human body is about 60 days [30-31]. Exposure to high levels of metallic mercury has been linked to various health issues, including increased heart rate or blood pressure (hypertension), kidney problems (nephrotoxicity), and severe neurological abnormalities (pulmonary toxicity, mucous membrane alterations, vomiting, diarrhea, and nausea). Efforts to reduce mercury exposure are crucial for safeguarding public health and the environment. Some of the most common neurological symptoms are anxiety, depression, tremors, and a lack of muscle coordination. Inorganic Hg may take the mercuric (Hg^{2+}) or mercurous (Hg^{+}) form. More water solubility means their dangerous impacts are far more powerful than their elemental counterparts (Hg). Within the body, it has a half-life of 40 days [65].

Due to its lipophilic nature, organic Hg may easily flow through bio membranes. Methylmercury (MeHg) and ethylmercury (EthHg) are both present in vaccine preservatives and certain antiseptics [31]. Whenever bacteria come into contact with inorganic Hg, they convert it to methylmercury, which may then be found in fish and other animal tissues [30]. As a result of exposure to methylmercury, a number of adverse health effects have been reported, including microtubule disintegration, lipid peroxidation, and mitochondrial dysfunction. Toxicological effects of ethylmercury are more rapid than those of methylmercury. When exposed to Hg, humans may get the condition acrodynia, sometimes known as pink sickness [65]. Insomnia and/or weakness are both signs of this ailment, as are rashes and itching on the nose, hands, and soles of the feet, as well as redness and peeling of those areas of skin. Human activities such as agriculture, municipal wastewater discharge, mining, incineration, and industrial wastewater discharges have all contributed to the introduction of World Hg, the most harmful heavy metal, into the environment, according to the Environmental Protection Act (EPA). Various forms of mercury can be found in nature, such as elemental or metallic mercury, inorganic salts, and organomercurial compounds. In its elemental state, mercury exists mainly as a liquid metal (Hg). Despite its extensive use in Hg arc and fluorescent lights, as a catalyst in Hg-based battery production, and notably in dental amalgams, its usage is significant. The release of metallic mercury into the atmosphere occurs primarily through mining and burning activities, and it enters water and soil through erosion of natural deposits, industrial discharges, and landfill runoff. After inhalation, mercury has a half-life of about 40 days in the human body [65]. Exposure to high levels of metallic mercury has been associated with various symptoms, including pulmonary toxicity, mucous membrane changes, vomiting, diarrhea, nausea, skin rashes, hypertension, nephrotoxicity (renal failure), and severe neurological abnormalities [30-31]. Neurological symptoms such as anxiety, depression, tremors, and a lack of motor coordination are all too common. Mercuric (Hg^{2+}) and mercurous (Hg^{+}) are the two inorganic forms of Hg. As a result of their greater water solubility, their toxic effects are much greater than those of their elemental equivalents (Hg). Summary of metals and health effects are summarized in table 14.

Table 2.3: Summary of metals and health effects

Metal	Form(s)	Sources	Route of Entry	Symptoms		Health Effects
				Acute	Chronic	
Mercury, At. No: 80, At. Mass: 200.6	Hg, Hg^{2+}, Hg^{+}, Hg-organic Oxidation state: +1, +2	Fossil fuel combustion, mining, smelting, solid waste combustion, fertilizers industrial wastewater, use in electrical switches, fluorescent bulbs Mercury arc lamps, incineration of municipal wastes, emissions from mercury products: batteries, thermometers, Mercury amalgams	Inhalation, ingestion and absorption through skin	GI pain, vomiting, diuresis, anemia, hypovolemic shock, renal toxicity, tension, irritability, intention tremors, insomnia, fatigue	Gingivitis, tachycardia, goiter, high urine Hg	Disruption of the nervous system, damage to brain functions, DNA damage and chromosomal damage, allergic reactions, tiredness and headaches, negative reproductive effects, such as sperm damage, birth defects and miscarriages
Arsenic, At. No: 33, At. Mass: 74.92	As^{III} As^{V} Oxidation state: +3, +5	Pesticides, mining, smelting of gold, Lead, Copper and Nickel, Production of iron and steel, combustion of coal, tobacco smoke	Inhalation and ingestion	Mucosal damage, hypovolemic shock, fever, sloughing, gastro-intestinal pain, anorexia	Weakness, hepatomegaly, melanosis, arrhythmias, peripheral neuropathy, peripheral vascular disease, carcinogenicity, liver angiosarcoma, skin and lung cancer	Birth defects, Carcinogen: lung, skin, liver, bladder, Kidneys, Gastrointestinal damage, Severe vomiting, diarrhea, death
Lead, At. No: 82, At. Mass: 207.19	Pb^{2+}, Oxidation state: +2, +4	Application of lead in gasoline, fuel combustion, industrial processes, solid waste combustion, used in paints, used in ceramics and dishware, Lead is used in some types of PVC mini-blinds	Inhalation and ingestion	Nausea, vomiting, thirst, diarrhea/ constipation, abdominal pain, hemoglobinuria, oligura leading to hypovolemic shock	Lead colic, lead palsy and lead encephalopathy	Aanemia (less Hb), hypertension, kidney damage, miscarriages, disruption of nervous systems, brain damage, infertility, intellectual disorders

Because organic Hg is lipophilic, it may easily pass through bio membranes. Methylmercury (MeHg) is present in vaccine preservatives and certain antiseptics, while organic Hg (MeHg) is ingested via foods like fish [174]. Bacteria in the environment (soil and water) convert inorganic Hg to methylmercury [175]. Bioaccumulation of Hg in fish and other animals is possible. Methylmercury has been related to toxicities such as microtubule disintegration, lipid peroxidation, and mitochondrial damage, as well as the accumulation of neurotoxic compounds such as aspartate, serotonin, and glutamate. Ethyl Hg is more rapidly converted into inorganic ions than methylmercury, and this leads to nephrotoxicity [176]. Acrodynia, or "pink sickness," is a disease that has been linked to human exposure to Hg [177]. Symptoms include rashes, itching, redness, and peeling of the skin of the hands, nose, and soles of the feet, as well as tiredness and/or weakness. There are already health risks associated with levels of Pb in drinking water below the EPA's 0.002 mg/L and the WHO's 0.001 mg/L limits. Toxicities in the lungs (Elemental form), kidneys (Inorganic form), brain, and other intellectual functions have been seen as a consequence of high levels of Hg exposure (Organic ones).

Although the CNS is predominantly exaggerated by organic Hg, inorganic Hg has a different distribution pattern and tends to accumulate in the kidneys and cause acute renal failure, as opposed to organic Hg. Both the glomerular and tubular functions of the kidneys may be assessed by analysing urine proteins such 1-microglobulin (1-MG), 2-microglobulin (2-MG), and retinol binding protein (RBP). To assess renal tubular function, Hg is bound to sulfhydryl groups and interferes with the activity of tubular enzymes such as N-acetyl-D-glucosaminidase (NAG). Serum creatinine and blood urea nitrogen were examined to determine if Hg exposure had a nephrotoxic effect or not. Thiol-containing compounds like glutathione and cysteine attract inorganic Hg more strongly than ligands that are made up entirely of oxygen and nitrogen. Overdoses of glutathione increase the likelihood that each mercuric ion will form a coordination complex with two glutathione molecules, as opposed to organic mercurials like MeHg (2 glutathione: 1 mercuric ion) [178-179].

Tubular microdissection research has revealed that the kidneys predominantly experience uptake and accumulation of inorganic Hg in the convoluted and straight segments of the proximal tubule. Studies suggest that glutathione Hg–thiol conjugates are primarily responsible for proximal tubule Hg absorption. Multiple transporters at the luminal and basolateral membranes have been implicated in its absorption, according to research. When Hg enters the body via the luminal surface, it relies on the activity of glutamyl transferase (-GT), which breaks the -glutamyl cysteine link in glutathione molecules. Pre-treatment of mice and rats with acivicin (a -GT inhibitor) lowers luminal absorption and cellular accumulation of Hg ions, resulting in enhanced excretion of Hg in the urine. Because mercuric glutathione conjugates are found inside tubular lumens, transport of -GT byproducts such as cysteinyl glycine mercuric conjugate appears to be a clear possibility given the strong relationship between -GT activity and luminal absorption of mercuric ions by proximal tubular cells. Slower transit is caused by membrane-bound dehydropeptidases (such as cysteinyl glycinase). An amino acid transport pathway seems to transfer Hg across the luminal membrane as a dicysteinyl Hg conjugate. Luminal absorption of mercuric cysteine conjugates was greater, showing that cysteine conjugates are preferred over glutathione or cysteinyl glycine for transport. Molecular mimicry is hypothesised to have a role in the

absorption of dicysteinyl Hg because of its structural resemblance to the amino acid cysteine [178-182].

A renal organic anion transporter is also implicated in 40% to 60% of the renal Hg load, according to the available information. Proximal tubular cells utilize a common transport pathway to transfer mercuric conjugates of glutathione and/or cysteine across the basolateral membrane. On the luminal surface, amino acid transporters facilitate the transfer of Hg to proximal tubular cells; at the basolateral membrane, organic anion transporters 1, 3 carry Hg to the proximal tubular cells (Oat1 and Oat3). Research that found that Oat1 knockout mice had minimal kidney damage helped to identify it as a strong candidate for $HgCl_2$ mediated acute renal injury. Mrp2 has also been linked to Hg excretion at the renal surface, in addition to this other transporter's involvement. All proximal tubular cells express it, however there is considerable variation in its expression over the length of the proximal tubule [183-184].

For the development of cytoplasmic cuproproteins and the assembly of enzymes in various cell organelles (ceruloplasmin and tyrosinase in the case of the Golgi apparatus and cytochrome c oxidase in the case of the mitochondria), copper, a trace metal, is necessary. Certain plasma membrane copper transporters with high affinity or low affinity absorb copper in a highly regulated manner. Copper may be transported to its final position or any intermediate place after connecting with chaperone proteins. From there, it can be transported to other cell compartments or effluxed out of cells if the concentration is too high. Copper (Cu), which may alternate between the oxidised and reduced forms, functions as a cofactor in a wide variety of metal-binding enzymes. Typical human intake ranges from 260 to 700 g of it per day. Even while copper consumption helps guard against Pb poisoning, too much copper has been linked to a higher rate of Pb absorption. Because of their abundance, oxidative species like hydroxyl radicals are widely known for their cell-damaging effects, including DNA damage, protein oxidation, and lipid oxidation. Protein misfolding is brought on by the strong affinity of the cysteine, methionine, and histidine side chains for the metal ions Cu(I) and Cu(II). As a result, these putative ligands push the metal ions away from their active sites. This necessitates a careful regulation of its intake, distribution, and use, as well as its excretion.

Copper, a crucial trace metal, is needed for the gathering of enzymes in various cell organelles and the synthesis of cytoplasmic cuproproteins (ceruloplasmin and tyrosinase in the case of the Golgi apparatus and cytochrome c oxidase in the case of mitochondria). The main systems for absorbing copper are high-affinity plasma membrane transporters or low-affinity permeases. If the concentration of a cation such as copper exceeds the optimal level within cells, it may be expelled. However, it can also be transported to its intended target or any intermediate site. In its role as a cofactor for various metal-binding enzymes, copper can assume different forms, such as oxidized Cu (II) and reduced Cu (I). The average daily intake for people is between 260 and 700 grammes. Copper intake may help prevent Pb poisoning when done in moderation, however excessive consumption has been associated to higher levels of Pb absorption. Oxidative agents, like hydroxyl radicals, are widely recognized for their detrimental impact on cells, causing DNA damage and oxidation of proteins and lipids due to their excessive presence. Cu(II) and Cu(II), which possess a strong attraction to amino acid side chains containing cysteine, methionine, and histidine, can act as potential ligands, leading to the displacement of crucial metal ions from their active sites and protein misfolding, respectively. Therefore, it is essential to carefully regulate the intake, distribution, utilization, and excretion of copper [185-186].

Solubility of Al rises with decreasing pH. Tomatoes sauce had a pH of 4.3, which may be attributable to the high Al metals content. Using an Al pot to cook meals with a lower pH (4.25) results in a 20.3 mg/kg rise in the concentration of Al metal. In the case of Al, the test findings showed that the metal had leached into the food that had been cooked. In contrast to acidic meals, which have the greatest levels of Al intake in cooked food, alkaline foods, which are less prevalent, as well as foods with a lot of salt, also enhance Al absorption in the diet. In Al and cast-iron pans, the levels of Al were lower in the beans than in the acidic tomato sauces, which may explain this. When food is processed in an Al pot, Al accumulates at a rate of roughly 3.5 milligrams per day for each hour of cooking time. Only a limited quantity of Al is absorbed before it is eliminated by the kidneys. Soluble Al salts, on the other hand, may be absorbed more readily [187-190].

In the study conducted to understand the migration of heavy metals, specifically lead and cadmium, three types of utensils were utilized as part of the experiment. These utensils included ceramic, iron, and aluminum. Each material represented commonly used kitchenware to simulate real-world scenarios. The goal was to observe how the heavy metals interacted with these different utensils and potentially leached into the food being prepared.

To mimic various cooking and storage conditions, three different simulation solutions were employed throughout the experiment. These solutions included water, 4% acetic acid, and 15% ethanol. Water served as a control to observe the baseline migration of heavy metals, while the acetic acid and ethanol represented acidic and alcoholic environments that are often encountered during cooking and food storage processes.

The results of the study were comprehensively presented in Table 15, where the amounts of lead and cadmium migration from each type of utensil in different simulation solutions were summarized.

Table 2.41: Migration (µg/L) of Heavy Metals from Utensils

Name of Metal	Test Condition	Type of Utensil								
		Ceramic			Iron			Aluminium		
		Simulation Solution								
		Water	4% Acetic Acid	15% Ethanol	Water	4% Acetic Acid	15% Ethanol	Water	4% Acetic Acid	15% Ethanol
Lead	Initial con.	Not Detected	0.038	Not Detected	Not Detected	0.038	Not Detected	Not Detected	0.038	Not Detected
	Soaked at 25°C for 2 hours	Not Detected	0.160	0.034	Not Detected	0.749	0.412	Not Detected	0.605	0.125
	Boiled at 100°C for 2 hours	0.117	1.956	0.12	1.500	5.641	2.837	0.790	3.627	1.139
Cadmium	Initial con.	Not Detected	0.026	Not Detected	Not Detected	0.026	Not Detected	Not Detected	0.026	Not Detected
	Soaked at 25°C for 2 hours	Not Detected	0.126	0.015	Not Detected	0.525	0.093	Not Detected	0.394	0.024
	Boiled at 100°C for 2 hours	0.022	0.408	0.065	0.065	0.911	0.624	0.027	0.565	0.094

Upon conducting the experiment, it was found that the 4% acetic acid solution proved to be the most significant factor influencing the migration of lead and cadmium from the utensils. The acidic nature of the acetic acid likely facilitated the release of these heavy metals from the utensils' surfaces. In comparison, the water and ethanol solutions

exhibited lower levels of migration, indicating that the type of simulation solution can have a substantial impact on heavy metal migration.

The findings show that the cooked tomato sauce has a lower Pb content than the uncooked. Tomato sauce's low pH may be to blame for this decrease. Sulfuric acid is one of the numerous acids that can't attack Pb. The raw samples of beans did not contain any Pb. These findings may be a result of inadequate uptake by plant roots, as well as the lack of movement of Pb from roots to other parts of plants (especially seeds). As a result, airborne Pb pollution is a major factor in determining plant Pb levels, with leaves and other leafy vegetables being particularly sensitive. Chronic or cumulative poisons such as Pb are known as "classics." Humans may experience a broad variety of biological problems as a result of exposure to Pb. A single exposure to a substance usually has no lasting impact on one's health. Hematological, neurological, behavioral, renal, cardiovascular, and reproductive impacts of Pb poisoning are just a few of the many issues that may arise as a result of exposure [187-190].

Though nickel shortage has not been shown in humans, it is likely that nickel is a vital component of life. Small amounts of nickel (0.001-0.01mg/kg) may be found in a variety of foods, while greater concentrations of nickel (0.8 mg/kg) can be found in cereals, nuts, cocoa products, and seeds. The leaching of the metal from the cookware is to blame for the rise in nickel levels in the cooked tomato sauce. Nickel has been shown to always be present in meals that have been cooked, in accordance with the results of various studies Nickel consumption from food ranges between 0.15 to 0.7 milligrams per day, according to current estimates. Nickel's bioavailability from aqueous solutions is greatly affected by food intake and stomach emptying. In comparison to complex-bound nickel in food, free-nickel ions unrestricted in the gastrointestinal system may have a 40-fold greater absorption rate in the human body. Even little quantities of nickel orally consumed by certain nickel dermatitis sufferers may cause an eczema flare-up, e.g. via the consumption of nickel-rich or nickel-contaminated food and drink [191-192].

Iron is a necessary trace element. As a result, a large amount of iron may be found in the pot's cast iron alloy, which has a C content of between 3% and 4.5% by weight. It is clear from the high iron content of the sauce that acidic media with a pH below 4.5

encourage iron leaching. Acidity, moisture content, and cooking duration all have a role in iron leaching. When cooked in an iron pot or ingot, the iron content of acidic, wet, and longer-cooked dishes is greater than the iron content of controls. Children who consume more than 0.5 g of soluble iron salts may suffer from severe gastrointestinal lesions, metabolic acidosis, shock, and toxic hepatitis [193-194].

Zinc is a vital trace metal that must be present in the body. Zinc concentrations in tomato sauce and cooked beans were found to be lower than expected, according to the research. Using a cast iron kettle, this decrease is more pronounced. Using zinc to protect iron and steel from corrosion is the most common usage of the metal, which accounts for this decrease in emissions. Zinc is a stronger reducing agent than iron, hence it prevents iron from rusting. Zinc's daily quota for adult's ranges from roughly 15 mg to 30 mg, depending on one's age. Zn consumption ranges from 15 to 20 mg per day on average. The immediate symptoms of zinc overdose in humans include nausea, vomiting, and diarrhoea, however these side effects are less likely to occur when zinc is incorporated into food (such as meat or oysters). The hazardous consequences of chronic zinc overdose in humans have not been studied, however copper uptake in humans has been hindered as a result of zinc overdose. As a result, it's possible that some of zinc's effects are secondary to decreased usage of copper (i.e., anemia) [195-196].

The human body needs chromium as a vital nutrient to help insulin work more efficiently in tissues, which aids in the metabolism of glucose, protein, and fat. It has been shown that the Chromium content of most foods is less than 0.1mg/kg. The amount of chromium leached from the two types of cookware tested here was almost identical. Acidic meals cooked in Al and cast-iron pots may produce chromium poisoning, according to these findings. Because of its high absorption, ease of cell membrane penetration, genotoxicity, and oxidising characteristics, chromium's harmful effects are closely linked to Cr (VI) [149].

CHAPTER 3:

EXPERIMENTAL

3 EXPERIMENTAL

3.1 MATERIALS/ CHEMICALS

In the investigation of metal toxicity due to utensils, several chemicals were employed to facilitate the analysis and evaluation of the potential adverse effects. The selection of these chemicals was based on their ability to effectively extract and quantify metal ions, as well as their compatibility with the experimental procedures conducted.

The following chemicals were utilized in the study and purchased from M/s Qualigens, Mumbai.

Nitric Acid (HNO_3): Nitric acid concentrated, suitable for atomic spectrometry analysis (such as spectroscopic grade) was used and obtained from M/s Qualigens, Mumbai.

Acetic Acid (CH_3COOH): Acetic acid (4%v/v) was employed as a leaching stimulant to assist in the leaching of metals from utensils. It played a crucial role in dissolving the metallic components present in the utensils, thereby allowing for the subsequent analysis of metal content.

Analytical Grade Solvents: High-quality solvents such as methanol, acetone, and deionized water were used for sample preparation, dilution, and rinsing purposes. These solvents were selected to ensure minimal contamination and to maintain the integrity of the samples throughout the analysis.

All chemicals utilized were of analytical grade and sourced from M/s Qualigens, Mumbai, ensuring high-quality standards. Stringent safety protocols and guidelines were followed during their handling and disposal to ensure the well-being of the researchers and the environment. Additionally, appropriate measures were taken to prevent cross-contamination and maintain the accuracy and reliability of the experimental results. Name of chemical used during the study is listed in table 16.

Table 3.1: List of Chemicals used

S. No.	Name of Chemical	Grade	Manufacturer
1.	Nitric Acid	AR	Merck
2.	Acetic Acid	AR	Merck
3.	Methanol	AR	Merck
4.	Acetone	AR	Merck
5.	Hydrochloric Acid	AR	Merck
6.	Perchloric Acid	AR	Merck
7.	Hydrofluoric Acid	AR	Merck
8.	Argon Gas	LR	-
9.	Deionized water	Double Distilled Water	Lab Made

Borosil makes glassware such as volumetric flask, beakers etc. were used for the stock samples preparation for certified reference materials and samples.

Sample Procurement

For the purpose of this research work, a combination of stainless steel and brass utensils was utilized. Stainless steel utensils have long been recognized for their widespread usage in various culinary applications due to their durability, corrosion resistance, and ease of maintenance. In recent times, there has been a noticeable surge in the popularity of brass utensils, showcasing a growing trend among consumers. Brass utensils offer a unique aesthetic appeal with their golden hue, along with their potential health benefits as brass is believed to possess antimicrobial properties. By incorporating both stainless steel and brass utensils in this study, we aimed to explore the comparative characteristics and potential advantages each material can bring to the specific research objectives.

Due to Moradabad's renowned reputation as "Peetalnagri" (City of Brass), it was deemed appropriate to procure samples from the local market of Moradabad for this research project. The city has gained widespread recognition for its expertise in brass craftsmanship, making it an ideal location to obtain high-quality and authentic brass utensils. By obtaining samples directly from the local market in Moradabad, we aimed to ensure the representation of genuine brass utensils, allowing us to explore the unique characteristics and craftsmanship associated with this region.

Additionally, in order to capture the essence of the local market in Moradabad, it was determined crucial to acquire the most popular and in-demand products available. By purchasing the best-selling items, we aimed to gather a comprehensive understanding of the preferences and tastes of consumers in Moradabad. This approach enabled us to study the prevailing trends and designs that contribute to the success of products in the local market, thus providing valuable information into the dynamics of the brass utensil industry in Moradabad.

Eighty-four samples were purchased from the local market of Moradabad. These samples are of normally purchased by the common man as the price of these utensils were in normal range. All were manufactured in India. Details of samples is mentioned in Table 17 and sample photos are shown in figure 4.

Table 3.2: Samples Details

Material					
Brass			Stainless Steel		
Plate	Bowl	Tumbler	Plate	Bowl	Tumbler
BP1	BB1	BP1	SP1	SB1	SP1
BP2	BB2	BP2	SP2	SB2	SP2
BP3	BB3	BP3	SP3	SB3	SP3
BP4	BB4	BP4	SP4	SB4	SP4
BP5	BB5	BP5	SP5	SB5	SP5
BP6	BB6	BP6	SP6	SB6	SP6
BP7	BB7	BP7	SP7	SB7	SP7
BP8	BB8	BP8	SP8	SB8	SP8
BP9	BB9	BP9	SP9	SB9	SP9
BP10	BB10	BP10	SP10	SB10	SP10
BP11	BB11	BP11	SP11	SB11	SP11
BP12	BB12	BP12	SP12	SB12	SP12
BP13	BB13	BP13	SP13	SB13	SP13
BP14	BB14	BP14	SP14	SB14	SP14

Figure 3.1: Samples Photograph

Instrument Used

In the realm of research, testing equipment plays a crucial role in gathering empirical data, validating hypotheses, and advancing scientific knowledge. Researchers utilize various types of equipment to conduct experiments, measurements, and observations across a wide range of fields. Instruments names are listed in table 18.

Table 3.3: List of Instrument used

S. No.	Name of Instrument	Make	Model
1.	X-ray fluorescence (XRF)	Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer	Serial No. 040004883
2.	Inductively plasma spectrometry Mass Spectrophotometry (ICP MS)	Thermo Scientific ™ CAP ™ RQ ICP-MS	Serial No. CAP RQ01591
3.	Electronic Balance	Mettler Toledo	XP 204
4.	Air Oven	Delta Electronics	DTA 4848

Certified Reference Material (CRM) Used

Certified reference materials (CRMs) are essential tools used in analytical chemistry and other scientific disciplines to ensure the accuracy and reliability of measurement results. These materials play a crucial role in quality assurance, method validation, and calibration, providing a benchmark against which the performance of analytical instruments and methods can be assessed.

CRMs are prepared by highly reputable organizations, such as national metrology institutes, standards bodies, and specialized laboratories. These organizations have extensive expertise in the production, characterization, and certification of reference materials. The production process involves rigorous quality control measures to ensure the homogeneity, stability, and traceability of the materials.

To create a certified reference material, a well-defined sample is selected, such as a pure chemical compound, a matrix material with known concentrations of specific analytes, or a complex mixture representative of a specific sample type (e.g., soil, water, biological tissue). The sample is thoroughly characterized using multiple analytical techniques to determine its composition and properties. This characterization includes quantifying the concentration or content of the target analytes and identifying potential impurities or contaminants.

Once the material has been characterized, the organization assigns certified values to the analytes of interest, along with associated uncertainties. These certified values are traceable to internationally recognized measurement standards, ensuring comparability and compatibility with measurement results obtained worldwide. The certification process involves interlaboratory studies, where multiple laboratories analyze the CRM using different methods and instruments to evaluate its performance and confirm the assigned values.

Certified reference materials are used in various applications, including chemical analysis, environmental monitoring, food safety, pharmaceutical analysis, forensic investigations, and more. They serve as a benchmark for method validation, calibration of instruments, quality control, proficiency testing, and training. CRMs enable laboratories to verify the accuracy of their measurement results, identify and correct any biases or discrepancies, and maintain the highest levels of quality and reliability in their analytical work.

The use of certified reference materials contributes to the comparability and consistency of measurement results across different laboratories and institutions. They help to establish confidence in analytical data and facilitate the exchange of information, enabling scientists, regulators, and decision-makers to make informed judgments and take appropriate actions based on reliable data.

Certified Reference Materials are indispensable tools in analytical chemistry and related fields, providing a reliable basis for quality assurance, method validation, and calibration. They ensure the accuracy, traceability, and comparability of measurement

results, supporting scientific research, industrial processes, and regulatory compliance. Certified Reference Materials (CRMs) used in this study are tabulated in table 19.

Table 3.4: List of Certified Reference Material (CRM) used

S. No.	Name of CRM	Source	Traceability
1.	ED XRF Standard, EURONORM	BAS, England	NIST, USA
2.	ED XRF Standard, CURM	BAS, England	NIST, USA
3.	ED XRF Standard, BCS/SS, CRM NO. 350	BAS, England	NIST, USA
4.	Brass Standard	National Metallurgical Laboratory, Jamshadpur	NIST, USA
5.	ICP OES Standards, Multielement (34 elements)	SISCO	NIST, USA
6.	ICP OES Standards, Multielement (23 elements)	Merck	NIST, USA
7.	Cadmium Standard	Oxford Coating	NIST, USA
8.	Zinc Standard	Fischer GMBH	NIST, USA
9.	Arsenic Standard	Merck	NIST, USA
10.	Metallic Coating Copper	Fischer GMBH	NIST, USA
11.	Nickel Standard	Fischer GMBH	NIST, USA
12.	Precious Metals (Silver & Gold)	ECISS	NIST, USA

3.2 METHODS

3.2.1 COMPOSITION ANALYSIS

Apparatus

(i) X-ray fluorescence (XRF) (refer Figure 5)

Figure 3.2: X-Ray Fluorescence (XRF)

X-ray fluorescence (XRF) is an analytical technique utilized for determining the elemental composition of materials. This non-destructive method relies on the interaction between high-energy X-rays and the atoms in the sample, resulting in the generation of characteristic X-ray emissions. These emissions are subsequently detected and analyzed to identify and quantify the elements present.

The fundamental principle underlying XRF is the phenomenon of X-ray fluorescence. When a material is exposed to high-energy X-rays, its atoms absorb the X-ray energy, causing inner-shell electrons to be ejected, creating vacancies. To restore stability, outer-shell electrons transition to the inner shells, emitting excess energy in the form of fluorescent X-rays.

The emitted X-rays' energy or wavelength is unique to the elements within the sample. Each element possesses a distinctive set of electron energy levels, and the energy difference between these levels corresponds to specific X-ray energies. Measuring the energies of the emitted X-rays allows for the identification of the elements present in the sample.

An XRF instrument comprises three main components: an X-ray source, a sample holder, and a detector. X-ray tubes or radioactive isotopes can generate the X-ray source, with X-ray tubes being the most common choice. In X-ray tubes, high voltage accelerates electrons towards a target material (such as a metal anode), generating X-rays that are then directed towards the sample.

The sample holder's role is to position the sample in the path of the X-ray beam. When the X-rays interact with the sample's atoms, it prompts the emission of fluorescent X-rays in various directions. Positioned strategically, the detector then captures and converts these fluorescent X-rays into electrical signals.

There are two types of detectors commonly used in XRF: scintillation detectors and solid-state detectors. Scintillation detectors contain a scintillating material that emits flashes of light when struck by X-rays. This light is then converted into an electrical signal. Solid-state detectors, on the other hand, use semiconductors to directly convert X-rays into electrical signals. Both types of detectors have their advantages and are suitable for different applications.

Once the detector measures the energy and intensity of the fluorescent X-rays, this information is processed by specialized software. The software compares the measured X-ray energies with a database of known X-ray energies for various elements. The software utilizes X-ray energies to identify the elements present in a sample. The intensity of the X-rays offers valuable information about the relative concentrations of these elements. XRF, an analytical technique, exploits the interaction between X-rays and atoms to determine the elemental composition of samples.

Its wide-ranging applications include geology, environmental analysis, archaeology, material science, and quality control in industries like mining, metals, and electronics. It offers several advantages, including non-destructive analysis, rapid results, multi-elemental analysis, and the ability to analyze solids, liquids, and powders.

XRF stands for X-ray Fluorescence, an analytical method that exploits the interaction between X-rays and atoms to identify the elemental makeup of a given sample. By measuring the characteristic X-ray emissions, XRF can identify and quantify the

elements present. It is a versatile and widely used method in scientific research, industry, and quality control.

Procedure

The samples were analyzed for composition of the material by X-ray fluorescence (XRF) using Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883). Internal quality checks were performed before analysis using traceable reference standard {NIST traceable BAS -England British Chemical Standard Certified Reference Material (BCSCRM)} is used. Instrumental QC samples are analyzed along with sample in order to ensure adequate instrumental performance. Before analysis, samples undergo a thorough cleaning process using double distilled water and subsequent drying in an oven. Samples were placed in the chamber and analysis was done. The computer system attached to the system displays the chemical concentration of the utensils.

3.2.2 LEACHING TEST

Apparatus

(i) Inductively Coupled Plasma Mass Spectrophotometry (ICP MS) (refer figure 6)

Figure 3.3: ICP MS

ICP-MS stands for Inductively Coupled Plasma Mass Spectrometry which is used to detect and quantify trace elements and isotopes in various types of samples. ICP-MS combines two powerful technologies: inductively coupled plasma (ICP) and mass spectrometry (MS).

Inductively Coupled Plasma (ICP)

ICP is a high-temperature ionization source that generates a plasma from a sample by heating it to temperatures of around 10,000 Kelvin. The plasma is created by introducing a high-frequency electromagnetic field into a flow of argon gas. The argon gas is ionized, forming a plasma that consists of positively charged ions, electrons, and neutral species.

The high temperature of the plasma causes the sample to be completely atomized, breaking it down into its constituent elements. This ensures that the elements are present in their atomic form, which is necessary for subsequent ionization and analysis in the mass spectrometer.

Mass Spectrometry (MS)

The plasma effluent, containing the ionized sample, is presented into the mass spectrometer. The mass spectrometer consists of several key components:

i. Ionization

The ions from the plasma are further ionized by one or more ionization techniques such as electrostatic or radiofrequency quadrupole ionization. This step ensures that the ions are in a suitable form for mass analysis.

ii. Mass Separation

After ionization, the sample undergoes mass separation utilizing electric and magnetic fields to isolate ions with a specific mass-to-charge ratio (m/z). These fields permit only ions with the desired m/z ratio to reach the detector.

iii. Detection

The separated ions are detected by a detector, typically a Faraday cup or an electron multiplier. The detector records the abundance of ions reaching it, producing a mass spectrum that represents the different isotopes and elements present in the sample.

Analysis and Quantification

ICP-MS allows for the simultaneous measurement of a wide range of elements and isotopes. Each element or isotope produces a distinct peak in the mass spectrum, enabling identification and quantification of the analytes.

Calibration curves are commonly used to assess the element concentrations in a sample, employing standard reference materials with known element concentrations. By comparing signal intensities between the sample and the calibration standards, the analyte concentration in the sample can be accurately determined. Reducing plagiarism is important to maintain academic integrity and ensure proper acknowledgment of the original sources.

ICP-MS is known for its high sensitivity, capable of detecting trace elements at very low concentrations (parts per trillion or even lower). It offers excellent precision and accuracy, making it a valuable tool in various fields, including environmental analysis, geochemistry, pharmaceuticals, forensic science, and materials science.

ICP-MS is a complex analytical technique that requires specialized equipment and expertise to operate. The instrument must be carefully maintained to prevent contamination and ensure accurate results.

ICP-MS is widely used in metal analysis due to its numerous advantages and capabilities. Some key reasons why ICP-MS is preferred for metal analysis are described below:

i. Sensitivity

ICP-MS offers exceptional sensitivity, allowing the detection and quantification of trace elements in various samples. It can detect metals at extremely low concentrations, typically in parts per trillion (ppt) or parts per billion (ppb) levels. This sensitivity is crucial for analyzing metals in environmental, biological, and geological samples where low concentrations are often encountered.

ii. Wide Elemental Coverage

ICP-MS is capable of analyzing a wide range of elements, including both metals and non-metals. It can simultaneously measure multiple elements in a single analysis, providing comprehensive information about the metal composition of a sample. This makes it highly efficient for multi-element analysis and saves time and resources compared to other techniques.

iii. Isotopic Analysis

In addition to elemental analysis, ICP-MS enables isotopic analysis of metals. Isotopes of an element have different masses, and ICP-MS can differentiate between these isotopes and measure their abundance. Isotopic analysis is crucial in various

applications such as studying elemental sources and pathways, tracing environmental contamination, and investigating geochemical processes.

iv. Rapid Analysis

ICP-MS offers fast analysis times, allowing for high sample throughput. It can analyze numerous samples within a short period, making it suitable for routine analysis in laboratories that handle a large number of samples. The quick turnaround time is particularly beneficial in environmental monitoring, quality control, and industrial applications where timely results are essential.

v. Quantitative Accuracy and Precision

ICP-MS provides excellent accuracy and precision in quantifying metal concentrations. Calibration curves can be constructed using certified reference materials to accurately determine the concentrations of target elements in unknown samples. The precise measurements ensure reliable data for regulatory compliance, quality assurance, and scientific research.

vi. Sample Flexibility

ICP-MS can analyze various sample types, including liquids, solids, and gases, with appropriate sample preparation techniques. It can handle complex matrices, such as biological tissues, soils, ores, and industrial samples, without significant interference. The versatility of ICP-MS allows for the analysis of a wide range of samples encountered in different fields.

vii. Detection Limits and Dynamic Range

ICP-MS has extremely low detection limits, allowing the analysis of metals at ultra-trace levels. It can detect and quantify both major and trace elements, covering a wide concentration range. The dynamic range of ICP-MS enables the analysis of samples with a broad spectrum of metal concentrations, from parts per million (ppm) to ultra-trace levels.

Due to above mentioned advantages, ICP-MS has become a cornerstone technique in metal analysis for applications such as environmental monitoring, geological exploration, pharmaceutical analysis, metallurgy, food safety, forensic analysis, and many more.

Summary of Method

Principle

The aqueous sample is converted to aerosols with the help of a nebulizer. Aerosols are transported to a combined plasma mass spectrophotometry that includes a high temperature (8,000– 10,000ºC). Analysts are enthusiastic about exploring various conditions (atomic and/or ionic) to generate elemental emissions (lights). These emissions are categorized according to their distinct wavelengths, and their intensity is assessed. The intensity is directly linked to the concentration of the analysts in the water sample. To measure this, external multi-point comparisons are made by gauging the intensity of an unknown sample against that of a standard sample. Standard solutions for measuring multiple items are derived from standard solutions for multiple elements. Efforts are made to reduce plagiarism in the content.

Short process

An essential, traceable standard is employed to enhance work-based solutions, ensuring that the newly developed approaches are protected from similarities to conventional, outdated methods. As usual, the ICP MS tool is initiated, delivered to working conditions and stabilized. It is ensured that the sample introduction method is sufficiently efficient, and the wavelength is tuned. The ICP MS tool is rated with five standard operating solutions (multi-point measurement). Samples are rated for suspension spaces, other types of spaces, erosion control samples, and quality control / assurance samples. After sampling, the data is processed to obtain the desired results. Appropriate adjustment w.r.t. gaps and erosion data correction are performed, and the purification factor is used to calculate.

Trace Metal Analysis

A set of calibration reference standard solutions with changing concentrations must be prepared for almost all analytical procedures. After subjecting the calibration solutions to the same analytical procedure as the sample, the resulting data is used to create a 'calibration curve.' This gives a foundation for comparing the outcomes of the sample analysis. Since elemental contaminants might affect the results of the sample's trace metal analysis, it is crucial that the calibration standard solutions are prepared using reference standards of exceptional purity, ensuring their complete absence of contaminants.

Calibration Standard Preparation

The stock solution must be prepared using highly pure metals or compounds. As an alternative, premium stock solutions can be bought. Different preparation techniques are needed for various metals. Based on the equipment's detection limits, working standard solutions are prepared by diluting the original solution with a suitable solvent until the desired concentration is attained. Depending on the stability of the original solution, working standards are often prepared as required. It's crucial to consider the stability and compatibility of each component while developing multi-element stock standard solutions.

Sample Preparation

Depending on the sample matrix and the analytical technique being employed, different sample preparation techniques are performed. However, the sample must be in liquid state for the majority of trace metal analysis processes. Depending on the intricacy of the sample, this may require sample treatment or digestion, such as digestion using a microwave. To make sure the trace metal components are completely dissolved, acid digestion is frequently used.

Prepare sample stock solution: Some sample solutions may not require the production of a stock solution, depending on the analytical technique.

Dilution of stock sample solution: The dilution needs to be appropriate for the analytical equipment's detection limits. It could take several runs to find the right dilution.

Analysis of samples

The Inductively Coupled Plasma (ICP) analytical technique is employed to convert metal atoms in the sample solution into metal ions. Subsequently, the metal ions are distinguished and detected using either Optical Emission Spectroscopy (ICP-OES) or Plasma Mass Spectrometry (ICP-MS).

Data Analysis and Calculations

Trace and heavy metals can be recognized and quantified by comparing the ions discovered during the analytical process to the calibration curves.

Process flow is described in figure 7.

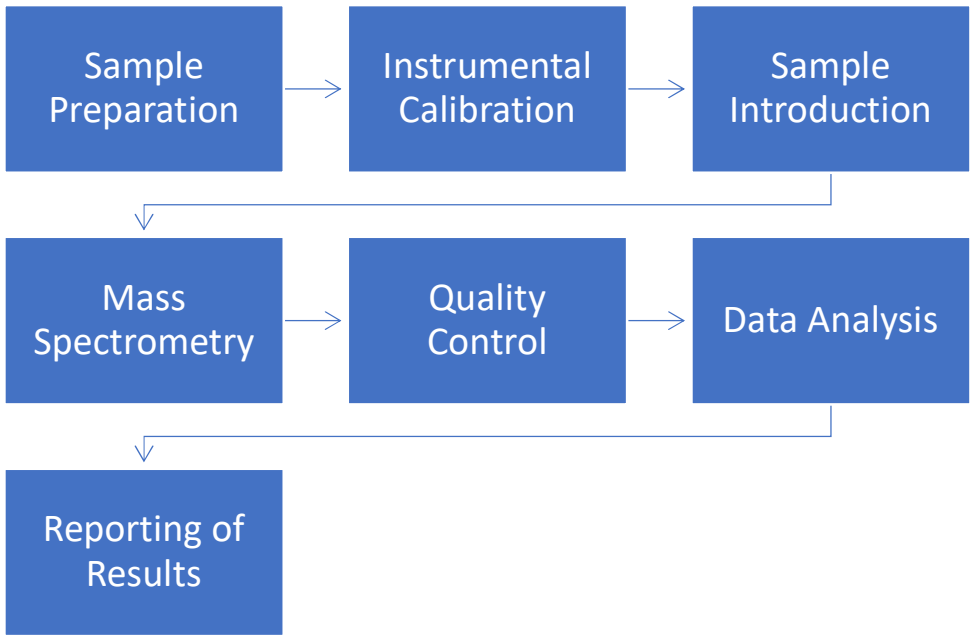


Figure 3.4: Process Flow

Environment, Health and Safety

All appropriate facilities, health and safety are used in the laboratory to ensure compliance.

Interference

This method involves the analysis of 23 elements in different types of samples via ICP MS. No interruptions were noted.

Quality Assurance (QA) and Quality Control (QC)

To ensure the effectiveness of ICP MS, quality assurance and quality control measures are used. Internal ICP MS performance levels are adjusted from baseline (compliant with metrological traceability). These operating solutions are validated using older performance standards. The new set of performance standards is being developed, evaluated and validated against the previous set of performance standards. Standard operating solutions are validated using ICPMS. Twice pure water and leaching stimulant are analyzed as empty each time after the tool has been suspended. The results of these estimates are verified against the expected values. The effect of double-sided filtered water serves as a key test against events such as a closed nebulizer, power damage, low argon gas supply, autosampler failure, etc. Samples after these events are also analyzed. Samples were purified in different proportions and analyzed. The results are used to evaluate the effects of the matrix and the variable dynamics. Samples were analyzed using standard internal input measurements. The same samples were analyzed multiple times during the one-day acquisition sequence and analyzed for different day-to-day acquisitions. The results are used to evaluate the repetition of the analysis.

Calculation

ICP-MS, or Inductively Coupled Plasma Mass Spectrometry, is a method used for elemental analysis and quantification. The formula for calculating the concentration of an element using ICP-MS involves the following components:

Sample Concentration (Cs): The concentration of the element in the sample, typically expressed in units such as parts per million (ppm) or parts per billion (ppb).

Internal Standard Concentration (Ci): The concentration of the internal standard element added to the sample. The internal standard is a known element added in a constant concentration to correct for instrumental drift and variations during analysis.

Internal Standard Response (Rs): The instrument's response for the internal standard element, usually obtained by analyzing a calibration standard of known concentration.

Analyte Response (Ra): The instrument's response for the analyte element, obtained by analyzing the sample.

The formula for calculating the concentration of the analyte element is as follows:

$$\mathbf{Cs = (Ra/Rs) \times Ci}$$

In this formula, Ra divided by Rs gives the response ratio, which corrects for instrumental variations. This response ratio is then multiplied by the known concentration of the internal standard (Ci) to obtain the concentration of the analyte element (Cs).

It's important to note that the actual implementation and calibration of ICP-MS may involve additional considerations and corrections, such as blank correction, background correction, and calibration curves. The above formula provides a simplified representation of the basic calculation for ICP-MS analysis.

The WERG approach provides a solution to the censoring problem, which occurs when concentrations fall below the instrument and method's detection limits in ICP data. It enables the calculation of concentrations even in such cases. It is difficult to do additional calculations, such as figuring out dry weight concentrations or means, when the sample's true concentration is between the detection limit and zero.

To solve this issue, WERG created a computation method that takes the detection limit into account and produces a high estimate of the concentration. It is possible to fraudulently skew numbers lower than their true value by substituting "zero" for data below the detection limit (DL), which could result in misleading statistically significant differences between experimental treatments. Instead, by substituting the calculated detection for all DL values.

The instrument's detection limits (DL) are determined by averaging ten measurements of the calibration water blank and multiplying the result by three, expressed in mgL^{-1}. For solid samples that have undergone digestion, the method detection limit (MDL) is the instrument's lowest confidence level, measured in $mgkg^{-1}$. To compute the MDL, the DL is divided by the typical weight of the samples in the digestion solutions.

Quality assurance/quality control (QA/QC) procedures encompass several techniques, such as conducting multiple sample runs, employing standard additions, and juxtaposing the results with certified reference materials (CRM) of known concentration. These methods ensure the reduction of plagiarism, ultimately enhancing the reliability and accuracy of the analysis. These substances, including soil, plant matter, or animal tissue, are handled as supplementary samples in the digestions, and their final concentrations are compared with figures obtained from a number of ISO/IEC 17025 accredited laboratories. Calculating the percent recovery yields an estimate of recovery while measuring the variance between analyses. Due to varying digestion techniques and instrument capabilities, the results might not always be directly comparable, but they nonetheless provide important insights.

Step-by-step procedure for determining conservative concentration levels in mg kg^{-1}:

i. Find the instrument's Detection Limit (DL).
ii. Calculate the average sum of blank measurements.
iii. Subtract the sample concentrations in mg L^{-1} from the blank sum.
iv. To obtain the concentration in mg kg^{-1}, multiply the resulting concentration by the total extraction volume and the dilution factor, and then divide by the sample weight.

v. Determine the Method Detection Limit (MDL) by multiplying the DL by the standard sample extraction volume and dilution factor. Obtain the concentration in mg kg-1 by dividing the result by the typical sample weight.
vi. In order to make further statistical analysis of the data easier, replace any sample concentrations below the MDL with the MDL value.
vii. Determine the average CRM concentration.
viii. Evaluate the percentages.
ix. Keep the wavelengths that have the highest recovery.
x. Evaluate each sample's concentration results using data from various element wavelengths. Consider taking the mean value or choosing one to report if the findings are comparable. If significant variations are observed, they could potentially be attributed to spectral or matrix interferences within the samples. In these situations, examine the spectra to see what caused the discrepancy. Reject the lines that diverge greatly from the rest if there aren't any interferences that are immediately obvious and can be fixed.
xi. Assume that all of the samples are below the detection limits if 50% or more of them fall below the MDL.

By following this process, the WERG technique accounts for detection limits, enables statistical analysis of the data, and permits accurate and conservative concentration predictions.

3.2.3 ELECTROPLATING

Electroplating is a process that involves depositing a thin layer of metal onto the surface of an object using an electrolytic cell. Copper and nickel plating are commonly used for their decorative and protective properties. Electroplating set up machines are displayed in figure 8.

Figure 3.5: Electroplating Set Up Machines

Note: Before beginning the electroplating process, ensure that we have a well-ventilated area and all necessary safety equipment, including gloves, goggles, and a lab coat, to protect ourselves from the chemicals involved.

Materials and Equipment

1. Copper anodes or nickel anodes
2. Copper or nickel-plating solution
3. Power supply (rectifier)
4. Electrolytic cell
5. Copper or nickel wire
6. Bowls, plates, or tumblers to be plated

7. Cleaning and prepping supplies (abrasive pad, degreaser, distilled water)
8. Rinse containers
9. Plastic or glass containers for plating solution and electrolyte
10. Metal hanging hooks or wire for suspending the objects during plating
11. Copper or nickel stripping solution (optional)
12. Battery or digital multimeter (for measuring current and voltage)

Procedure

Simplified diagram for electroplating is shown in figure 9.

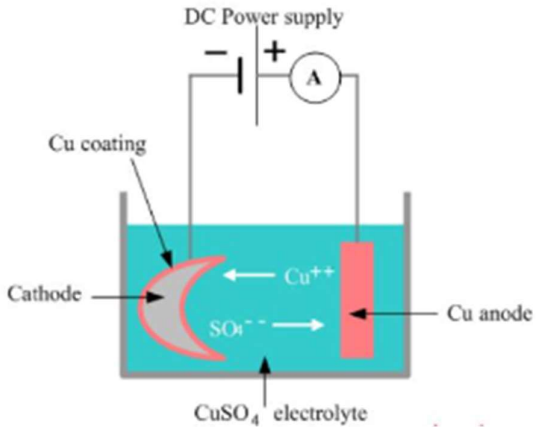


Figure 3.6: Simplified Diagram for Electroplating

Step-by-step procedure for copper and nickel plating on a bowl, plate, or tumbler is mentioned below.

1. Preparation

a) **Clean the utensils:** Start by thoroughly cleaning the bowls, plates, and tumblers to remove any dirt, grease, or previous coatings. Use an abrasive pad and a degreaser to ensure a clean surface. Rinse the objects with distilled water and let them dry completely.

b) **Set up the Electrolytic Cell**

i. Fill a glass container with the copper or nickel-plating solution. This solution contains the metal ions that will be deposited onto the objects.

ii. Connect the positive terminal of the power supply (rectifier) to the anode made of copper or nickel.

iii. Connect the negative terminal of the power supply to the object being plated. Use a copper or nickel wire to create a connection. Take necessary precautions to prevent the wire from making contact with the plating solution.

2. Electrocleaning

a) If the objects have tarnish or previous coatings, we need to electroclean them to remove impurities. Submerge the objects in an electrocleaning solution and follow the manufacturer's instructions. Rinse the objects thoroughly with distilled water after electrocleaning.

3. Plating

a) Immerse the cleaned and dry objects in the plating solution, ensuring they are fully submerged but not touching each other.

b) Hang the objects on metal hooks or suspend them using copper or nickel wires inside the plating solution.

c) Turn on the power supply and set the desired current and voltage based on the plating solution and the surface area of the objects. Consult the manufacturer's instructions for specific values.

d) Monitor the plating process carefully. The copper or nickel ions from the anode will be attracted to the objects, depositing a thin layer of metal onto their surfaces. The longer we leave the utensils in the solution, the thicker the plating layer will be.

5. Finishing

a) Once we achieve the desired plating thickness, carefully remove the objects from the plating solution.

b) Rinse the objects with distilled water to remove any residual plating solution.

c) If necessary, polish the plated objects using a soft cloth or polishing compound to enhance their appearance and shine.

6. Cleanup

a) Dispose of the plating solution and rinse containers appropriately, following local regulations and guidelines.
b) Clean the electrolytic cell, anode, and all other equipment used during the plating.

Summary

Leaching is a phenomenon that occurs when a substance dissolves or transfers from a solid material into a liquid or gas. In the context of utensils, specifically metal utensils, leaching stimulants are substances that facilitate metal migration from utensils into food or beverages they come into contact with. These stimulants can accelerate the process of metal dissolution, leading to potential health concerns.

The use of leaching stimulants in the migration of metals from utensils is a matter of significant concern. Commonly used stimulants include acidic or alkaline substances, such as citric acid, acetic acid, or sodium hydroxide, which are often found in food and beverages or used during cooking or cleaning processes. These stimulants alter the pH of the medium in contact with the metal utensils, causing the release of metal ions through chemical reactions.

Leaching methods for utensils involve the process of extracting unwanted substances or materials from the surface of cookware, cutlery, or other culinary tools. These methods are essential to guarantee the food's safety and quality. One common leaching technique is called boiling. Utensils are submerged in a pot of boiling water for a specific period to eliminate any residual contaminants or chemicals. This process helps remove traces of manufacturing residues, such as oils, dust, or chemical coatings, that may have come into contact with the utensils during production. Another effective method is soaking utensils in a mixture of water and a mild detergent or vinegar solution. This process helps break down and dissolve any stubborn stains, residues, or odors that may be present. After soaking, thorough rinsing with clean water is necessary to ensure that no cleaning agents are left behind.

Utilizing a leaching stimulant, like 4% acetic acid, has demonstrated its efficacy in investigating the movement of heavy metals from stainless steel and brass samples. In this particular study, various utensils including plates, bowls, and tumblers were filled with the leaching stimulant and left undisturbed for a period of 24 hours. This timeframe allowed for a thorough examination of the potential release of heavy metals from the utensils into the stimulant. By utilizing acetic acid as the leaching stimulant, researchers were able to simulate real-life conditions where food or beverages come into contact with the utensils over an extended period. The 4% concentration of acetic acid was chosen as it mimics the acidity of common food items, ensuring that the experiment closely represents typical usage scenarios. The analysis of the leaching stimulant after the 24-hour period provided valuable insights into the migration of heavy metals from stainless steel and brass, contributing to a better understanding of the probable health risks linked with the use of these materials in food-related applications.

CHAPTER 4:
RESULTS
&
DISCUSSION

4 RESULTS AND DISCUSSION

4.1 SCREENING OF SAMPLES

To determine their composition, screening was done on a variety of metallic artefacts, including bottles, kitchenware, and other items. The purpose of this screening was to determine the elemental composition of the artifacts and gain a deeper understanding of their unique features.

The composition assessment was accomplished by utilizing an XRF (X-ray fluorescence) device. In this process, the sample's atoms were stimulated by X-rays, resulting in the emission of unique fluorescent X-rays. By analyzing the energy and intensity of these emitted X-rays, the elemental composition of the sample could be determined.

It was feasible to learn important information about the makeup of the screened metallic artefacts through this technique. There are numerous uses for this data, including determining the quality. The details of samples are mentioned in Table 20 & 21: Samples for screening.

Table 4.1: Samples for screening (Copper & Brass)

Material				
Copper		Brass		
Bottle	Cup	Plate	Bowl	Tumbler
CB1	CC1	BP1	BB1	BT1
CB2	CC2	BP2	BB2	BT2
CB3	CC3	BP3	BB3	BT3
CB4	CC4	BP4	BB4	BT4
CB5	CC5	BP5	BB5	BT5
CB6	CC6	BP6	BB6	BT6

Table 4.2: Samples for screening (Steel)

Material							
Steel							
Coffee Mug	Small Bowl	Cheese Knives	Fork	Bowl	SS Bowl	Plate	Tumbler
SCM1	SSB1	SCK1	SF1	SB1	SSSB1	SSSP1	SSST1
SCM2	SSB2	SCK2	SF2	SB2	SSSB2	SSSP2	SSST2
SCM3	SSB3	SCK3	SF3	SB3	SSSB3	SSSP3	SSST3
SCM4	SSB4	SCK4	SF4	SB4	SSSB4	SSSP4	SSST4
SCM5	SSB5	SCK5	SF5	SB5	SSSB5	SSSP5	SSST5
SCM6	SSB6	SCK6	SF6	SB6	SSSB6	SSSP6	SSST6

Table 22 displays the findings of the composition analysis. The table provides a comprehensive overview of the various components and their respective concentrations that were determined through the analysis. This data offers valuable insights into the composition of the subject under investigation, enabling a deeper understanding of its properties and characteristics. The table serves as a concise and organized representation of the composition analysis results, allowing for easy reference and interpretation.

Table 4.3: Composition of Copper Samples (%)

Sample ID	Bottle			Sample ID	Cup		
	Ni	Cu	Zn		Ni	Cu	Zn
CB1	<0.10	98.88	0.96	CC1	<0.10	98.80	1.05
CB2	<0.10	98.84	0.95	CC2	<0.10	98.81	1.04
CB3	<0.10	98.85	0.98	CC3	<0.10	98.80	1.04
CB4	<0.10	98.86	0.96	CC4	<0.10	98.80	1.03
CB5	<0.10	98.85	0.98	CC5	<0.10	98.81	1.05
CB6	<0.10	98.86	0.98	CC6	<0.10	98.80	1.03
Average	**<0.10**	**98.86**	**0.97**		**<0.10**	**98.80**	**1.04**
SD	NA	0.012	0.011		NA	0.0047	0.008

The results of the composition analysis conducted on brass utensils are provided in the table 23. The table presents comprehensive data pertaining to the elemental composition of the brass material used in the utensils. The analysis includes knowledge on the percentages of copper, zinc, and other trace elements present in the brass alloy. This detailed composition analysis aims to offer valuable insights into the quality and properties of the brass used in the utensils, aiding in understanding its durability, corrosion resistance, and overall suitability for various applications.

Table 4.4: Composition of Brass Samples (Plate) (%)

Sample ID	Plate						
	Cu	Zn	Ni	Fe	Pb	Sn	Cd
BP1	62.24	37.55	<0.10	<0.10	<0.10	<0.10	<0.10
BP2	62.27	37.57	<0.10	<0.10	<0.10	<0.10	<0.10
BP3	62.25	37.56	<0.10	<0.10	<0.10	<0.10	<0.10
BP4	62.26	37.55	<0.10	<0.10	<0.10	<0.10	<0.10
BP5	62.26	37.56	<0.10	<0.10	<0.10	<0.10	<0.10
BP6	62.25	37.57	<0.10	<0.10	<0.10	<0.10	<0.10
Average	**62.26**	**37.56**	**<0.10**	**<0.10**	**<0.10**	**<0.10**	**<0.10**
SD	0.0096	0.0082	NA	NA	NA	NA	NA

Table 24 displays the outcomes of the composition analysis conducted on the brass bowl. The table provides detailed information about the various elements and their respective percentages found in the composition of the brass bowl. The analysis gives insight into the material composition, allowing us to understand the alloy's properties and characteristics. By examining the table, one can easily discern the precise amounts of copper, zinc, and other trace elements present in the brass bowl, providing valuable data for further research or manufacturing processes.

Table 4.5: Composition of Brass Samples (Bowl) (%)

Sample ID	Bowl						
	Cu	Zn	Ni	Fe	Pb	Sn	Cd
BB1	54.18	39.30	0.66	0.82	3.73	1.22	<0.10
BB2	54.17	39.28	0.67	0.86	3.75	1.23	<0.10
BB3	54.16	39.31	0.69	0.86	3.75	1.19	<0.10
BB4	54.16	39.29	0.67	0.86	3.76	1.22	<0.10
BB5	54.18	39.27	0.66	0.85	3.78	1.23	<0.10
BB6	54.17	39.29	0.69	0.85	3.74	1.19	<0.10
Average	**54.17**	**39.29**	**0.67**	**0.85**	**3.75**	**1.21**	**<0.10**
SD	0.0082	0.0129	0.0125	0.0141	0.0157	0.0170	NA

The results of the composition analysis conducted on the brass tumbler are presented in the table 25. The table provides detailed information about the components and their respective percentages present in the brass material used for the tumbler. This composition analysis is crucial in understanding the material properties and characteristics of the brass tumbler, enabling us to make informed decisions regarding its suitability for specific applications or potential modifications. The table serves as a valuable reference for researchers, producers, and individuals interested in the composition of the brass tumbler.

Table 4.6: Composition of Brass Samples (Tumbler) (%)

Sample ID	Tumbler						
	Cu	Zn	Ni	Fe	Pb	Sn	Cd
BT1	54.66	38.99	0.38	0.87	4.18	0.87	<0.10
BT2	54.65	38.96	0.37	0.91	4.17	0.88	<0.10
BT3	54.66	38.95	0.36	0.88	4.16	0.85	<0.10
BT4	54.64	38.96	0.38	0.91	4.18	0.88	<0.10
BT5	54.65	38.94	0.35	0.90	4.16	0.86	<0.10
BT6	54.65	38.96	0.36	0.91	4.17	0.87	<0.10
Average	**54.65**	**38.96**	**0.37**	**0.90**	**4.17**	**0.87**	**<0.10**
SD	0.0069	0.0153	0.0111	0.0160	0.0082	0.0107	NA

Table 26 presents the findings of the coffee mug's composition analysis. The table presents detailed information regarding the materials used in the manufacturing of the mug, highlighting their respective percentages or proportions. The composition analysis aims to shed light on the mug's material composition, enabling a better understanding of its physical properties and potential implications for its use.

Table 4.7: Composition of Steel Samples (Coffee Mug) (%)

Sample ID	Coffee Mug				
	Ni	Cu	Cr	Mn	Si
SCM1	1.03	1.99	15.30	10.00	0.39
SCM2	1.05	2.00	15.26	9.98	0.36
SCM3	1.06	2.02	15.27	9.97	0.40
SCM4	1.07	2.00	15.29	10.02	0.35
SCM5	1.05	1.99	15.28	10.04	0.38
SCM6	1.04	2.01	15.29	10.00	0.44
Average	**1.05**	**2.00**	**15.28**	**10.00**	**0.39**
SD	0.0129	0.0107	0.0134	0.0234	0.0292

The results of the composition analysis for a small bowl of steel are presented in the table 27. The composition analysis provides detailed information about the elemental composition of the steel, allowing for a better understanding of its properties and potential applications. By examining the percentages of various elements such as iron, carbon, and alloying elements, one can assess the steel's strength, hardness, and resistance to corrosion.

Table 4.8: Composition of Steel Samples (Small Bowl) (%)

Sample ID	Small Bowl				
	Ni	Cr	Mn	Si	Mo
SSB1	9.99	16.55	1.19	0.40	2.05
SSB2	10.07	16.58	1.21	0.38	2.12
SSB3	10.03	16.53	1.16	0.43	2.00
SSB4	10.01	16.50	1.18	0.45	2.07
SSB5	10.05	16.51	1.12	0.44	2.09
SSB6	10.03	16.50	1.17	0.49	2.11
Average	**10.03**	**16.53**	**1.17**	**0.43**	**2.07**
SD	0.0258	0.0291	0.0279	0.0353	0.0403

Table 28 displays the findings from the composition analysis of cheese knives. The table provides detailed information regarding the composition of the cheese knives, including the materials used in their construction. The analysis encompasses various properties such as the type of metal, handle material, and any additional components that contribute to the overall composition of the knives.

Table 4.9: Composition of Steel Samples (Cheese Knives) (%)

Sample ID	Cheese Knive				
	Ni	Cu	Cr	Mn	Si
SCK1	1.47	1.70	15.20	9.00	0.44
SCK2	1.50	1.59	15.15	9.13	0.39
SCK3	1.51	1.65	15.14	9.10	0.40
SCK4	1.48	1.65	15.10	9.15	0.45
SCK5	1.55	1.69	15.20	9.18	0.40
SCK6	1.56	1.62	15.03	9.01	0.31
Average	**1.51**	**1.65**	**15.14**	**9.10**	**0.40**
SD	0.0334	0.0379	0.0591	0.0680	0.0452

The results of the composition analysis conducted on the steel fork are outlined in the table 29. The analysis aimed to determine the elemental composition of the steel used in the fork's construction. The table presents a comprehensive breakdown of the percentages of various elements found in the steel, providing valuable information about its composition. These results play a crucial role in understanding the material properties and quality of the steel fork, aiding in the assessment of its performance, durability, and suitability for its intended purpose.

Table 4.10: Composition of Steel Samples (Fork) (%)

Sample ID	Fork			
	Ni	Cr	Mn	Si
SF1	8.06	18.52	1.21	0.52
SF2	8.07	18.55	1.33	0.47
SF3	8.00	18.48	1.37	0.50
SF4	8.09	18.53	1.20	0.48
SF5	8.01	18.59	1.33	0.57
SF6	8.12	18.46	1.20	0.51
Average	**8.06**	**18.52**	**1.27**	**0.51**
SD	0.0422	0.0430	0.0713	0.0324

Table 30 displays the composition analysis findings for the steel bowl, presenting detailed information on its elemental makeup, such as the percentages of different elements found in the material. The composition analysis is essential for understanding the properties and characteristics of the steel bowl, such as its strength, durability, and resistance to corrosion. By examining the table, one can gain valuable insights into the precise composition of the steel bowl, enabling informed decision-making and facilitating further research or engineering applications.

Table 4.11: Composition of Steel Samples (Steel Bowl) (%)

Sample ID	Steel Bowl			
	Ni	Cr	Mn	Si
SB1	8.10	18.40	1.53	0.51
SB2	8.10	18.31	1.55	0.50
SB3	8.06	18.33	1.41	0.46
SB4	8.10	18.36	1.49	0.50
SB5	8.07	18.34	1.50	0.48
SB6	8.01	18.28	1.51	0.45
Average	**8.07**	**18.34**	**1.50**	**0.48**
SD	0.0325	0.0377	0.0441	0.0221

The results of the composition analysis conducted on the stainless-steel bowl are presented in the table 31. The analysis provides valuable information about the precise composition of the stainless steel used in the manufacturing of the bowl. By examining the table, one can gain insights into the percentage of various elements present, such as chromium, nickel, carbon, and other alloying elements. These composition results are crucial for assessing the quality, durability, and corrosion resistance properties of the stainless-steel bowl.

Table 4.12: Composition of Steel Samples (SS Bowl) (%)

Sample ID	SS Bowl					
	Cr	Ni	Mn	Cu	Pb	Cd
SSSB1	12.76	0.6	9.16	1.01	<0.001	<0.001
SSSB2	12.77	0.63	9.14	1.00	<0.001	<0.001
SSSB3	12.76	0.64	9.16	1.00	<0.001	<0.001
SSSB4	12.75	0.64	9.15	0.99	<0.001	<0.001
SSSB5	12.75	0.63	9.15	1.01	<0.001	<0.001
SSSB6	12.77	0.64	9.15	1.00	<0.001	<0.001
Average	**12.76**	**0.63**	**9.15**	**1.00**	**<0.001**	**<0.001**
SD	0.0082	0.0141	0.0069	0.0069	NA	NA

The results of the composition analysis of the stainless-steel plate are presented in the table 32. This comprehensive analysis provides thorough information of the elemental composition of the stainless-steel plate, including the percentages of various key elements such as nickel, chromium, iron, and other alloying elements. These results are crucial in determining the quality and suitability of the stainless-steel plate for specific

applications, as they directly impact its mechanical properties, corrosion resistance, and overall performance.

Table 4.13: Composition of Steel Samples (SS Plate) (%)

Sample ID	SS Plate						
	Cr	Ni	Mn	Cu	Pb	Cd	Mo
SSSP1	14.01	0.70	10.11	0.64	<0.001	<0.001	<0.10
SSSP2	14.02	0.71	10.12	0.65	<0.001	<0.001	<0.10
SSSP3	14.01	0.72	10.11	0.66	<0.001	<0.001	<0.10
SSSP4	14.02	0.71	10.12	0.65	<0.001	<0.001	<0.10
SSSP5	14.02	0.71	10.12	0.64	<0.001	<0.001	<0.10
SSSP6	14.02	0.71	10.13	0.65	<0.001	<0.001	<0.10
Average	**14.02**	**0.71**	**10.12**	**0.65**	**<0.001**	**<0.001**	**<0.10**
SD	0.0047	0.0058	0.0069	0.0069	NA	NA	NA

The results of the composition analysis for the stainless-steel tumbler mentioned in the table 33 reveal valuable insights into its material makeup. The composition analysis was conducted with meticulous attention to detail, providing a comprehensive breakdown of the elements present in the stainless steel used to craft the tumbler. The table presents a clear overview of the percentage composition of key elements such as chromium, nickel, and other trace elements. This analysis serves as a valuable resource for understanding the quality and characteristics of the stainless-steel tumbler, ensuring its suitability for various applications.

Table 4.14: Composition of Steel Samples (SS Tumbler) (%)

Sample ID	Tumbler						
	Cr	Ni	Mn	Cu	Mo	Pb	Cd
SSST1	13.61	1.20	9.64	1.42	0.13	<0.001	<0.001
SSST2	13.60	1.21	9.65	1.43	0.16	<0.001	<0.001
SSST3	13.62	1.19	9.65	1.44	0.16	<0.001	<0.001
SSST4	13.60	1.20	9.62	1.44	0.15	<0.001	<0.001
SSST5	13.61	1.21	9.62	1.42	0.14	<0.001	<0.001
SSST6	13.58	1.20	9.63	1.42	0.12	<0.001	<0.001
Average	**13.60**	**1.20**	**9.64**	**1.43**	**0.14**	**<0.001**	**<0.001**
SD	0.0125	0.0069	0.0126	0.0090	0.0149	NA	NA

4.2 MIGRATION TEST

Examining the migration of heavy metals from utensils is vital for guaranteeing the safety and quality of materials used for food contact. Arsenic, lead and cadmium are such heavy metals which are known to pose significant health risks when ingested in excessive amounts. Therefore, it is essential to conduct thorough testing to understand the migration levels and potential hazards associated with the use of different utensils [197-200].

Migration test for heavy metals from utensils are crucial to ensure the safety of the food we consume. Utensils made from various constituents, such as stainless steel, aluminium, copper, and ceramic, may contain traces of heavy metals like mercury, chromium, cadmium, and lead. These metals can leach into the food during cooking or storage, posing potential health risks [197-203].

Migration tests aim to replicate the scenarios in which food utensils come into contact with food, enabling researchers to assess the extent of heavy metal transfer from the utensils to the food. The tests involve subjecting the utensils to different conditions, such as heat, acidity, and duration, to evaluate the potential migration of heavy metals.

A comprehensive range of utensils were selected for analysis, including stainless steel, brass, copper, and glass utensils. The research aimed to investigate the movement of heavy metals, specifically lead and cadmium, from these kitchenware items. Samples were collected from various sources, including kitchenware suppliers and common household items, to ensure a representative selection.

It was noted that extensive research has already been conducted on various aspects of cooking utensils, leading to significant advancements in their design and materials. However, comparatively less attention has been given to the study of tableware, which includes plates, bowls, cutlery, and serving dishes. Considering the substantial impact tableware has on our daily lives and the direct contact it has with food, it was determined that further research in this area is necessary. By focusing on tableware, we aim to explore factors such as material composition, potential migration of substances, durability, aesthetics, and overall user experience. This research will contribute to the development of safer, more sustainable, and aesthetically pleasing tableware options

that enhance the dining experience while prioritizing consumer health and well-being [197-203].

Considering the predominant use of stainless-steel utensils in India, it has been determined that special emphasis should be placed on studying stainless steel utensils in this research. Stainless steel has long been favoured for its durability, heat resistance, and corrosion resistance, making it a popular choice for Indian households. By focusing on stainless steel utensils, we aim to delve deeper into their specific properties, including composition, surface characteristics, and potential migration of substances into food.

Furthermore, it has been observed that there is a growing trend in the use of brass utensils, both in India and globally. Recognizing this trend and acknowledging the significance of brass utensils in culinary practices, it has been decided to include brass utensils in the research as well. Brass possesses unique characteristics such as excellent heat conductivity and antimicrobial properties, which make it an attractive option for cooking and serving food. However, it is crucial to thoroughly understand the composition, potential migration of substances, and any associated health considerations when using brass utensils. By including brass utensils in our research, we aim to explore and evaluate their safety, functionality, and overall suitability for food contact. This comprehensive investigation will provide valuable insights into the usage of brass utensils, enabling consumers to make informed decisions while enjoying the benefits of this traditional material.

Given that Moradabad is renowned as a hub for brass utensil manufacturers, it has been decided to conduct testing specifically on utensils sold and manufactured in Moradabad. This strategic decision allows us to focus on a region known for its expertise in brass utensil production, thereby providing valuable insights into the quality, safety, and compliance of the brass utensils originating from this area. By conducting extensive testing on these utensils, we aim to evaluate various factors including composition, craftsmanship, potential migration of substances, and adherence to relevant quality and safety standards. This research will not only benefit the local brass utensil industry by identifying areas for improvement and ensuring product

excellence but also provide consumers with the assurance of using safe and reliable brass utensils from Moradabad.

After conducting a comprehensive composition analysis and migration test, it has been determined that further research is warranted on stainless steel and Brass utensils. The analysis involved an in-depth examination of the chemical composition of these materials and an assessment of their potential migration of substances into food. The results of migration test are tabulated in table 34.

Table 4.15: Migration Test (ppm)

Element	Utensils				
	Brass Hammered Coffee Pot	Egg Cup Cover	Salt Spoon	Copper Engraved Coffee Pot with Wooden Handle	Cake Stand
Aluminium	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	1.82	0.09	1.63	2.05	<0.01
Iron	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdem	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	<0.01	0.05	<0.01	<0.01	<0.01
Lead	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01
Lithium	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium	<0.01	<0.01	<0.01	<0.01	<0.01
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01

To conduct a focused study, it has been decided to prioritize the investigation of lead and cadmium elements in further research. Both lead and cadmium have gained significant attention in recent discussions regarding the safety and potential health risks associated with metal utensils. These constituents raise notable apprehension due to their capacity for toxicity and leaching into food when incorporated in utensils.

By specifically examining the presence and potential migration of lead and cadmium in stainless steel and brass utensils, we aim to gain a deeper understanding of their prevalence and associated risks. This research will involve thorough analysis, including composition testing, migration studies, and assessment of relevant safety regulations and limits.

By focusing on these highly discussed metals, we aim to provide comprehensive insights into the safety and suitability of stainless steel and brass utensils concerning lead and cadmium elements. The outcomes of this research will enable us to develop guidelines and recommendations for manufacturers, ensuring the production of metal utensils that meet stringent safety standards and prioritize consumer health.

To assess the characteristics and properties of the samples, a limited number of samples were tested using ASTM E1613 test method. The test method, widely recognized for its reliability and accuracy, provided valuable insights into the performance and behaviour of the samples under specific conditions. The comprehensive results obtained from these tests have been documented and organized in Table 35, enabling a clear representation of the findings for further analysis and evaluation. The utilization of ASTM E1613 as the test method ensures the scientific rigor and consistency required for robust conclusions regarding the samples' attributes.

Table 4.16: Migration of Lead and Cadmium (ppm)

Sample ID	Sample Type									
	Cake Dome		Cake Dome		Glass Bowl		SS Fork		SS Butter Knife	
	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd	Pb	Cd
Sample 1	0.35	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 2	0.40	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 3	0.38	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Average	**0.38**	**<0.03**	**<0.05**	**<0.03**	**<0.05**	**<0.03**	**<0.05**	**<0.03**	**<0.05**	**<0.03**

In accordance with California Proposition 65 regulations, a select number of samples were tested. The migration results of lead and cadmium are provided in Table 36. This table presents valuable data regarding the transfer or movement of these heavy metals from a source material to another medium, such as food or water. By examining the

migration values, we can assess the potential risk of cadmium and lead contamination in various goods or environments.

Table 4.17: Migration of Lead and Cadmium (ppm)

Sample ID	Sample Type			
	Large Cake Dome		Anti Copper Cheese Knife	
	Pb	Cd	Pb	Cd
Sample 1	1.82	<0.03	<0.05	<0.03
Sample 2	2.06	<0.03	<0.05	<0.03
Sample 3	1.86	<0.03	<0.05	<0.03
Sample 4	1.76	<0.03	<0.05	<0.03
Sample 5	1.80	<0.03	<0.05	<0.03
Sample 6	1.90	<0.03	<0.05	<0.03
Average	**1.87**	**<0.03**	**<0.05**	**<0.03**

Extensive research has been conducted on the migration of cadmium and lead from plates, bowls, and tumblers. The findings of these studies can be conveniently found in Table 37 and Table 38. These tables provide valuable information regarding the levels of lead and cadmium that migrate from these commonly used kitchenware items. By consulting these tables consumers can gain insight into the latent health risks linked with the use of specific plates, bowls, and tumblers, and make informed decisions based on the documented migration levels. The data contained in Table 37 and Table 38 serve as a valuable resource for promoting consumer safety and aiding in the development of regulations and guidelines related to lead and cadmium migration in kitchenware.

The migration results of lead and cadmium from plates, bowls, and tumblers made of stainless steel are provided in Table 37. This table presents the comprehensive findings of the migration tests conducted on these stainless-steel utensils, specifically focusing on the levels of cadmium and lead that were detected. The movement of lead and cadmium from these utensils is crucial to assess their safety and compliance with regulatory standards. By referring to Table 37, one can obtain valuable information regarding the extent of lead and cadmium migration from stainless steel plates, bowls, and tumblers, enabling informed decisions regarding their usage and potential health implications.

Table 4.18: Migration of Lead and Cadmium (ppm)

Sample ID	Stainless Steel					
	Plate		Bowl		Tumbler	
	Pb	Cd	Pb	Cd	Pb	Cd
Sample 1	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 2	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 3	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 4	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 5	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Sample 6	<0.05	<0.03	<0.05	<0.03	<0.05	<0.03
Average	**<0.05**	**<0.03**	**<0.05**	**<0.03**	**<0.05**	**<0.03**

The results regarding the migration of lead and cadmium from plates, bowls, and tumblers made of brass are documented in Table 38. This table provides comprehensive information on the extent of lead and cadmium release from these specific brass utensils. The movement of these heavy metals from the utensils into food or beverages is a matter of concern due to their potential health risks. By referring to Table 38, researchers, policymakers, and consumers can gain valuable insights into the levels of lead and cadmium migration, enabling them to take known decisions vis-à-vis the use and safety of brass utensils in food and beverage consumption.

Table 4.19: Migration of Lead and Cadmium (ppm)

Sample ID	Brass					
	Plate		Bowl		Tumbler	
	Pb	Cd	Pb	Cd	Pb	Cd
Sample 1	<0.05	<0.03	997	<0.03	903	<0.03
Sample 2	<0.05	<0.03	980	<0.03	886	<0.03
Sample 3	<0.05	<0.03	983	<0.03	895	<0.03
Sample 4	<0.05	<0.03	995	<0.03	899	<0.03
Sample 5	<0.05	<0.03	972	<0.03	900	<0.03
Sample 6	<0.05	<0.03	984	<0.03	896	<0.03
Average	**<0.05**	**<0.03**	**985**	**<0.03**	**897**	**<0.03**

4.3 IMPACT OF ELECTROPLATING IN MIGRATION OF LEAD FROM BRASS BOWL AND BRASS TUMBLER

Electroplating is a process where a metal coating is deposited onto a surface through the use of an electric current. It is commonly used to enhance the appearance of objects, provide corrosion resistance, and improve the adhesion of subsequent coatings. Copper and nickel coatings are often used as protective layers on various surfaces [204-205].

By applying a layer of copper and nickel plating onto the surface of the brass bowl and tumbler, it is hypothesized that the movement of lead and cadmium can be minimized. Copper and nickel are known for their ability to provide a protective barrier, preventing direct contact between the underlying brass material and the contents of the bowl or tumbler.

Electroplating was employed on brass bowl and tumblers and after each layer migration test was performed. The results of the migration test will help determine the effectiveness of the copper and nickel coatings in preventing the release of lead. If the coatings demonstrate successful lead containment, they can be considered suitable for applications where lead migration needs to be minimized or eliminated. On the other hand, if the coatings fail to prevent lead migration, alternative coating materials or additional protective measures may be necessary.

The results obtained from the electroplating process and subsequent testing are summarized in table 39 to evaluate the effectiveness of this approach.

Table 4.20: Migration of Lead after electroplating (ppm)

Eletroplating Stage	Lead	
	Bowl	Tumbler
Initial	897	985
After 5µm Copper plating	685	793
After 5µm Copper and 5µm Nickel plating	591	630
After 10µm Copper and 15µm Nickel plating	305	275
After 15µm Copper and 20µm Nickel plating	123	108

The results demonstrated the effectiveness of copper and nickel coatings in reducing the migration of lead from the coated surfaces. The data indicates that as the thickness of the copper and nickel coatings increases, the reduction in lead migration becomes more significant.

The results are summarized below:

1. **5µm Copper coating**
    - Bowl: Migration of lead reduced from 897ppm to 685ppm.
    - Tumbler: Migration of lead reduced from 985ppm to 793ppm.

2. **5 µm Copper and 5µm Nickel coating**
    - Bowl: Migration of lead reduced from 897ppm to 591ppm.
    - Tumbler: Migration of lead reduced from 985ppm to 630ppm.

3. **10 µm Copper and 15µm Nickel coating**
    - Bowl: Migration of lead reduced from 897ppm to 305ppm.
    - Tumbler: Migration of lead reduced from 985ppm to 275ppm.

4. **15 µm Copper and 20µm Nickel coating**
    - Bowl: Migration of lead reduced from 897ppm to 123ppm.
    - Tumbler: Migration of lead reduced from 985ppm to 108ppm.

From the data provided, it is evident that increasing the thickness of both the copper and nickel coatings leads to a greater reduction in lead migration. The results indicate that the combination of 15micrometre copper and 20micrometer nickel plating demonstrates the highest reduction, with up to a 90% decrease in lead migration compared to the uncoated surfaces. Impact of electroplating in migration of lead is displayed in figure 10 and 11 and graph 1 and 2.

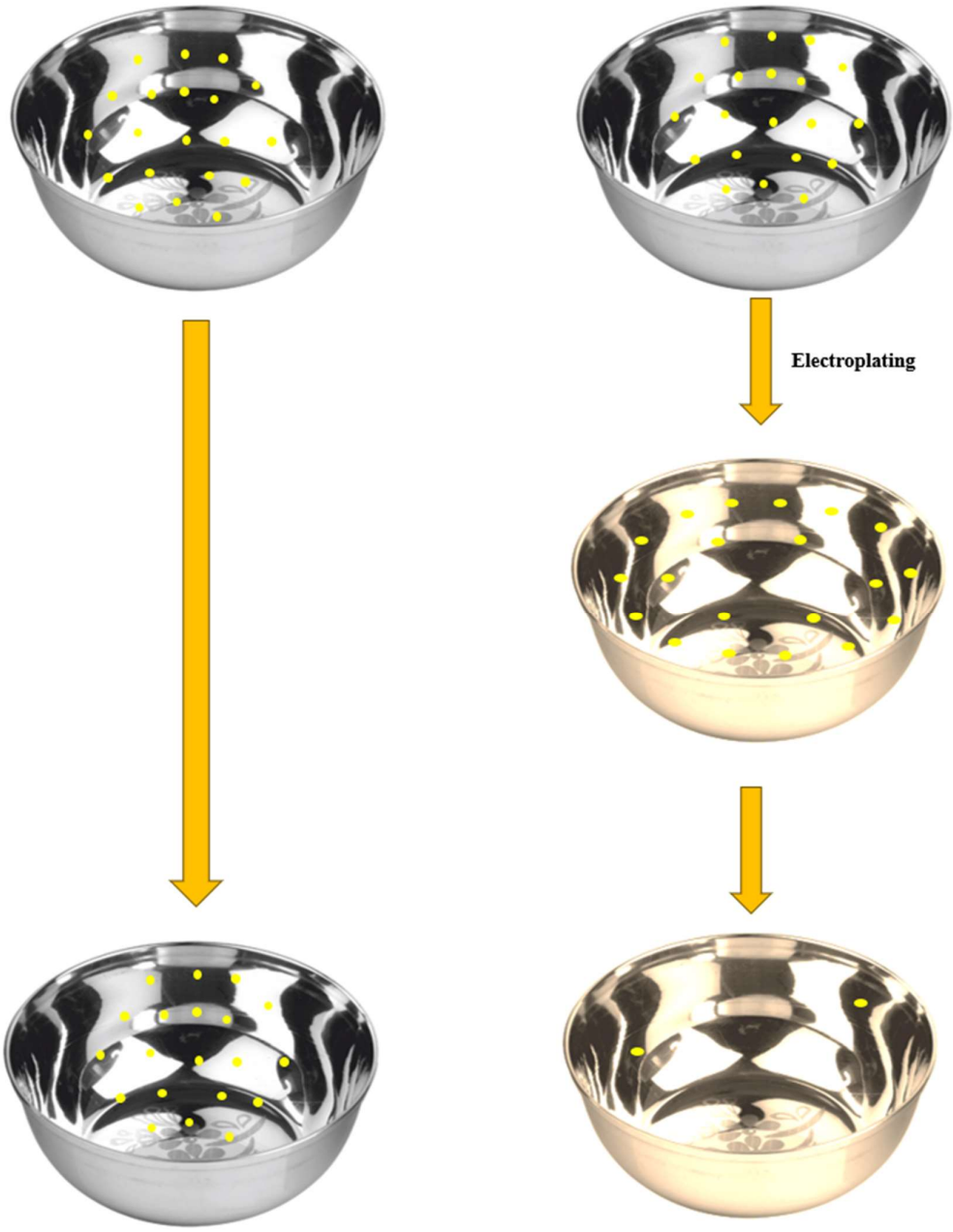


Figure 4.1: Impact of Electroplating in Migration of Lead (Bowl)

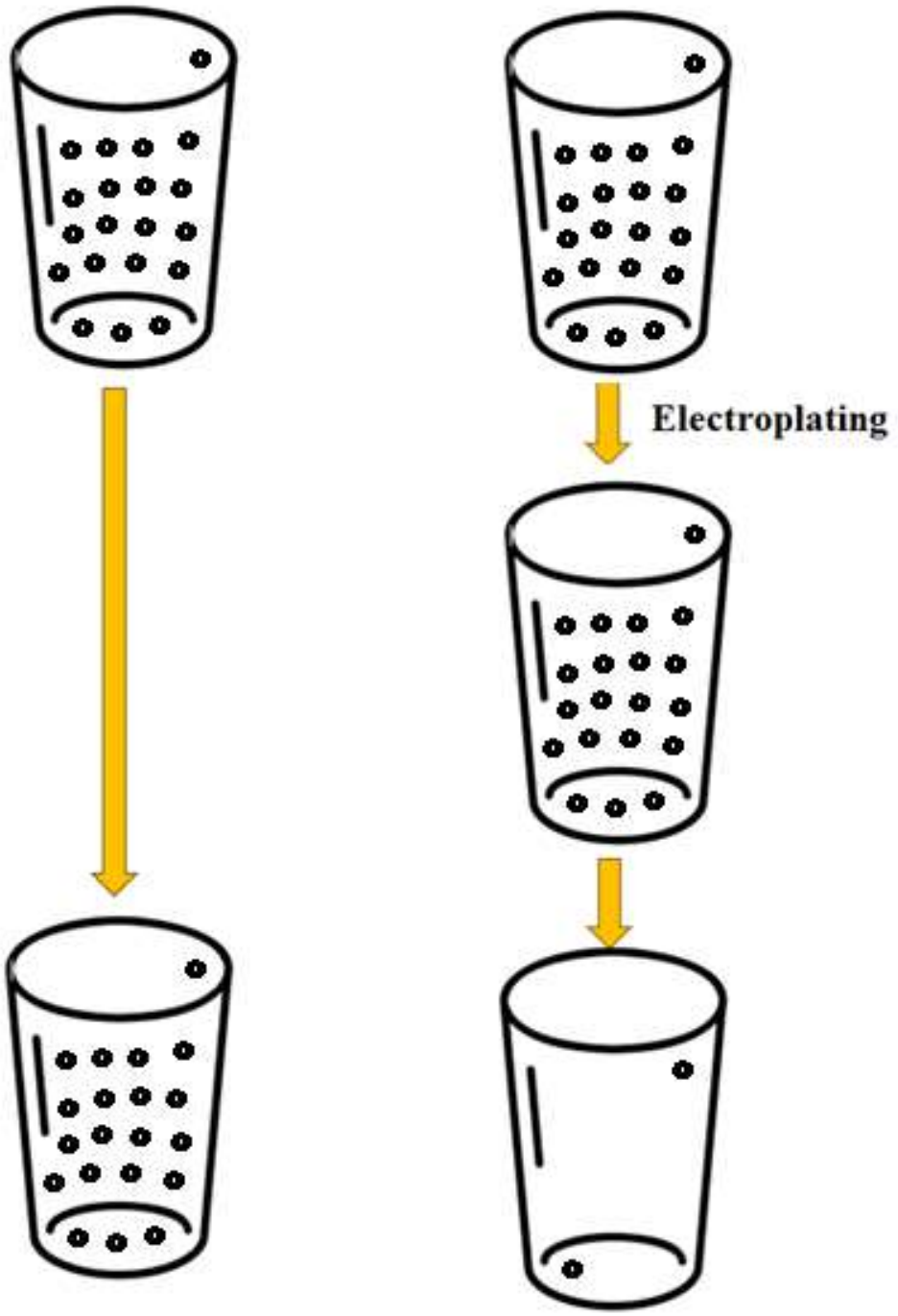
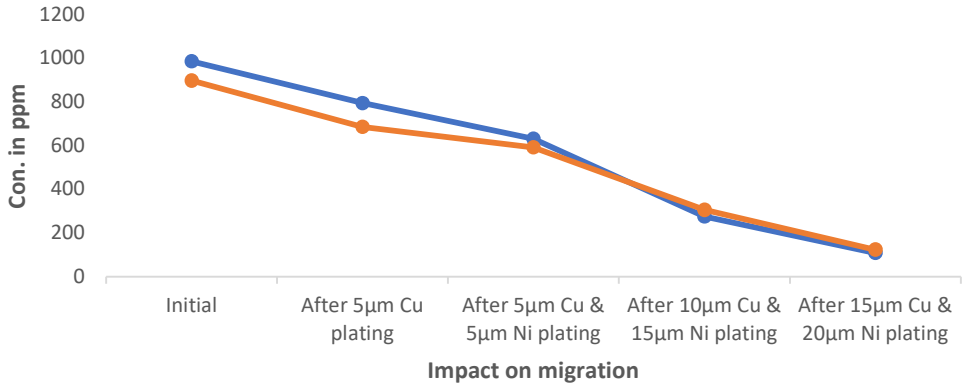
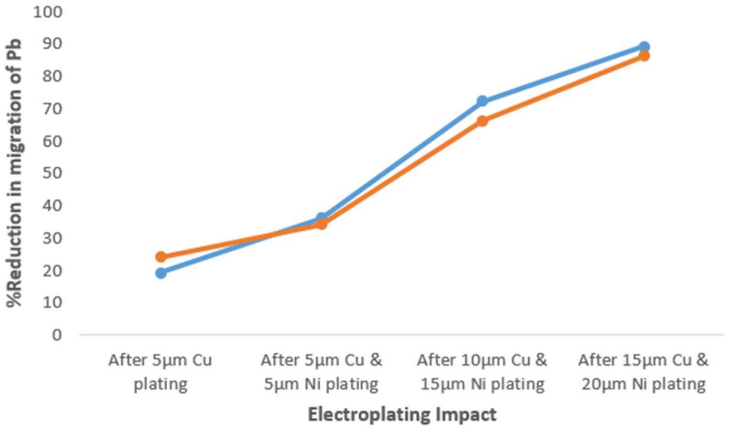


Figure 4.2: Impact of Electroplating in Migration of Lead (Tumbler)



Graph 4.1: Impact of electroplating in migration of Lead (ppm)



Graph 4.2: Impact of electroplating in migration of metals (%)

These findings suggest that using thicker copper and nickel coatings can be an effective approach to minimize the release of lead from the coated surfaces. However, it is important to note that the specific coating thicknesses and their effectiveness may depend on the application, regulatory requirements, and other factors specific to the scenario being evaluated.

Heavy metals presence in the environment is a stuff of significant concern due to their potential adverse effects on human health and ecosystems. To mitigate this risk, various international organizations have established allowable limits for heavy metal concentrations in different media. The World Health Organization (WHO), the European Commission (EC) and the Environmental Protection Agency (EPA) in the United States have independently set guidelines and regulations to ensure public safety and environmental protection. The detailed information on these permissible limits is mentioned in table 40 [206-208].

Table 4.212: Acceptable thresholds for heavy metal content

Heavy Metal	WHO (mg/kg body weight)	EPA (mg/L in drinking water)	European Commission (mg/kg food)
Arsenic	0.003	0.010	0.1
Cadmium	0.007	0.005	0.2
Lead	0.025	0.015	0.3 (0.1 for infants)
Mercury	0.001	0.002	0.5
Chromium	0.05	0.1	0.3

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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

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]

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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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Decision Letter (masy.202300102.R2)

From: ncmd2021@tmu.ac.in

To: divyabaj@gmail.com

CC: dipakdks@gmail.com, divyabaj@gmail.com, jain1dcy@gmail.com

Subject: Macromolecular Symposia - Acceptance of Your Manuscript masy.202300102.R2

Body: 14-Jun-2023

Dear Dr. TRIPATHY,

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Research Article
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Impact Assessment of Electroplating in the Leaching of Harmful Metals from Utensils

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Abstract: Electroplating is a widely used technique in the manufacturing of utensils for household and commercial use. This process involves the deposition of a metal coating onto a base material, such as steel or brass, to improve the aesthetics, durability, and corrosion resistance of the utensil. Several studies have investigated the migration of heavy metals from utensils, but there is a lack of research specifically focused on the impact of electroplating on this phenomenon. Therefore, this research paper aims to assess the impact of electroplating by analyzing the migration of heavy metals from such utensils. The objective of this research is to assess the impact of electroplating on the migration of heavy metals from utensils. The research also aims to evalaute impact of coating thickness. Stainless-Steel and Brass utensils (Plate, Tumbler and Bowl) were purchased. The samples were analysed as per standard test methods based on Inductively coupled plasma mass spectrometry (ICP-MS) techniques. Leaching stimulant was used for extraction process. Testing was performed in an ISO/IEC 17025: 2017 accredited laboratory. The experiments revealed that the electroplating process decreased the migration of lead from the utensils. These findings highlight the need for stricter regulations and standards to ensure the safety of electroplated utensils.

Keywords: Impact assessment, Electroplating, Migration, Heavy Metal, Utensils.

1. Introduction

The electroplating process is widely used in various industries, including the manufacturing of utensils. Electroplating involves the deposition of a layer of metal onto a substrate through an electrochemical process. The electroplating of utensils enhances their appearance, durability, and resistance to corrosion [1]. Metal migration from utensils can occur due to various factors, including the type of metal used in electroplating, the thickness of the metal layer, the pH of the food or beverage, and the duration and temperature of contact between the utensil and the food or beverage [2-3]. Therefore, it is essential to assess the impact of electroplating on the migration of metal ions from utensils into food and beverages [4-6].

The utensils were thoroughly cleaned before electroplating and it is ensured that there should not be any dirt, grease, or oxide layers. The utensils are then submerged into a specially formulated electrolyte solution that contains nickel and copper ions. An electrical current is applied to the utensils, with the copper and nickel ions in the electrolyte solution being attracted to the utensils surface. Through the electrochemical reaction, the copper and nickel ions are reduced and form a metallic layer that adheres to the utensils.

The impact assessment of electroplating in the migration of metal from utensils is an important area of research that can provide valuable insights into the potential health risks associated with the use of electroplated utensils [5-7].

Extensive studies have been conducted by researchers to investigate the effectiveness of electroplating in reducing metal migration from utensils. In one of the study the performance of electroplated coatings as a barrier against metal migration was evaluated. In this study, they have examined different coating materials, including tin, nickel, and silver, and their ability to reduce the migration of lead and cadmium from utensils. The results demonstrated that electroplating effectively reduced metal migration and provide a protective barrier. The impact of electroplating parameters on coating thickness and adhesion was also examined. The study parameters include factors such as plating time, current density, and bath composition. The findings highlighted the importance of optimizing these parameters to achieve uniform and adherent coatings, which are crucial for reducing metal migration.

Though researchers have made significant contributions to understanding the impact of electroplating on reducing metal migration from utensils but impact of thickness of electroplating was not evaluated. This research paper aims to investigate the impact of electroplating on metal migration from utensils and to assess the potential health risks associated with this process [8-10].

This research also aims to evaluate the impact of electroplating on the migration of metal ions from utensils into food and beverages [8-10]. The study will focus on the electroplating of commonly used metals in utensils, including copper and nickel. The research will also consider the effects of thickness of layer.

The results of this study will be valuable to manufacturers, regulatory agencies, and consumers. The findings will enable manufacturers to optimize their electroplating processes to minimize the migration of metal from utensils, while regulatory agencies can use the results to set guidelines and standards for the electroplating of utensils. Consumers will benefit from the knowledge of the potential health risks associated with the use of electroplated utensils and can make informed decisions about their use. This study will also contribute to the growing body of research on the potential health risks associated with the use of electroplated utensils and help raise awareness among consumers about the importance of safe utensil use.

The primary aim of this reaserch is to evalaute the impact of electroplating in reducing migration of heavy metals from utensils and increase awaeness about the same. The outcome of this research will provide valuable insights which can be utilized in improving the safety and quality of electroplated utensils, thereby protecting the health and well-being of public.

2. Materials and Methods

This research aimed to investigate the extent to which electroplating impacts the migration of metals from utensils. The methodology includes the research design, data collection, sample selection, and data analysis methods used in the study [9-17].

2.1 Research Design

The research design used for this study is a quantitative, experimental research design. The experiment involved testing the migration of metal from both electroplated and non-electroplated utensils. The independent variable was the electroplating process, while the dependent variable was the amount of metal that migrated from the utensils. The study used a controlled environment to reduce the effect of confounding variables**.**

2.2 Data Collection

The data for this study were collected through laboratory experiments. The experiments involved the use of electroplated and non-electroplated utensils. The study used leaching stimulant (4%v/v Acetic Acid for 24 hours). The metal migration tests were carried out in accordance with the validated test method.

2.3 Sample Selection

The sample for this study comprised of 42 stainless steel and 42 Brass utensils (Figure 1: Sample Details). The utensils were selected based on their popularity in the market and their manufacturing materials. The electroplating was done at in-house facility. Brass utensils were coated with a layer of copper and nickel.

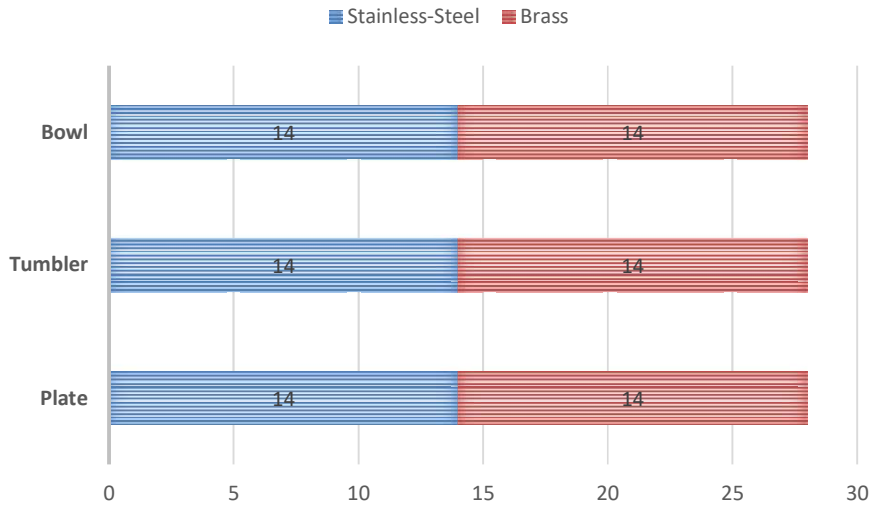


Figure 1: Sample Details

2.4 Data Analysis

The data collected in this study were analyzed using descriptive statistics and inferential statistics. Descriptive statistics were used to summarize the characteristics of the data, while inferential statistics were used to test hypotheses and make inferences about the results.

2.5 Composition analysis

The samples were analysed for composition of the material by X-ray fluorescence (XRF) using Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883). Internal quality checks were performed before analysis using traceable reference standard {NIST traceable BAS -England British Chemical Standard Certified Reference Material (BCSCRM)} is used. Instrumental QC

samples are analyzed along with sample in order to ensure adequate instrumental performance.

2.6 Migration of Metal from Utensils

Migration of metal from utensils can occur when metals leach out from the utensils and get into the food or beverages being prepared or stored in them. This can be a concern because certain metals, such as lead and cadmium, are toxic and can have harmful effects on human health when consumed in large amounts [15,17-20].

The amount of metal migration depends on several factors, including the type of metal used in the utensil, the quality of the utensil, the temperature and duration of exposure to the food or beverage, and the acidity or alkalinity of the food or beverage. For example, acidic foods or beverages can cause more metal migration than neutral or alkaline ones [9,11-15].

To minimize the risk of metal migration, it is important to use high-quality utensils made of materials that are known to be safe, such as stainless steel, titanium, or certain types of ceramic. It is also recommended to avoid using utensils that are chipped, cracked, or have scratches, as these can increase the surface area of the utensil and lead to more metal migration. Additionally, it is important to avoid storing food or beverages in metal containers for prolonged periods of time, as this can also increase the risk of metal migration [17-19].

For cooking, there is no uniform cooking methodology as it is an individual choice. To determine maximum leachability from the utensil, leaching stimulant (4%v/v Acetic Acid for 24 hours) was used. All utensils were cleaned and washed with soap and distilled water prior to conduct migration test.

After cleaning and washing with soap and distilled water, all the samples were filled with leaching stimulant (4%v/v Acetic Acid) and kept for 24 hours for leaching. After 24 hours, solutions were transferred in to volumetric flask for testing. The standard testing procedure was followed for testing.

2.7 Equipment Used: Inductively Coupled Plasma Mass Spectrophotometry (ICP MS)

Leaching solutions were analyzed by inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) (Thermo Scientific™ iCAP™ RQ ICP-MS Serial No. iCAP RQ01591). This analysis was conducted at Research Testing & Calibration Laboratory (A Division of Metal Handicrafts Service Centre), Moradabad. This laboratory is accredited in accordance with ISO/IEC 17025: 2017 “General requirements for the competence of testing and calibration laboratories” by National Accreditation Board for Testing and Calibration Laboratories (NABL) vide certificate number TC-6683 valid from 09/09/2020 to 08/09/2020.

2.8 Limitations

The study has some limitations that need to be considered. The sample size was relatively small which may limit the generalizability of the findings. The study also did not consider other potential sources of metal exposure, such as drinking water, air pollution, and occupational exposure. Despite these limitations, the study provides valuable insights into the potential health implications of metal migration from electroplated utensils.

2.9 Summary of Method

2.9.1 Principle

ICP-MS (Inductively Coupled Plasma Mass Spectrometry) is a highly sensitive analytical technique used for the detection and quantification of trace elements in various samples. The principle of ICP-MS involves several steps:

Sample Introduction: The sample is introduced into the ICP (Inductively Coupled Plasma) source, where it is vaporized, atomized, and ionized**.**

Ionization: The vaporized sample is ionized in the plasma source by applying an RF (Radio Frequency) field, which causes electrons to collide with gas atoms, leading to the formation of a high-temperature plasma. The sample ions are then formed through ionization and fragmentation.

Separation and Detection: The ions are then separated by their mass-to-charge ratio (m/z) using a mass spectrometer, which consists of a series of ion lenses, analyzers, and detectors. The ions are first focused and then accelerated through a potential difference, which separates them according to their m/z ratios. The detector then detects the ions and converts them into electrical signals.

Data Analysis: The electrical signals from the detector are then processed by a computer to provide a quantitative measurement of the elemental concentrations in the sample.

ICP-MS utilizes a combination of inductively coupled plasma and mass spectrometry to achieve highly sensitive and selective detection and quantification of trace elements in samples.

2.9.2 Brief Procedure

ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) is a powerful analytical technique used for elemental analysis in a wide range of applications. The brief overview of the procedure for testing using ICP-MS is mentioned in Figure 2: Procedure for analysis of samples by ICP-MS.

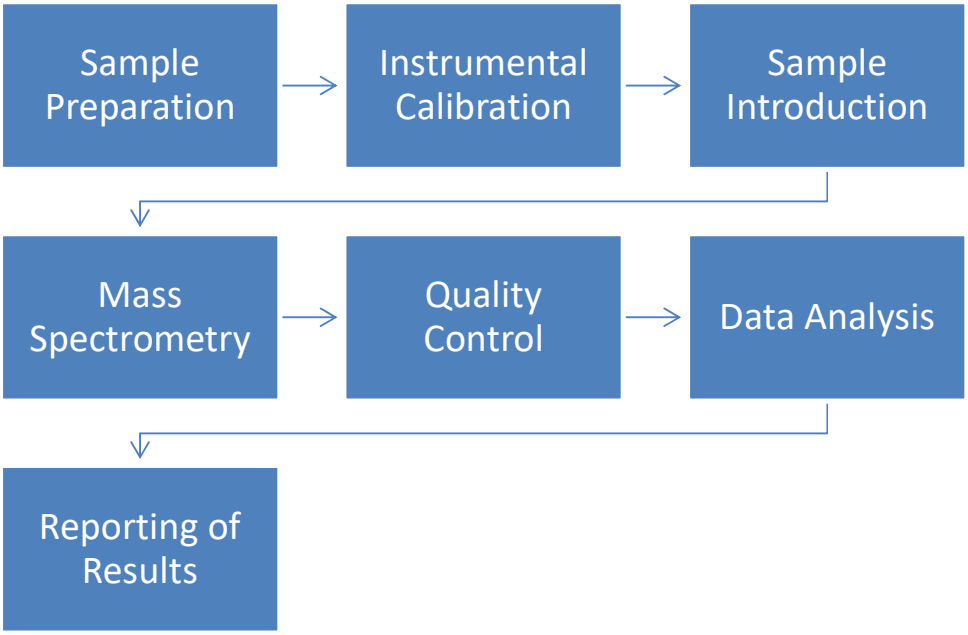


Figure 2: Procedure for analysis of samples by ICP-MS

2.9.3 Environment, Health and Safety

All relevant environment, health and safety aspects are employed in the laboratory to ensure compliance.

2.9.4 Interference

This method covers the analysis of 23 elements in various types of samples by ICP MS. There is no interference observed.

3. Results and Discussion

3.1 Composition Test

3.1.1 Composition of Stainless-Steel samples:

Eighteen samples (Six unit of each utensil i.e. six units of Plate, Tumbler and Bowl) were analysed for composition test by using X-ray fluorescence (XRF) i.e. Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Table 1: Composition of Stainless-Steel Samples).

Table 1: Composition of Stainless-Steel Samples (%)

Sample	Plate				Sample	Tumbler					Sample	Bowl			
ID	Cr	Ni	Mn	Cu	ID	Cr	Ni	Mn	Cu	Mo	ID	Cr	Ni	Mn	Cu
PSS01	14.01	0.70	10.11	0.64	TSS01	13.61	1.20	9.64	1.42	0.13	BSS01	12.76	0.63	9.16	1.01
PSS02	14.02	0.71	10.12	0.65	TSS02	13.60	1.21	9.65	1.43	0.16	BSS02	12.77	0.63	9.14	1.00
PSS03	14.01	0.72	10.11	0.66	TSS03	13.62	1.19	9.65	1.44	0.16	BSS03	12.76	0.64	9.16	1.00
PSS04	14.02	0.71	10.12	0.65	TSS04	13.60	1.20	9.62	1.44	0.15	BSS04	12.75	0.64	9.15	0.99
PSS05	14.02	0.71	10.12	0.64	TSS05	13.61	1.21	9.62	1.42	0.14	BSS05	12.75	0.63	9.15	1.01
PSS06	14.02	0.71	10.13	0.65	TSS06	13.60	1.20	9.63	1.42	0.12	BSS06	12.77	0.64	9.15	1.00
Average	**14.02**	**0.71**	**10.12**	**0.65**		**13.61**	**1.20**	**9.64**	**1.43**	**0.14**		**12.76**	**0.64**	**9.15**	**1.00**
SD	0.0047	0.0058	0.0069	0.0069		0.0075	0.0069	0.0126	0.0090	0.0149		0.0082	0.0050	0.0069	0.0069

3.1.2 Composition of Brass samples:

Eighteen samples (Six unit of each utensil i.e. six units of Plate, Tumbler and Bowl) were analysed for composition test by using X-ray fluorescence (XRF) i.e. Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Table 2: Composition of Brass Samples).

Table 2: Composition of Brass Samples (%)

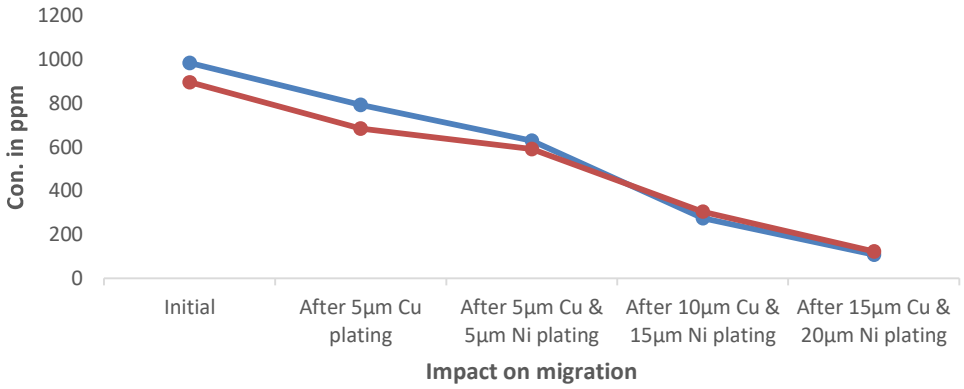
Sample	Plate							Sample	Tumbler							Sample	Bowl						
ID	Cu	Zn	Ni	Fe	Pb	Sn	Cd	ID	Cu	Zn	Ni	Fe	Pb	Sn	Cd	ID	Cu	Zn	Ni	Fe	Pb	Sn	Cd
PB01	62.24	37.55	<0.10	<0.10	<0.10	<0.10	<0.10	TB01	54.66	38.99	0.38	0.87	4.18	0.87	<0.10	BB01	54.18	39.30	0.66	0.82	3.73	1.22	<0.10
PB02	62.27	37.57	<0.10	<0.10	<0.10	<0.10	<0.10	TB02	54.65	38.96	0.37	0.91	4.17	0.88	<0.10	BB02	54.17	39.28	0.67	0.86	3.75	1.23	<0.10
PB03	62.25	37.56	<0.10	<0.10	<0.10	<0.10	<0.10	TB03	54.66	38.95	0.36	0.88	4.16	0.85	<0.10	BB03	54.16	39.31	0.69	0.86	3.75	1.19	<0.10
PB04	62.26	37.55	<0.10	<0.10	<0.10	<0.10	<0.10	TB04	54.64	38.96	0.38	0.91	4.18	0.88	<0.10	BB04	54.16	39.29	0.67	0.86	3.76	1.22	<0.10
PB05	62.26	37.56	<0.10	<0.10	<0.10	<0.10	<0.10	TB05	54.65	38.94	0.35	0.90	4.16	0.86	<0.10	BB05	54.18	39.27	0.66	0.85	3.78	1.23	<0.10
PB06	62.25	37.57	<0.10	<0.10	<0.10	<0.10	<0.10	TB06	54.65	38.96	0.36	0.91	4.17	0.87	<0.10	BB06	54.17	39.29	0.69	0.85	3.74	1.19	<0.10
Average	**62.26**	**37.56**	**<0.10**	**<0.10**	**<0.10**	**<0.10**	**<0.10**		**54.65**	**38.96**	**0.37**	**0.90**	**4.17**	**0.87**	**<0.10**		**54.17**	**39.29**	**0.67**	**0.85**	**3.75**	**1.21**	**<0.10**
SD	0.0096	0.0082	NA	NA	NA	NA	NA		0.0069	0.0153	0.0111	0.0160	0.0082	0.0107	NA		0.0082	0.0129	0.0125	0.0141	0.0157	0.0170	NA

3.2 Migration Test (Lead and Cadmium)

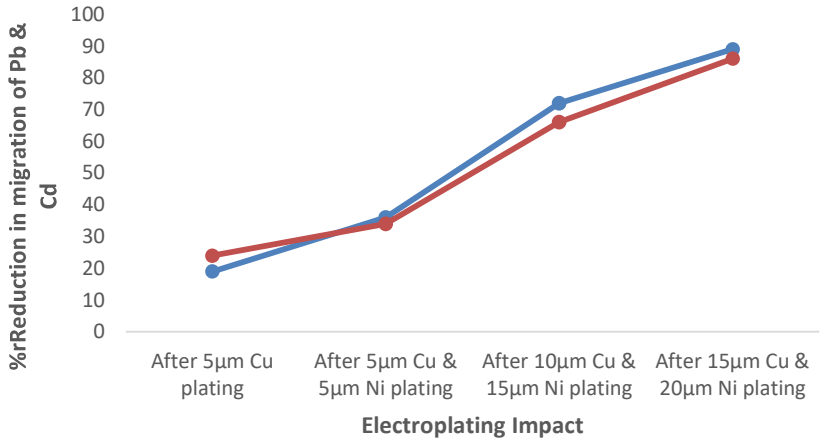
Leaching solutions were analyzed by inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) (Thermo Scientific™ iCAP™ RQ ICP-MS Serial No. iCAP RQ01591). The testing was conducted as per FDA guidelines. As per FDA guidelines, six samples are to be taken for testing. The results are mentioned in Table 3: Migration of Lead and Cadmium. The graphs {Graph 1: Line graph illustrating the impact of electroplating in migration of metals (ppm) and Graph 2: Line graph illustrating the impact of electroplating in migration of metals (%)} also representing the impact of electropaling in reducing migration of heavy metals from utensils.

Table 3: Migration of Lead and Cadmium (ppm)

Element	Test Condition	Type of Utensil					
		Stainless-Steel			Brass		
		Plate	Tumbler	Bowl	Plate	Tumbler	Bowl
Pb	Initial	<0.05	<0.05	<0.05	<0.05	985	897
	After 5µm Cu plating	NA	NA	NA	NA	793	685
	After 5µm Cu & 5µm Ni plating	NA	NA	NA	NA	630	591
	After 10µm Cu & 15µm Ni plating	NA	NA	NA	NA	275	305
	After 15µm Cu & 20µm Ni plating	NA	NA	NA	NA	108	123
Cd	Initial	<0.05	<0.05	<0.05	<0.03	<0.03	<0.03
	After 5µm Cu plating	NA	NA	NA	NA	NA	NA
	After 5µm Cu & 5µm Ni plating	NA	NA	NA	NA	NA	NA
	After 10µm Cu & 15µm Ni plating	NA	NA	NA	NA	NA	NA
	After 15µm Cu & 20µm Ni plating	NA	NA	NA	NA	NA	NA



Graph 1: Line graph illustrating the impact of electroplating in migration of metals (ppm)



Graph 2: Line graph illustrating the impact of electroplating in migration of metals (%)

Lead toxicity, also known as lead poisoning, is a serious health concern caused by the accumulation of lead in the body. Lead toxicity primarily occurs through ingestion or inhalation of lead-containing substances. Common sources of lead exposure include lead-based paints, contaminated soil, drinking water pipes, old plumbing fixtures, and certain traditional or imported products including utensils.

Once lead enters the body, it can interfere with the normal functioning of various organs and systems. The most vulnerable targets of lead toxicity are the nervous system, particularly the developing brains of children, and the kidneys. Lead can cross the blood-brain barrier and disrupt the development and function of neurons, leading to cognitive impairment, learning disabilities, behavioral problems, and reduced IQ. In adults, lead toxicity can cause neurological symptoms such as memory loss, confusion, and muscle weakness.

Recognizing the dangers of lead toxicity, many countries have implemented regulations to limit its use and exposure. Lead-based paints have been banned or restricted in many regions, and efforts have been made to reduce lead in drinking water systems and consumer products.

Regular monitoring and testing of lead levels in water, soil, and consumer goods are crucial to identifying and mitigating potential sources of exposure.

Cadmium is widely distributed in the environment and can be found naturally in the Earth's crust. Exposure to cadmium can occur through inhalation of contaminated air, ingestion of contaminated food or water, or direct contact with cadmium-containing materials. Once inside the body, cadmium accumulates primarily in the kidneys and liver but can also affect other organs such as the lungs, bones, and cardiovascular system.

Cadmium is a potent toxicant that can have both acute and chronic effects on human health. Acute exposure to high levels of cadmium can cause symptoms such as nausea, vomiting, abdominal pain, and diarrhea. In severe cases, it can lead to respiratory distress, kidney failure, and even death. However, chronic exposure to lower levels of cadmium over an extended period is more common and can have insidious health effects.

The most significant health concern associated with chronic cadmium exposure is its cumulative toxicity. Cadmium has a long biological half-life, meaning it persists in the body for an extended period. Over time, it can cause damage to various organs and systems, including the kidneys, bones, and the respiratory and cardiovascular systems.

To mitigate the risks associated with cadmium toxicity, it is crucial to minimize exposure to cadmium-containing products and environments. This can be achieved through the use of personal protective equipment, proper ventilation in industrial settings, and adherence to occupational safety regulations. Additionally, efforts should be made to reduce environmental contamination from industrial sources and to monitor and regulate cadmium levels in food and drinking water.
Understanding the sources of cadmium exposure and implementing preventive measures are essential for safeguarding human health and minimizing the risks associated with this toxic heavy metal.

The electroplating process is widely used in the manufacturing of utensils to provide a layer of metal that enhances the appearance, durability, and corrosion resistance of the utensil [1,4-6]. However, concerns have been raised about the potential for metal migration from these utensils into the food and beverages they come into contact with, which could result in health risks for consumers. This research aims to investigate the impact of electroplating on the migration of metals from utensils and assess the potential health risks associated with such migration [20-31].

The findings of this study demonstrate that the thickness of electroplating layer plays an important role in reducing the migration of heavy metal. It is important to note that the 5µm copper plating is reducing about 20% of Lead and Cadmium and upto 90% of migration of Lead and Cadmium can be reduced through electroplating.

The results of this study have several implications for both industry and consumers. From an industry perspective, there is a need for greater transparency and accountability in the use of electroplating in the production of utensils. Manufacturers should be required to conduct

regular testing of their products to ensure that they do not pose a health risk to consumers. In addition, regulatory bodies should consider revising safety limits for metal migration in light of the findings of this study.

From a consumer perspective, the findings of this study highlight the importance of being mindful of the types of utensils used to store and prepare food, as well as the types of food being stored and prepared. Consumers should be advised to be careful about using electroplated utensils.

This study provides important insights about the impact of electroplating in reducing migration of heavy metal through utensils and potential health risks associated with it. There is a need for greater regulation of the use of electroplating in the production of utensils, as well as greater consumer awareness of the potential health risks associated with the use of such utensils.

4. Conclusions

In conclusion, the research presented in this paper aimed to assess the impact of electroplating on the migration of heavy metals (Lead and Cadmium) from utensils. Through the use of various analytical techniques, such as ICP-MS, we were able to determine the impact of electroplating in reducing the migration of Lead and Cadmium from Brass utensils.

The results showed that electroplating does have a significant impact on the migration of metal from utensils, with lower levels of metal ions being released compared to non-electroplated Brass utensils. This finding is particularly important for industries that rely on electroplating as a means of producing utensils and other metal products.

It is also to be noted that the release of metal ions can be affected by factors such as pH and temperature, which highlights the need for careful consideration of these parameters in the manufacturing process. It is important for manufacturers to take into account the potential health risks associated with metal migration, and to implement appropriate measures to minimize these risks.

Based on outcome of this research, it is observed that there is need of stringent regulations and quality control measures in the utensils manufacturing indstry using electroplating processes. This will ensure that consumers are not subjected to detrimental levels of metal ions from electroplated utensils. It also emphasizes the need for consumers to be more aware of the risks associated with electroplated utensils.

It is concluded that this research provides valuable insights and better understanding into the impact of electroplating in reducing the migration of heavy metal from utensils, and highlights the need for further research to be conducted in this area to better understand the risks and potential health impacts associated with the use of electroplated utensils.

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Conflicts of Interest

The authors declare no conflict of interest.

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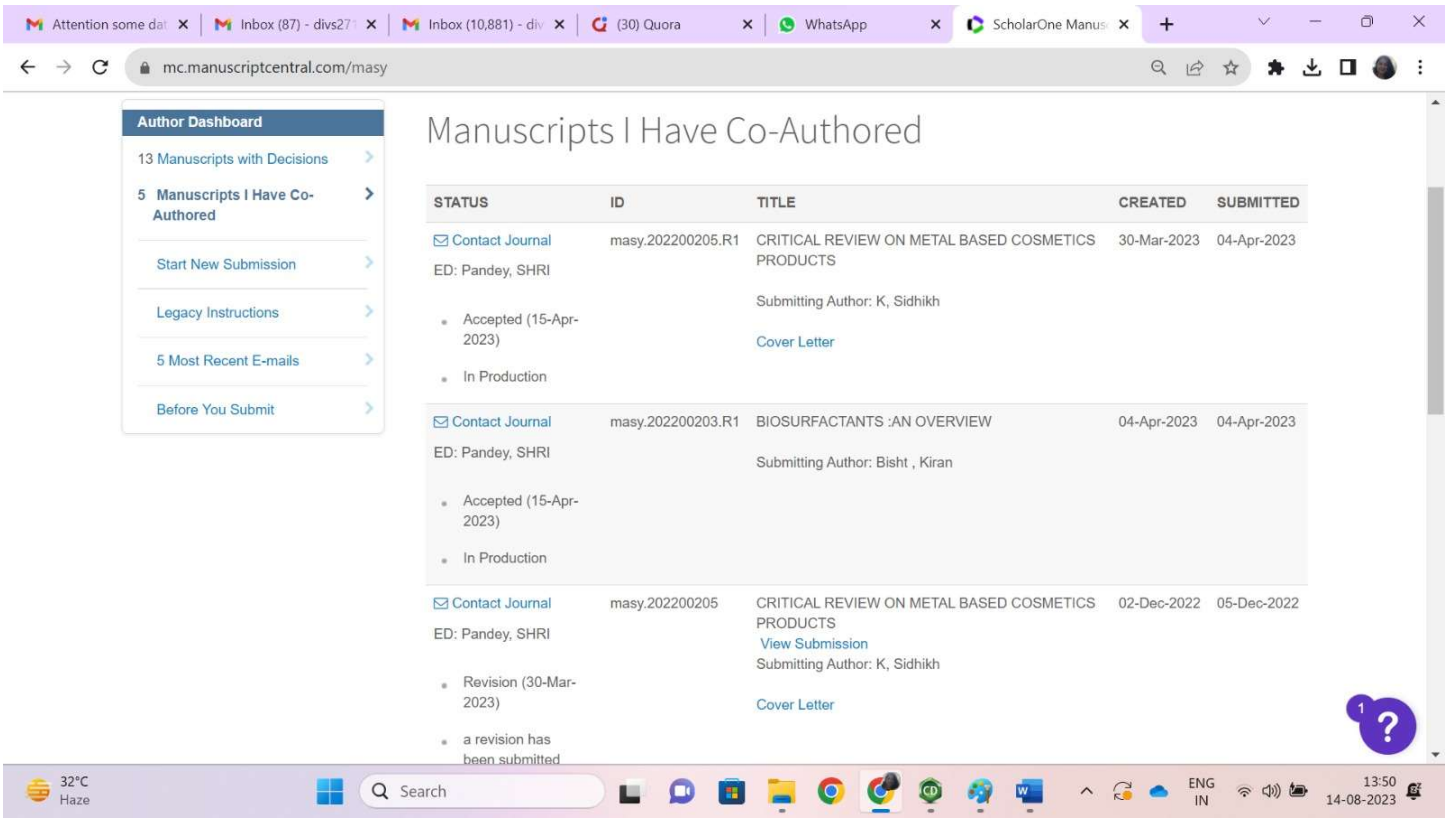
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CRITICAL REVIEW ON METAL BASED COSMETIC PRODUCTS

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Abstract

Most people utilize cosmetics to enhance or improve their physical appearance, regardless of their gender, race, or age. Heavy metals are impurities or ingredients in many cosmetic products. According to recent studies, these metals can result in a variety of skin and health issues. Numerous studies demonstrate that the mismanaged formulation of such products without sufficient standardization of toxic metals throughout the production process is the primary reason for the high level of heavy metal contamination in the samples. In order to prevent human exposure to such dangerous heavy metals, it is vital to monitor and manage the fate of heavy metals in cosmetic items, especially unbranded ones. Due to the wasteful interest of producers in making extra profit, the standards are not being imposed. Moreover, consumers are also ready to compromise with the product due to their unawareness of its hazardous impact on their skin and bodies. Short-term results on their looks may cause fatal effects on their health. Another significant issue that requires attention is the lack of safety regulations in the country for evaluating heavy metals in cosmetic products. Additionally, there is an urgent need to establish acceptable limits for potential impurities in cosmetic products that must be enforced at local levels. This review provides a comprehensive insight into the content of heavy metals in cosmetics and their effects on several organs and the site of application.

Keywords: Heavy metals, cosmetic analysis, instrumentation, toxicology, ICP MS etc.

1. Introduction

Any material or remedy meant for application to the body's various exterior portions is considered a cosmetic product. Humans are exposed simultaneously to a large number of chemicals from different sources. Cosmetics, especially the skin lightening types, contain surfactants, oils, and other components that are mixed together and must also be stable, long-lasting, and widely used by women [18, 35]. While some products may contain cancer-causing substances, it is challenging to keep track of every product's safety. Heavy metals can have different tolerable levels depending on the size of the population. Based on the concentration of chemicals present in cosmetic products, the amount applied, the amount of time spent over the skin, penetration enhancers, and the presence of moisture levels, these are a few of the variables that affect the absorption of ingredients in the product into the skin. Amounts of heavy metals in cosmetics based on the impact of risk to human health are difficult to establish in light of its skin absorption rate and complexity. Heavy metals are naturally occurring in the soil, water, and rocks. They are used in the production of dyes and other raw materials in all economic sectors, including the field of cosmetics. These heavy metal compounds like lead acetate, mercuric sulphide are used in majority of the cosmetic products either as an additive or as a preservative [16]. Due to the negative effects of heavy metals on human health, the national health legislations and World Health Organization (WHO), including European Union (EU) countries, Canada, Germany and, Jordan limited the use of metals in cosmetic products. These restrictions and their regulations are designed to offer consumers a high level of protection [11]. According to Food and Drug Administration (FDA) in the USA the Cosmetic Ingredient Review Expert Panel set criteria for using metals in cosmetic products. For example, they issue limitations on Pb (5 ppm), As (5ppm) and other heavy metals (20 ppm). [10]. The restrictions for the metals and its type are frequently inconsistent across different authorities. A number of researchers examined the probable presence of heavy metals in a variety of items. [10]. Hydrophilic and hydrophobic substances, as well as various organic and inorganic components, are used to make cosmetic products. In the production of colored cosmetics mineralized pigments are frequently used, which results the cosmetic products to get contaminated with heavy metals (HMs) like Cd, Cu, Pb, Ni, Co, Cr, and other elements. These heavy metals have been purposefully added into cosmetic items as, antiperspirants, preservatives,

antibacterial agents, and antifungal agents. UV radiation is one of the non-ionizing radiations emitted mainly from sun and other artificial sources can adversely affect the person's skin, eyes, and immune system in ways that are both acute and chronic. According to cosmetic producers, sunscreens are commonly used cosmetic products have the ability to protect the skin from various UV radiations. The UV filters are added to cosmetics that are topically applied over the skin, derivatives of these filter chemicals have the ability to connect to plasma proteins, circulate in the blood, and be processed in the liver. As per the studies conducted by different researchers it has been that metals and parabens are used as preservatives are also endocrine disruptors and can be easily absorbed through skin, having harmful impacts on human health [19]. It is essential to know how heavy metals absorbed by the body, their mortality rate as well as the toxicity [34]. The review paper discussing about the sources, its permitted limits and concentrations of metals present in various types of cosmetics, as well as the risk these substances provide to human health, were the main topics of the current review. It aims to raise awareness that the use of cosmetics may be an additional source of exposure to toxic metals. And that the detrimental effects reported adverse effects following the application of cosmetics may be related to the presence of metals in these products. In addition, this review highlights the fact that the presence of metals in cosmetics has been linked to some of the harmful effects that have been seen [17].

2. Heavy metals

Heavy metals are those elements that have specific densities of at least five times higher than those of water. When the body has difficult to digest the heavy metals it will accumulate in soft tissues causes toxic effects to the body [36]. It may occur naturally in soils, or it may be introduced by human activity. Naturally occurring heavy metals (HM) sources include migration of continental dust, via weathering process, and volcanic ash emissions owing to long-term exposure to air substantially increases the amount of HM in the environment. (i)The use of mines and smelters, (ii) the burning of fossil fuels and metal enriched sewage sludge in agriculture, (iii) the use of metal-based pesticides (iv) the manufacturing of electronics, and the use of military training etc., are the human activities. The human activities are divided into five categories like smelting and mining of metals, industry and agriculture [10].

2.1. Sources of heavy metals

Because of the toxicity, long half-lives in the environment, and capacity for bioaccumulation, heavy metals are widely recognized as an environmental contaminant. Among other forms, the heavy metals can be found in organic matrix, hydroxides, oxides, sulphides, phosphates, silicates, and carbonates. In the environment heavy metals are originated from certain man-made activities, natural sources, and geogenic activities. Human activities include mining and different industrial and agricultural operations like the use of pesticides and phosphate fertilizers, while the natural sources include the volcanic eruptions and weathering of metal-bearing rocks. According to certain studies, manmade and natural sources are the primary causes of environmental contamination. The release of heavy metals from various environmental components is influenced by a number of factors, including pH, temperature, dissolution, redox, and precipitation potential. This was also highlighted. Heavy metal contamination is mostly caused by mining and metallurgical activities, which have been identified as the main offenders. As a result, it should be mentioned that human activity is the main cause of the environment's heavy metal pollution. Leaching and weathering of various mineral-rich components in the environment can cause natural environmental contamination, which enriches the environment with heavy metals. Through both dry and moist deposition, heavy metals that are released into the air during, smelting, mining and other industrial activities directed into the ground. Environmentally harmful heavy metals are released when wastewaters, including home sewage and industrial effluents, are discharged. The use of chemical fertilizers and the burning of fossil fuels are further human-caused sources of heavy metal pollution. Phosphate fertilizers are commonly used commercial chemical fertilizers have more heavy metal contents. One of the main sources of heavy metals is from vehicle traffic. Cadmium, Lead and Arsenic become moderately volatile after coal burning, whereas Mercury becomes completely volatile. Among the anthropogenic sources of Cr are the steel, textile, leather tannery, and electroplating industries. The majority of the time, fertilizers also have high Cr content. Rock weathering and volcanic activity are two natural sources of Cd in the environment. Burning sewage sludge is another source of cadmium emission, along with coal combustion. Acid batteries, ancient plumbing systems, lead shot used in game bird hunting, and other sources all contribute to the release of Pb into the environment. Ecosystems in both the water and on land are seriously threatened by toxic trace metals. Water supplies, sediments, and soils will cause pollution due to the release of heavy metals from different sources. [1, 2, 3, 4, 5].

2.3. Toxicology of heavy metals

It has been established that heavy metals are hazardous to both human and environmental health. Numerous health problems are connected to heavy metal toxicity, which is seen as a severe threat. They may occasionally function as fictitious body parts, but occasionally they may also interfere with metabolic functions. Due to excessive damage brought on by oxidative stress brought on by free radical generation, metal toxicity is dependent on the route of administration, the length of exposure, and the amount of consumption as a result different disease may develop. [9]. Depending on the chemical make-up of the substance consumed as well as the method of administration, the toxicity of metal produces significant risk to human health. Metallic salts have different degrees of toxicity. The signs and symptoms of poisoning of metal from moderate to acute might change depending on the metal's chemical makeup. Analytical studies carried out on biological materials and their interpretation are greatly influenced by these characteristics. Some metallic compounds have an intense metabolism after uptake, whereas others cause long-lasting or acute toxicity. In order to determine the reason and manner of death in cases of self-destructive, or accidental poisoning of metal and to determine whether the heavy metal poisoning was caused by acute, or, chronic, and numerous death cases are regularly probed forensically (Table 1) [15].

Table 1: Toxicology of heavy metals [15].

Serial number	Metal	Fatal dose	Form of entering	Major route of absorption	Distribution	Major effects
1	Arsenic	120 - 200 g	Inorganic arsenic salts	Gastrointestinal and Respiratory and Skin	Predominantly soft tissues (highest in liver and kidney) Avidly	Cardiovascular shock, arrhythmias, CNS, encephalopathy, gastroenteritis, cancer

					bound in skin, nail, hair	
2	Mercury	1-2g	Elemental mercury, Inorganic mercury and tetraethyl mercury	Respiratory tract, Gastrointestinal and Skin	Soft tissues, Kidney, CNS	CNS, gingivostomatitis, acrodynia, pneumonitis, acute tubular necrosis, CNS effects
3	Lead	0.5-50-g	Inorganic lead oxides tetraethyl lead	Gastrointestinal respiratory and Skin	Soft tissues redistributed to Skelton soft tissues, liver, CNS	CNS, gingivostomatitis, acrodynia, pneumonitis, acute tubular necrosis, CNS effects
4	Zinc	15g	Zinc picolinate, Zinc glycerate	Small intestine and Gastrointestinal tract	Body tissues, fluids, plasma	Nausea, diarrhoea and abdominal cramps

5	Cadmium	20-30g	Enters through smoking	No	Liver, kidneys	Tracheobronchitis, pneumonitis and pulmonary oedema

3. Cosmetics

The cosmetics can be anything intended to be poured, sprinkled, sprayed on, rubbed, or applied to the human body (the, nail, hair, skin, teeth, etc.) or for cleansing, beautifying, or promoting attractiveness". [31]. They become an important part of human cultures. The agents that used to decorate different parts of the body, especially facial cosmetics used to beautify the facial feature, applying dyes and colors and other powders for modifying the facial appearance. Using cosmetics that improves the confidence and mental strength to appear more sociable and active in works. The waxes, dyes, pigments, and solvents are the main components of cosmetics and they are naturally non-volatile and permanent. [18,32].

The human attraction with beautification dates back thousands of years. Moreover, as time passed, people became more worried about the quality of cosmetics and the effects individuals had and also, there are different types of diseases caused by the cosmetics and they have been found as trace evidence in different types of forensic crimes. By analyzing the trace elements in cosmetic items from crime, can link accused/victim with the related crime scene. [32]. Depending on the ingredients present in the cosmetic, it can be natural or synthetic. [33].

Men and Women, use various types of cosmetics as beautifying agents, creams, lotions, gels, oils, face masks, skin lighteners, skin bleachers, beauty masks, makeup powders, toilet soaps, perfumes, deodorants, hair care products, and shaving products .The majority of them are unaware of the negative impact produced by these products, due to heavy metal toxic contamination [33,50].Some toxic elements in cosmetics may be able to cross and penetrate this barrier, causing serious dangers such as cancer. Some cosmetics contain heavy element concentrations that exceed the minimum limits set by the World Health Organization [5]. It is important to note that small amounts of metals are necessary to the humans, when these metals exceed in their permissible limits, they cause many

damages to the body. Toxic metals include Cr, Cd, Bi, As, Au, Fe Mg, Sb, Ga, Se, Zn, Pt, Co, Ni, Pb, Ag, U, Hg, Te, Tl, V. [18].

3.1. Classification of cosmetics

Studies have shown that Cosmetics are classified into three main categories

1. Based on their use
2. Based on their function
3. Based on their physical nature

1. Based on their use

Cosmetics are categorized into five main categories according to the area of application.

1) Skin care products
2) Nail products
3) Oral care products
4) Hair care products
5) Eye makeup products [52].

1) **Skin care products:** Skin cosmetics are a category of cosmetics that are poured, rubbed, or otherwise applied to the skin and support skin integrity. Powders, creams, etc. [52,53].

2) **Nail products:** In order to modify, shine or colour, people have decorated the nail plates on their hands and feet. E.g., nail polish, manicure, pedicure. [52,53].

3) **Oral care products:** The purpose of dental care products is to maintain the dental structure's health and defend it from infections. tooth paste, mouth wash etc. [52,53].

4) **Hair care products:** hair cosmetics are the products used for styling hair involving coloring, hair growth stimulant, shampoo etc. [52,53].

5) **Eye make- up products:** eye cosmetics are applied to the eye for the purpose of beautification and styling. [52,53].

2. Based on their function

1.**Therapeutic:** Some cosmetics that are used to enhance beauty are also intended to have curative and therapeutic effects. e.g., antiperspirants and hair preparations. [52,53].

2.**Protective:** Some skincare products have protective qualities that not only shield our skin from environmental aggressors but also lessen their intensity to give the skin time to build its own defences against exposure. e.g. sunscreens. [52,53].

3.**Corrective:** The cosmetic products which are applied to correct or improve tone and mask the imperfection either from face, hairs, heals, nails, teeth etc. e.g., Crack creams.

4.**Decorative:** By using different cosmetic products that serves as a decorative item which enhances various body parts, such as the nail and hairs. etc. e.g., lipsticks, nail lacquer, eyelashes, mascara etc. [52,53].

3. Based on their physical nature

Aerosols: Pressurized dosage forms with one or more active ingredients are known as aerosols. Aerosols allow the product to be delivered directly to the affected area because the product material can be removed without contaminating other materials. E.g. Hair perfumes, after shave lotion, etc. [52,53].

Emulsions: when two immiscible liquids are made miscible by adding a third substance known as emulsifying agent. this includes vanishing cream, cold cream, cleansing cream, all-purpose cream. [52,53].

Oils: Any chemical compound that is neutral, non-polar, viscous at room temperature, hydrophobic, and lipophilic is referred to as an oil. Oils can come from petrochemical, vegetable, or animal sources. E.g., Hair oil. [52,53].

Pastes: These preparations are meant for external application to the skin. Pastes form and maintain a protective coating over the areas they are applied to because they are stiff and do not melt at room temperature. E.g. Tooth paste, deodorant paste. [52,53].

Powder: They come in crystalline and amorphous varieties. Powders are used in cosmetics by both men and women for face and body care. e.g., tooth powder, talcum powder, face powder.

Solution: A homogeneous mixture made up of two or more substances is called a solution. e.g. after shave lotions, hand lotions, astringent lotions, etc. [52,53].

Soaps: soaps are Cleaning agents made by reacting fats and oils from plants or animals with strong bases in water.eg, shampoo soaps, shaving soaps, and bathing soaps [52,53].

The industrialization of cosmetics in the modern era significantly contributed to human exposure to various toxic metals through cosmetics. Beyond-permissible limits metal exposure may result in complications. According to data on the toxic effects of metals, the majority of developing nations pay little attention to metal contamination of cosmetic products. [51]. The studies conducted in Libya showed that, face foundations and face powders had very consumption rate, different chemical materials present in the powders may interact together and become harmful to the skin. Out of 170 females' participants, 66,6% participants suffered from problems as a result of applying a face powder. Problems appeared was dryness is 56.7%, irritation is 29.8%, Acne is 26.9% and Spots is 16.3%. [54]. Examination performed in India confirmed that lead content in lipstick brands sold across Indian markets, induce toxicity to the women using them, the unborn foetus, if used in pregnancy, and infants, when used during lactation due to higher level of lead content. [55]. Omenka.S.S & Adeyi.A.A studied about the levels of zinc, cadmium, lead and nickel were assessed in 3 different classes of personal care products commonly used in Ibadan, Nigeria. The concentrations of zinc ranged from 3.75 to 19.3, 1.88 to 112,000 and 19.8 to 217 respectively in creams, powders and eyeliners. Cadmium ranged from ND-0.50, ND-36.3 and ND-0.50 mg/kg while lead ranged from ND-6.25, ND-468 and 3.73-27.5 mg/kg and nickel ranged from ND-6.25, 0.13-107 and 2.75-22.7 mg/kg respectively. [56].

3.2. Toxicology of cosmetics and its uses

Cosmetics have a wide range of chemicals compounds, some of which are used as ingredients and others as preservatives .There are many high-quality cosmetic products on the market, that contain very few metals and non-metals and may be beneficial to human health because they are not much adulterated with any harmful chemicals and also there are some low-quality or low-cost cosmetic products that can have a negative impact (toxic)on both the human body and the environment[18].

There are different kinds of skin diseases caused by cosmetics. Cosmetic toxicity may be caused by inorganic (metallic) components such as chromium, arsenic, lead, antimony, and mercury, cadmium, as well as chemical molecules such as chemical preservatives and harmful by-products. These metals enter the cosmetics manufacturing cycle via three major routes. First, they are added to produce desired outcome. Second, certain metals are created as impurities as a result of the production

methods, residual from the initial raw materials, etc. Third, unwanted metals may be present in several plant-derived ingredients such as cotton seed oil and rice variants. When these metals are used for an extended period of time, they may be absorbed into the body and cause toxicity, especially if the individual is allergic or more sensitive. [32,47].

When cosmetics are directly applying on epidermal layer of the body causes skin allergies, these will penetrate inside the body through small pores that present in the skin layer and cause frequent health risks. Cosmetics may contain nitrosamines that come from their raw materials or that are created by substances found in the raw materials, such as amides, alkyl amines, secondary amines, tertiary amines, and quaternary amines. The epidermis is penetrated by these nitrosamines, which frequently pose health hazards. Additionally, it has been claimed that fragrances are one of the main reasons for skin-dependent contact dermatitis. [32]. Some metals, such as antimony, lead, arsenic, magnesium, cadmium, are extremely poisonous and have a wide range of long-term health effects, although these, cobalt, nickel and chromium are well known skin stimulants. Some of them are known to be powerful carcinogens and respiratory toxins. [20]. Phthalates and formaldehyde releasing ingredients, parabens, hydroquinone, and formaldehyde are synthetic cosmetic substances that may be harmful to the human body. In products like soap, in order to prevent bacterial growth during storage formaldehyde is used. Formaldehyde is easily absorbed by the human skin and can cause cancer. Hydroquinone is a skin lightening agent. It reduces the production of melanin pigments. It is carcinogenic, and a decrease in melanin increases the risk of cancer due to decreased UV protection. Hydroquinone impairs natural immunity and causes reproductive and developmental problems [33]. Another aspect of cosmetics involves the toxicological effects of cosmetic color options. There are many types of coloring agents added and they cause toxicological impact, resulting in multiple adjustments to the number of permitted cosmetic dyes. [32]. The common but harmful ingredient mercury is present in many cosmetic products. It is the main ingredient in many of the skin lightening products. Suppose a cosmetic product containing mercury applied on the skin, the outer layer of the skin directly absorbs the mercury through transcellular and intercellular routes (Figure 1). Only a small amount of mercury can cross the blood barrier due to its low lipid solubility. After absorption it distributes to all tissues and transfer melanosome from melanocytes to keratinocytes, then shows the involvement of dendrites in the transfer of melanosomes which results in depigmentation [51].

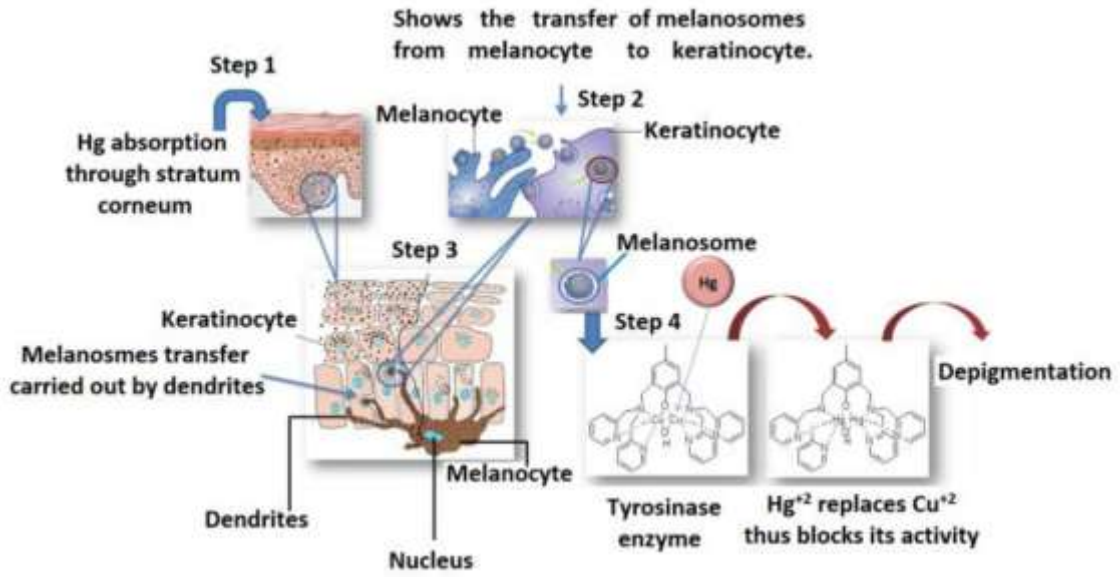

Figure 1 Pictorial representation of mercury absorption on skin

Lipstick: It is a cosmetic item that gives the lips colour, texture, and protection. Lipstick's main ingredients are coloring agents, waxes, oils, and, preservatives and perfumes are found in lesser amounts. Lipsticks and other cosmetic products are frequently made using lakes such as Sudan red, lake red, rhodamine B lithol red, which contain metal oxides. [25,49]. Bromine, barium and bismuth should be mentioned as they are toxic metallic elements that can cause sickness. Lipstick in shades of red and purple frequently contain bromine. As was previously mentioned, bismuth acts as a lubricant in lipstick, and some cosmetic formulations still use barium in the form of barium sulphate [29].

Eyeliner: To bring more attention to the shape of the eyes, it is applied to the tops of the eyelids. Eyeliners are available in liquid and pencil form. Eyeliners are made with the same ingredients as other cosmetic products, including castor oil, lanolin oil, ozocerite wax, carnauba wax, and propyl stearate. Propylene glycol, ammonium acrylate copolymer, tri-ethanolamine, and lecithin are among the chemicals used in the production of liquid eyeliners. [25].

Kajal: Women have used kajal for several years to enhance their appearance and because of its alleged medicinal ability to treat eye conditions. To enhance the expressiveness of the eyes, it is used

on the eyelids. Kajal is available in pencils form, pot form and in stick form and is made from vegetable carbon and fatty base. [25].

Eye Shadow: Eyeshadows give eyelids colour and gloss. Pressed powder, cream, and stick forms of eyeshadow are all readily available. The most popular eyeshadow type is press powder. Tale, iso-propyl lanolate, zinc stearate, liquid ester (binder), hydrogenated lanoline, microcrystalline wax, and coloring agents are the main ingredients in press powder eyeshadow. Wax, coloring agents and oils make up the typical composition of cream eyeshadow. [25]. Cu was confirmed to be present in green eye shadow, proving its presence as inorganic pigment. The powder base matrix contains Rb. Variations in potassium, titanium and iron concentration are correlated with sample shadow tones, decreasing with higher concentrations being related to the samples' dark coloring. [29].

Vermillion: Hindu women apply vermilion/sindoor, a brilliant red/scarlet pigment, to their foreheads where their hair is parted [25]. Bright orange, a duller bluish red, red, and maroon version of vermilion are also available. It is made up of a common base that is turmeric powder and calcium compounds that have been made wet with water, oils, or other substances like iodine, camphor, sandalwood, deer musk, alum, or other substances [29]. In order to produce brilliant red colour at a low cost, artificial materials like, mercury sulphite, crude red lead and rhodamine B have now replaced the compounds used in traditional vermilion. When used for an extended period of time, these materials are discovered to be toxic to humans. [25].

Nail Polish: Plasticizers like adipate esters, benzoate esters, and n-toluene sulfonamide, solvents like ethyl acetate, n-butyl acetate, titanium dioxide, pearlescent agents iron oxide and propyl acetate, are present in nail polish. Films are made flexible by adding plasticizers, whereas solvents affect film hardness, long-term stability, viscosity, drying time, and applicability. The solvent evaporates after nail lacquer or nail polish is applied to the nail substrate, leaving a thin and hard film layer on the nail. Colors are added to nail polish using coloring agents (dyes, lakes, and pigments)’. [25].

3.3. Permissible limits

Today manufacturing of cosmetics with a variety of components has raised health and safety issues. variety of chronic health effects a including cancer, contact allergies¸ biological disorders¸ neurological disorders and reproductive disorders and hair loss are caused by multiple usage of heavy metals [20]. Several regulatory authorities tried to define cosmetics to separate them from topical medicines. In European Unions, Article 1 of Council Directive 93/35/ EEC amending Directive

76/768/EEC defines cosmetics. First portion of the article is about, cosmetics are used on exterior bodily parts. Other bodily parts are excluded; thus, cosmetics shouldn't be applied to them. The second portion is about cosmetic 'activities.' These distinguish cosmetics from topical medicines used to treat or diagnose illnesses. Cosmetics aren't rigorously tested before being sold, unlike topical medicines. Cosmetic makers, importers and distributors are accountable for the safety of products. The latter legislation lists banned elements in cosmetics. Authorities banned some metals and their salts (e.g., nickel, arsenic, tin, lead and cadmium,), whereas specified salts are allowed with a restriction (e.g., mercury, chromium, cobalt, gold, and selenium amongst others). The Panel of Cosmetic Ingredient Review Expert establish certain limitations for Pb (5 ppm), As (5 ppm), and other heavy metals (20 ppm). WHO limits Cd (0.3 ppm), and Pb (10 ppm), Hg (1 ppm). Whereas European countries sets regulations for lead, chromium Cadmium, as 0.5, 1.0 and 0.5ppm. The authorities of Canadian countries issue limits are 3 ppm, 10 ppm, and 3 ppm for cadmium, lead and mercury respectively. Various authorities have different metal types and restrictions. This lack of uniformity confuses regulators, producers, and consumers. [10].

3.4. Manufacturing of cosmetics

The manufacturing process of Cosmetics is divided into five critical stages. The manufacturing process starts from raw material acceptance to the delivery. Every stage is managed in accordance with the protocols and procedures. The quality of products and standards are among the highest in the industry, ensuring that each product is both safe and effective. [34].

Acceptance of raw materials: -

- Checklist for ordering materials
- Disinfection of raw materials and temperature control
- Internal identification via our barcode system is generated in the system and then passed on to the Quality Control Team.
- Weighing system for weighing and re-weighing raw materials one at a time
- In any weight difference, the system rings an alarm to suspend work. [34].

Screening and Inspection of Microorganisms: -

- Color, scent, and texture inspection of raw materials
- Screening for microorganisms to detect contamination
- Moisture content, flowability, and vibration tests [34].

Mixing and Filling: -

- The barcode system will confirm the materials once they have been measured.
- Following approval, the materials will be mixed and distributed in the appropriate production machines.
- Solubility, temperature control, and separating are all part of the manufacturing process.
- Mixtures will be packaged correctly. [34].

Finished product appearance testing and inspection: -

- finished products are inspected for shades, styles, and fragrances in the same way that our customers would.
- Testing of finished products for expiry date [34].

Shipment: -

- Products are shipped to the storeroom after passing all tests and check - ups.
- Products are routed through a computerized method of scanning before being shipped to customers all over the world. [34].

4. Metal based cosmetic products

Cosmetic products generally contain chemical compounds mixtures, which include both natural and synthetic substances. Heavy metals like cadmium, lead, nickel, arsenic etc. are found in various types of cosmetic products. Cosmetic products will produce toxic effects on the body after being used for a long period Some metals, such as iron, chromium, aluminium etc. are necessary, but if they are

present in excess amounts, they will create harmful effects. Some authorities, including the World Health Organization /WHO, European Union /EU, and The Cosmetic Ingredient Review Expert Panel established by FDA in USA have imposed limitations on the certain metals present in cosmetics due to the potential rise in metal concentration. [9].

4.1. Distribution of heavy metals in cosmetic products

LEAD: It is commonly found in all types of cosmetic products. studies show that the people who use eye cosmetics have greater level of lead in their blood than the non-consumers. According to research, users of eye cosmetics had higher blood levels of lead than non-consumers. Lipstick, foundation, face powders, eyeshadow, mascara, and other cosmetics have been discovered to have high amounts of lead, although face powders contain minimal lead. Face cleansers contain more Pb than allowed by the FDA, whereas face creams hardly do. A significant quantity of Pb is included in hair shampoos, conditioners, and beauty creams. Body lotions have minimal Pb levels, whereas skin-lightening creams have significant Pb levels. [10].

CADMIUM: it is exploited for its colored salts (yellow-orange). So that it is usually found in lipsticks and eye shadows, eyebrow pencil. It can also be found in face creams, face cleansers, tonic creams and face powders. Hair shampoos, conditions, body lotions and cleansers are free of cadmium. Very small amount of cadmium is found in hair dyes. Most toothpastes contain negligible Cd. [10].

ARSENIC: It is one of the other major contaminants presents in the environment. When considered to cosmetics it is least contaminants than other heavy metals. It can be found in eye shadows, shampoos, conditioners, lipsticks, etc. The amount of Ar in face cosmetics, including creams and foundations, is low. Low amounts of Ar are present in hair colors, conditioners, and shampoos.

[10].

NICKEL: Nickel and its salts having a greenish colour so that most commonly it is used as colorants for the cosmetics. Cosmetics that may be consumed increase the risk of Ni intoxication. Among these possibilities are lipsticks and lip products. Oral consumption might result from toothpaste that was accidentally swallowed. Ni seems to be present in significant concentrations in the majority of makeup foundation products. However, the level was observed to be very low in various cosmetic products like, shampoos, conditions, face washes and creams. Body products' Ni content varies. [10].

when nickel components come in contact with skin produce certain irritations like eczema, erythema, and other skin problems. [45].

MERCURY: In its organic form is used for skin-lightening properties, e.g. ammoniated mercury. In its organic forms is utilized as a preservative in eye makeup cleansing products and mascaras e.g. phenyl mercuric and ethyl mercuric salts. In some products, such as lipstick, face creams, sunblock creams and face paints contain minimal amounts of Hg. [10,48]. High concentration of metallic inorganic and organic Hg can harm the developing foetus, kidney and brain. [46].

5. Detection of heavy metals

5.1. Sample preparation

The cosmetic product must go through the necessary pre-treatments such that the heavy metals are liberated and they are transformed to high oxidation stage before using the suitable analytical technique. As a result, prior to spectroscopic examination, several processing procedures are established for the separation of heavy metals from cosmetics. The sample's homogeneity is also very important. Before using the analytical procedure, heterogeneous items of cosmetic samples, such as microemulsions and emulsions, must be homogenized. A suitable quantity of sample is taken and put through a solubilization process after sampling, or homogenization, if that is required. Based on the component to be identified, a specific solubilization procedure must be employed. A variety of techniques are chosen for the inorganic substances solubilization including trace elements and minerals. Wet digestion, chelation solvent extraction, dry digestion, and solid phase microextraction are the techniques that are most effective. [21].

Methodologies for the preparation:

5.1.1. Wet digestion

Strong acids such HNO_3/HCl (1:3) HF, HNO_3, and H_2SO_4, as well as the mixture of a H_2O_2 and strong acid are used for the wet digestion of the sample. Under the influence of powerful acids, the sample's organic content is damaged during liquid digestion, which also turns the carbon in the sample into CO_2. The metals within, reaches their highest oxidizing state before being transformed into soluble salts. A drawback of this approach is the reduction of metals during digestion due to the extreme temperatures involved, as well as the drop in residual acid strength. [21].

5.1.2. Wet digestion method along with heat and microwaves

The second technique is Wet Digestion Methods with Heat and Microwaves. The primary acids utilized HNO_3 or acid mixtures such as HNO_3-HCl and HNO_3-H_2SO_4. When a sample immersed in an acid solvent is heated by microwave radiation, it can achieve temperatures that are significantly higher than the acid solution's boiling point. As a result, the metals oxidize and turn into soluble nitrates, while the organic material decomposes. The benefits of employing microwaves include their capacity to manage temperature, pressure, and metal loss, which helps to prevent inaccurate measurement findings. [21].

New Extraction Methods

5.1.3. Chelation solvent extraction method

Recent research studies discuss heavy metal extraction of for the purpose of examination of substrates such as seawater and soil. Heavy metals are known to react with organic nucleophilic reagents due to presence of d orbital, and result in chelate compounds. Chelates have a high degree of lipophilicity and stability. The organic ligand, which increases the metals' fat solubility and makes them more extractable from an aqueous environment by organic solvents, is the cause of their high lipophilicity. Sample preparation depends on the development of complexes between metals and suitable chelating agents. The key benefits of this approach are its quickness, simplicity, and typically low cost of implementation. [21].

5.1.4. Solid phase micro extraction /SPME

It is a new method of sample preparation. The approach has the benefit that organic solvents are not required, unlike traditional extraction methods that employ a two-phase water/organic solvent system, for the acquisition and extraction of organic compounds. In cosmetology, SPME [40]. is used as a pre-treatment technique to separate organic substances like preservatives (parabens), UV filters, and colors from other ingredients. Instrumental analysis techniques like HPLC, UV and LC-MS can be used to determine both their qualitative and quantitative composition once they have been isolated [21].

5.2. Types of analysis

Heavy metal assaying techniques can be divided into two categories. Traditional techniques use colorimetric bench chemistry techniques where the heavy metal concentrations are calculated as a composite of related elements. Modern techniques use sophisticated technology to test individual elements, and then combine the data to determine the overall amount of heavy metals. Using standard laboratory glassware, chemicals, and equipment, traditional colorimetric methods may be carried out in the most basic of facilities. They don't call for any costly equipment. The majority of these techniques are easy to execute. These approaches' drawbacks include their high detection limits and extremely low specificity. In terms of present and future product safety compliance, such methods are increasingly seen as outmoded and inadequate [23].

Locard’s exchange principle states that every contact leaves traces. Consequently, traces of cosmetic products are generally found at a crime scene. As a result, a crime scene usually has cosmetic product remnants. According to the approach employed for the analysis, the evidentiary value of such trace evidence would vary. The best technique should be non-destructive, repeatable, and able to analyse a limited number of specimens with little to no sample preparation. Actually, the complexity of cosmetic evidence limits the efficiency of approach in forensic cosmetic evidence analysis. For efficient differentiation of cosmetic exhibits obtained in criminal cases, many techniques must be used in conjunction. Chromatographic methods are used to separate colouring ingredients in cosmetics, while spectroscopic methods are used to examine other organic and inorganic substances. Visual examination is done with the help of microscope (Figure 2) [25].

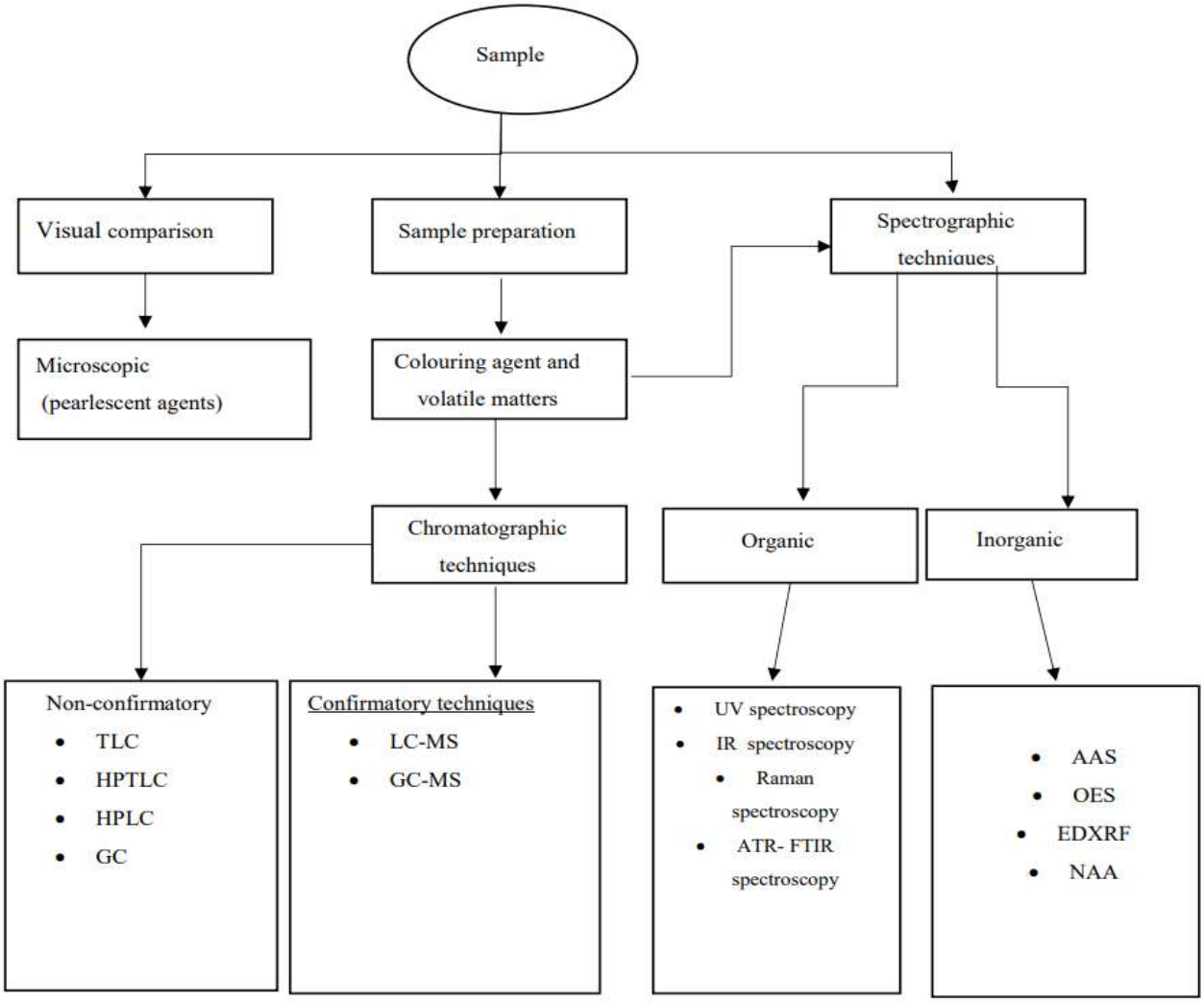

Figure 2 Flow chart for the cosmetic evidence analysis [25].

5.3. Instrumentation methods

There are many instrumental methods that are used to analyze heavy metals like AAS, ICP MS, XRF, XRD, Ion Chromatography. [24]. All of these techniques rely on sample preparations, which use strong acids like nitric and hydrofluoric acids, as well as hydrogen peroxide, to dissolve samples [23].

5.3.1. Atomic absorption spectrometry /AAS

Atomic absorption spectrometry analysis is frequently used to identify the trace components present in the samples. In AAS, a beam of light travels through the sample. Depending on how concentrated these components are, a certain portion of this light will be absorbed. The immersion of these elements might potentially be measured by evaluating the high degree of the initial beam and of this beam after passing the sample. The AAS instruments contain different sources of lighting for each element since each element absorbs light at a certain wavelength. It is applicable to observational studies of certain elements like Cd, Cr, As, and Pb [15].

The Flame Atomic Absorption Spectroscopy /FAAS is the oldest instrumental technique. This technique depends on the ability of metals to absorb energy from light of particular wavelengths due to their electrochemical characteristics. By measuring the quantity of light that a sample absorbs, sample concentrations may be calculated using the relation between the quantity of light absorbed and the concentration of analytes present in known standards. [23]. It is the method that is most frequently used to find trace components in various samples. [24]. GFAAS/ Graphite Furnace Atomic Absorbance Spectroscopy is very similar to FAAS but employs a different sampling system. GFAAS is capable of atomizing the complete sample and retaining it in the light's path for a considerable amount of time by employing an electrically heated graphite tube as opposed to a flame. A considerable increase in detection limits results from this distinction. However, a significant drawback of both GFAAS and FAAS is their inability to assess multiple elements simultaneously. [23,39,40].

5.3.2. Inductive coupled plasma-mass spectrometry /ICP-MS

Inductively Coupled Plasma Atomic Emission Spectroscopy is one of the most popular instrumental procedures for heavy metal test (ICP AES or ICP OES), the results are extremely sensitive, precise, and accurate. In this method, ionized argon gas interacts with a radio frequency field to maintain an argon inductively coupled plasma, which is used to excite atoms into unstable energy configurations. Energy is released as specific emitted light wavelengths as the atoms revert to more stable stage. The energy released has wavelengths that are particular to the elements in the sample, and the intensity of the emission depends on the concentration of atoms that are impacted. [23,41].

Inductively Coupled Plasma Mass Spectroscopy and Inductively Coupled Plasma Atomic Emission Spectroscopy are both multi-element simultaneous measurements techniques that use a sample introduction method. ICP MS, on the other hand, directs the atomic ions generated by the argon plasma into a mass spectrometer where they are separated based on their mass to charge ratio. In order to identify and quantify the elements of interest, ions with the selected mass to charge ratio are send towards the detector, which measures the number of ions present in the system. [23]. This specific approach of laser ablation inductively coupled plasma mass spectrometry is helpful when it is required to determine the variation of the elemental composition in the sample. [24].

5.3.3. X ray fluorescence / XRF

XRF spectroscopy is based on the radiations produced due to atom interaction. This analytical technique is sensitive and used for analysis of metal. The primary benefit of XRF is its capacity for precise quantitative analysis over a broad range of elements. XRF is used to analyses cosmetic samples to identify the amount of metal ions present, including heavy, necessary, and light metals like (Cd, Mn, Ni, Co, Fe, Hg, Cr, Zn As, Cu, Pb, and Al) [26].

The basis of XRF is the detection of secondary, or fluorescence X rays released from a sample when it is exposed to high-energy X rays. Materials can get ionized when they are excited with Xrays. The atom becomes unstable and an outer electron takes the place of the missing inner one, if the radiation's energy is high enough to knock an inner electron out of position. Due to the inner electron orbit's lower binding energy than an outer one, energy is then liberated. The generated fluorescence X rays can be utilized to detect individual elements in the sample since they each have distinctive photonic-energy signatures. With little preparation and no harm to the sample, portable XRF machines can quickly determine the metal content of samples in the field. It is necessary to validate the results of handheld units using techniques like AAS/ atomic absorption spectroscopy, ICP AES/ inductively coupled plasma atomic emission spectroscopy, or ICP MS/ inductively coupled plasma mass spectrometry analysis due to concerns about potential interference from substances like Pb or water. [27]. The sample is not destroyed during XRF spectrometry, therefore minimal specimen preparation is necessary. The turnaround time for samples is really quick. When compared to alternative elemental analysis techniques, these features result in a significant reduction in the analytical cost per sample. [28,44].

Energy Dispersive X ray Fluorescence (EDXRF) provides simultaneous assessments of elements from Na to U (usually used for metals determination), high speed measurements (5 to 1000 s, depending on the sample and aims), and even the drawbacks and benefits are well established. In contrast to other analytical procedures, its instrumentation is affordable and simple to use. With fewer stages of sample preparation or even no handling, EDXRF is a nondestructive technology that may be used to analyses any form of solid or liquid sample (thick, thin, or moderate thickness, in small amounts starting at 0.1 mg). Depending on the measurement's conditions, it offers adequate sensitivity for both quantitative and qualitative examination, with detection limits of tenths of parts per million from trace elements. [29].

5.3.4. X ray diffraction / XRD

X ray diffractometry is an effective method used to analyses and interpret the inorganic mineralized artefacts like metal, ceramics, and paints. t is a versatile, non-destructive analytical approach that can quickly get phase and structure information of materials. XRD patterns of materials shows the characteristic diffraction peaks that indicated the major component of the sample. Materials' XRD patterns exhibit distinctive diffraction peaks that identify the main component of the sample [26]. The X-ray diffractometer is a useful instrument for the examination and testing of materials used in cosmetics, electronics, studies in nanomaterials, forensics, blood, food, and medicines. Constructive interference between a crystalline sample and monochromatic X rays is the basis principle of X ray diffraction. X ray diffractometers have 3 basic parts: An X ray sensor, a sample holder, and an X ray tube. [15]. A cathode ray tube generates the X rays, which is filtered to create monochromatic radiation, collimated to concentrate, and then directed onto the sample. When the conditions agree with Bragg's Law (n=2d sin), results in constructive interference (and a diffracted ray) due to the interaction of the incident rays with the sample. The diffraction angle and crystalline lattice spacing in a sample are related to the EMRs wavelength by this rule. Then these diffracted X-rays are then traced, processed and recorded. The conversion of the diffraction peaks to d-spacings allows for mineral identification since each mineral has a unique set of d-spacings. Often, this is done by comparing the d-spacings to accepted reference patterns. [30].

5.3.5. Ion chromatography /IC

Ion chromatography (IC) is an appropriate technique used for quantification and isolation of water-soluble trace heavy metals in complicated matrices, because residual organic molecules do not

interact with it. It is advantageous for quality control of cosmetic items since it is a low-cost and precise approach in light of instrumentation costs and maintenance. A cation exchange column might be used to separate weakly complexed and hydrated heavy metals as cations. The total charge on the metal would decrease if weak organic acids like oxalic, citric, and tartaric acid were employed as chelating agents in the eluent because they would be in an anionic state in solution above their pKa's. The difference in the degrees of association between the chelating agents and the metals, which are generating distinct total charges on the metal complexes, were the actual cause of the separation's selectivity. The total charge on the metal complexes may be negative if strong chelating agents are used in large amounts. These negatively charged metal complexes are separated from one another on the column by anion exchange, which enables the separation of metals as cations and anions on a single column. simultaneous assessment of heavy metals was proven to be fast and sensitive by this method due to rare interference, which can enhance the quality control process for safe cosmetic items. [22].

ICP MS, ICP, GF-AAS and Flame AAS are some techniques for heavy metal analysis. There are benefits and drawbacks to each of the aforementioned instrumental procedures. ICP MS is one of the best analysis techniques because it is fast and highly sensitive in metal analysis. ICP-MS, however, is unable to analyses trace metals like Fe, Cu, Zn, and Ni simultaneously due to interference from polyatomic ions produced by the interaction of Ar, N, O, and H. Due to interference from residual organic compounds in the test sample, ICP-MS, GF-AAS, and Flame AAS are not appropriate for the detection of trace water soluble metals. Ease of use, sample throughput, interferences, precision, cost per sample, detection limits, and operating costs are just a few of these instruments' drawbacks. While detection limits differ from different elements and methods, ICP MS is the best overall technique for the 4 main heavy metals (arsenic, cadmium, lead, and mercury). ICP-MS is the method with the fewest interferences, and its dynamic range frequently exceeds that of ICP AES. [23]. Liquid chromatography tandem mass spectrometry (LC-

MS/MS) can be applied for identifying preservatives and synthetic dyes in cosmetics [42].

6. Discussion

Zinc, cadmium, copper, chromium, lead, etc. are examples of the heavy metals that make up inorganic pollutants. Through manmade activity and geological cycles, they find a way to survive in

our environment. Heavy metals, which are naturally poisonous, manifest their harmful effects in the form of bioaccumulation and bio magnification in the tissues and food webs of living things. It has been claimed that exposure to heavy metals can cause neurological impairment, a suppression of the immune system, and anomalies in embryonic development in mammals, including humans. When livestock that has been poisoned owing to the entry of heavy metals in the food chain, it can cause major problems both economically and health-wise [5]. The group of metals includes iron, copper, zinc, cobalt, manganese, selenium, molybdenum, chromium, all of which are vital nutrients involved in both physiological and biological mechanism. However, some metals, like mercury (Hg), arsenic (As), lead (Pb), zinc (Zn), and cadmium (Cd) are potentially dangerous when consumed in big enough amount or in certain metallic salt forms. The acute poisoning effects of certain toxic metals, includes zinc (Zn), mercury (Hg), lead (Pb), and arsenic (As), are evident, although the long-term effects of other metals are also apparent [15]. Nickel is found in the environment in small amounts, and it can cause a number of lung problems, such as inflammation, fibrosis, emphysema, and tumors [37]. Copper is a critical component in the production of haemoglobin and is required by a number of enzymes. However, research has shown that consuming excessive amounts of copper can lead to negative effects on one's health. [38]. Both manmade and natural sources of arsenic have large environmental footprints. The inorganic and organic forms of mercury, when consumed by humans, both have substantial levels of toxicity. When ingested in high concentrations, inorganic mercury, such as mercury vapor, is poisonous and can result in severe pneumonia [18]. Many people use facial and personal care products on a daily basis. When cosmetics are applied to human skin in a way that is not indirect, the skin becomes subjected to a wide range of potentially lethal substances. Despite of the skin's protective function against endogenous and external pollutants, certain components of cosmetic products are able to generate systemic exposure by penetrating the skin and causing it to absorb them. It would be better if consumers were more aware of the potential dangers associated with frequent use of cosmetics. While laws are common in high-income nations, they are lacking in low-income nations. Restrictions on the acceptable level of heavy metals are tight in the majority of the nations for which these legislative requirements have been established. Existing regulations must be strictly enforced, and their effectiveness must be carefully evaluated. Metals in cosmetics are a cause for alarm because of the potential they pose as a daily, and often long-term, source of exposure to a large portion of the population. Metals can accumulate in the body over time, and a number of them are known to exhibit various chronic health impacts, including cancer, contact dermatitis,

developmental, neurological, and reproductive issues, brittle hair, and hair loss. Some metals are strong respiratory poisons and endocrine disruptors. Furthermore, some metals are highly poisonous with a wide variety of chronic health impacts, such as Cd, As, Pb, Hg, and Sb, whereas Cr, Ni, and Co are well recognized skin sensitizers. Since the issue of heavy metals as intentional cosmetic ingredients has been addressed, the focus is now on their presence as impurities [20]. Atomic absorption spectrometry (AAS), inductively coupled plasma mass spectrometry (ICP-MS), X-ray fluorescence spectroscopy (XFS), and inductively coupled plasma atomic emission spectrometry are the techniques that are utilized in the process of analyzing heavy metals and trace metals, respectively (ICP-AES). However, atomic absorption spectrometry is more accurate and appropriate, and atomic absorption spectrometry is typically less expensive than ICP-MS, ICP-AES, and XFS [18,43].

7. Conclusion

The hazardous ingredients that are frequently contained in cosmetic items' compositions are blamed for persistent unpleasant effects and potential health hazards. Although the different systems in place across the world to regulate and oversee the quality of cosmetics are fairly intricate and thorough, they should be more stringent when adding new compounds with the potential to be harmful to the composition of cosmetics in order to prevent harm to human health. It is essential to implement a global cosmetic-vigilance in order to promote improvements in the production, marketing, and consumer usage of cosmetic products. This public health strategy is a reliable way to learn about the safety of cosmetic goods and their ingredients, preventing the dangers connected to cosmetic usage from becoming a problem.

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Assessment of Heavy metal migration from utensils and it's Impact on family health: a study on potential health risks and prevention strategies

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Abstract: Heavy metals such as lead, cadmium, nickel and chromium can migrate from cookware made of metal or metal alloys into food during cooking and storage, posing a potential health risk for families who consume such food. This study aimed to assess the extent and factors of heavy metal migration from utensils and its impact on family health. The study also proposed some prevention strategies to reduce the exposure and intake of heavy metals from utensils. The study involved screnning of steel, copper, brass and glass for heavy metal migration. These utensils were made up of stainless steel, aluminum, brass, iron etc. The study also conducted to evaluate impact of electroplating in reducing the migration of heavy metals from utensisl. The results showed migration of lead from brass utensils. The resulst also showed that nickel and copper plating reduces migration of lead from brass utensils. Previous researches shows that migration of heavy metals is influenced by several factors such as the material, coating, corrosion, abrasion, acidity and duration of cooking. The results also indicated that the intake of heavy metals from food cooked in utensils exceeded the safe limits recommended by the World Health Organization. The study suggested use of stainless steel utensils are safe. The study also showed that migration of lead can be reduced by electroplating of nickel and copper. This study highlights that heavy metal migration from utensils is a serious public health issue that requires awareness and intervention from both consumers and authorities.

Keywords: Metal Toxicity, Lead, Migration of Heavy Metal, Utensils.

1. Introduction

Heavy metal migration from utensils and cookware is a complex phenomenon that is influenced by various factors such as pH, temperature, and cooking time. The migration of heavy metals can occur through different pathways, including migration from coatings, migration from the surface, and migration from the bulk material [6]. Studies have shown that the type of material used for the manufacture of utensils and cookware can significantly influence heavy metal migration. For instance, lead and cadmium are commonly found in ceramic and porcelain utensils, while nickel and chromium are commonly found in stainless steel utensils [3], [4], [22], [23], [33].

The migration of heavy metals from utensils can be accelerated by acidic foods and drinks, high cooking temperatures, and prolonged cooking times. A study by Oyarzun et al. (2018) found that the migration of lead and cadmium from ceramic utensils was significantly

higher when the utensils were used to cook acidic foods such as tomato sauce and lemon juice compared to neutral foods such as water. Similarly, a study by Song et al. (2019) found that the migration of nickel and chromium from stainless steel utensils was significantly higher when the utensils were exposed to acidic solutions.

Health Risks Associated with Heavy Metal Contamination

The consumption of food and drinks contaminated with heavy metals can pose potential health risks to humans. Heavy metals can accumulate in the body over time and cause damage to various organs such as the liver, kidneys, and central nervous system. Studies have shown that exposure to lead can lead to developmental delays in children, while exposure to cadmium can increase the risk of cancer [34].

Mercury is another heavy metal that can pose significant health risks. Mercury can accumulate in fish and seafood, and consumption of contaminated fish can lead to mercury poisoning. Mercury poisoning can cause neurological damage, developmental delays in children, and cardiovascular disease.

Arsenic is another heavy metal that is commonly found in rice and other grains. Long-term exposure to arsenic can increase the risk of skin, lung, and bladder cancer. Chromium is another heavy metal that is commonly found in water and can increase the risk of lung cancer and respiratory diseases.

Prevention Strategies for Heavy Metal Contamination

Several prevention strategies can be employed to mitigate the risks associated with heavy metal contamination. These strategies include:

- ✓ Using utensils and cookware made from safe materials such as stainless steel, glass, and enamel.
- ✓ Avoiding the use of ceramic and porcelain utensils for cooking acidic foods and drinks.
- ✓ Limiting the use of aluminum cookware, which can react with acidic foods and drinks and release aluminum into food.
- ✓ Avoiding the use of old and worn-out utensils and cookware, which can leach heavy metals into food.
- ✓ Washing utensils and cookware thoroughly before use to remove any contaminants.
- ✓ Using water filtration systems to remove heavy metals from drinking water.
- ✓ Choosing fish and seafood that are low in mercury.

2. Materials and Methods

This study aimed to screen the various types of utensils to undersatnd migration of heavy metal. The methodology includes the research design, data collection, sample selection, and data analysis methods used in the study.

2.1 Sampling

Different types of utensils were randomly selected. Stainless steel, copper, brass and glass utensils were used in this study. These utensils were selected based on their popularity and widespread use in the community.

2.2 Research Design

This study's research design is a quantitative, experimental research design. The experiment examined metal migration from various types of utensils including electroplated utensils [16], [19], [20], [21], [35], [36], [37]. The electroplating process was the independent variable, and the amount of metal that migrated from the utensils was the dependent variable. To limit the effect of confounding variables, the study was conducted in a controlled environment [1], [2], [5], [7], [8], [9], [10], [11], [12], [13], [14], [15], [17], [18].

2.3 Sample Preparation

To prepare the samples, each utensil was washed with distilled water and then air-dried. The samples were stored at room temperature until further analysis.

2.4 Data Collection

This study's data was gathered through laboratory experiments. The leaching stimulant (4%v/v Acetic Acid for 24 hours) was utilised in this study. The metal migration experiments were performed in accordance with the standard procedure.

2.5 Calibration Curve:

A series of standard solutions with known concentrations of heavy metals were prepared from the certified reference standards. These solutions were used to establish the calibration curve for quantification of heavy metals in the samples.

2.6 Data Analysis

The descriptive and inferential statistics were used to analyse the data acquired in this study. Descriptive statistics were used to summarise the data's properties, while inferential statistics were used to test hypotheses and draw conclusions from the results.

2.7 Composition analysis

X-ray fluorescence (XRF) analysis was performed on the materials using a Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883). Internal quality checks were performed prior to analysis utilising NIST traceable BAS-England British Chemical Standard Certified Reference Material (BCSCRM). In order to assure acceptable instrumental performance, instrumental QC samples are analysed alongside sample.

2.8 Metal Migration from Utensils

Metal migration from utensils is the process of metal ions leaching from food contact materials made of metal, such as stainless steel, aluminum, copper, etc. into food or beverages. This can happen due to various factors such as acidity, temperature, time, and surface area of the utensils. Metal migration can pose a health

risk for consumers if the intake of certain metals exceeds the tolerable levels set by health and regulatory authorities[2]. Some metals such as iron, copper, and zinc are essential for human health in trace amounts, but can be toxic in excess. Other metals such as aluminum, chromium, and nickel have no known biological function and can cause adverse effects on the nervous system, bones, and blood. Therefore, it is important to monitor and control the metal migration from utensils to food and beverages [24], [25], [26], [27], [28], [29], [30], [42].

The type of metal used in the utensil, the utensil's quality, the temperature and length of contact to the food or beverage, and the food or beverage's acidity or alkalinity all affect how much metal migrates. Acidic foods or drinks, for instance, can promote metal migration more than neutral or alkaline ones [41].

Use of high-quality utensils made of materials recognised to be safe, such as titanium, stainless steel, or specific types of ceramic, to reduce the danger of metal migration. Additionally, it is suggested that you stay away from using utensils that are chipped, cracked, or scratched because these flaws increase the surface area of the item and promote metal migration. In order to reduce the risk of metal migration, it's also wise to avoid keeping food or beverages in metal containers for extended periods of time.

There is no standard cooking procedure because it is a personal preference. Leaching stimulant (4%v/v Acetic Acid for 24 hours) was employed to assess the utensil's maximum leachability. Utensils were cleaned and washed with soap and distilled water prior to conduct migration test.

After cleaning and washing with soap and distilled water, all the samples were filled with leaching stimulant (4%v/v Acetic Acid) and kept for 24 hours for leaching. After 24 hours, solutions were transferred in to volumetric flask for testing. The standard testing procedure was followed for testing.

2.9 Equipment: Inductively Coupled Plasma Mass Spectrophotometry (ICP MS)

Inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) (Thermo Scientific™ iCAP™ RQ ICP-MS Serial No. iCAP RQ01591) is used for analysis of leaching solution. This testing was performed at Research Testing & Calibration Laboratory (A Division of Metal Handicrafts Service Centre), Moradabad. This laboratory is accredited in accordance with ISO/IEC 17025: 2017 “General requirements for the competence of testing and calibration laboratories” by National Accreditation Board for Testing and Calibration Laboratories (NABL) vide certificate number TC-6683 valid from 09/09/2020 to 08/09/2020 [31], [32], [38], [39], [40].

2.10 Summary of Method

2.10.1 Principle

ICP-MS stands for “Inductively Coupled Plasma Mass Spectrometry”, which is a technique for measuring the elemental and isotopic composition of samples. The basic procedure of analysis by ICP-MS is summarized below.

Sample preparation: The sample must be in liquid form. The sample solution may need to be diluted, filtered, or spiked with internal standards depending on the concentration and matrix of the analytes.

Sample introduction: The sample solution is introduced into the ICP-MS instrument by a nebulizer, which converts it into a fine aerosol. The aerosol is then transported by a stream of argon gas into the plasma torch.

Ionization: The plasma torch generates a high-temperature plasma (about 10,000 K) by applying a radiofrequency current to a coil of copper tubing around a quartz tube. The plasma ionizes the sample atoms and molecules into positively charged ions.

Mass analysis: The ions are extracted from the plasma through a vacuum interface and focused by a series of ion lenses. They are then separated by their mass-to-charge ratio using a mass analyzer, such as a quadrupole or a magnetic sector. The mass analyzer scans over a range of masses or selects specific masses of interest.

Detection: The ions are detected by an electron multiplier, which converts the ion signal into an electrical signal. The signal is proportional to the ion abundance and is recorded by a computer. The signal is then calibrated using external or internal standards to obtain the elemental and isotopic concentrations in the sample.

ICP-MS utilizes a combination of inductively coupled plasma and mass spectrometry to achieve highly sensitive and selective detection and quantification of trace elements in samples.

2.10.2 Brief Procedure

ICP-MS (Inductively Coupled Plasma-Mass Spectrometry) is a powerful analytical technique used for elemental analysis in a wide range of applications. The brief overview of the procedure for testing using ICP-MS is mentioned in Figure 1: Procedure for analysis of samples by ICP-MS.

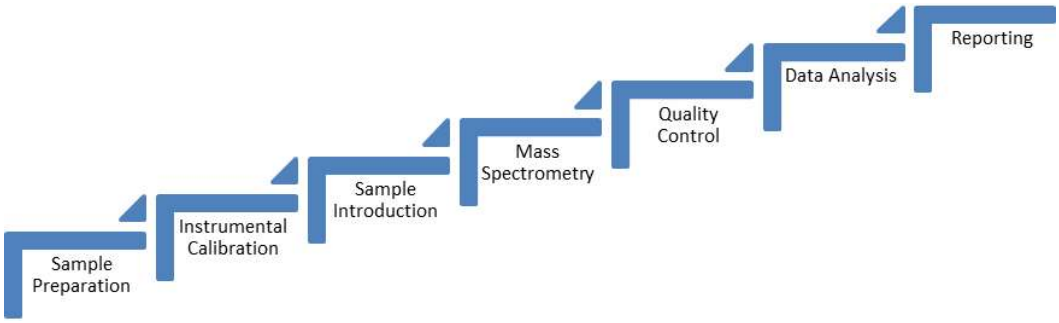

Figure 1: Procedure for analysis of samples by ICP-MS

2.10.3 Environment, Health and Safety

All relevant environment, health and safety aspects are employed in the laboratory to ensure compliance.

2.10.4 Interference

This method covers the analysis of 23 elements in various types of samples by ICP MS. There is no interference observed.

3. Results and Discussion

3.1 Composition Test

Samples (Six unit of each utensil i.e. six units of Plate, Tumbler and Bowl) were analysed for composition test by using X-ray fluorescence (XRF) i.e. Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Table 1: Composition of Samples).

Table 1: Composition of Samples (%)

	Copper		Brass			Steel								
	Bottle	Cup	Plate	Tumbler	Bowl	Coffee Mug	Small Bowl	Cheese Knive	Fork	Steel Bowl	Bowl	Plate	Tumbler	Bowl
Nickel	<0.10	<0.10	<0.10	0.37	0.67	1.05	10.03	1.51	8.06	8.07	0.56	0.71	1.20	0.63
Copper	98.86	98.80	62.26	54.65	54.17	2.00		1.65			1.98	0.65	1.43	1.00
Chromium						15.28	16.53	15.14	18.52	18.34	14.96	14.02	13.60	12.76
Manganese						10.00	1.17	9.10	1.27	1.50	10.26	10.12	9.64	9.15
Lead			<0.10	4.17	3.75						<0.001	<0.001	<0.001	<0.001
Cadmium			<0.10	<0.10	<0.10							<0.001	<0.001	<0.001
Silicon						0.39	0.43	0.40	0.52	0.48	0.38			
Molybdneum							2.07				<0.001	<0.10	0.14	<0.10
Zinc	0.97	1.04	37.56	38.96	39.29									
Iron			<0.10	0.90	0.85									
Tin			<0.10	0.87	1.21									

3.2 Migration Test

Inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) was used to analyse the leaching solutions (Thermo ScientificTM iCAPTM RQ ICP-MS Serial No. iCAP RQ01591). The testing was carried out in accordance with standard procedure. The results are shown in Table 2: Leahcing of Heavy Metals and Table 3: Lead and Cadmium Migration.

Table 2: Migration of Heavy Metals (ppm)

Element	Brass Hammered Coffee Pot	Egg Cup Cover	Salt Spoon	Copper Engraved Coffee Pot with Wooden Handle	Cake Stand
Aluminium	<0.01	<0.01	<0.01	<0.01	<0.01
Cobalt	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	1.82	0.09	1.63	2.05	<0.01
Iron	<0.01	<0.01	<0.01	<0.01	<0.01
Silver	<0.01	<0.01	<0.01	<0.01	<0.01
Manganese	<0.01	<0.01	<0.01	<0.01	<0.01
Molybdenum	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	<0.01	<0.01	<0.01	<0.01	<0.01
Tin	<0.01	<0.01	<0.01	<0.01	<0.01
Thallium	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Vanadium	<0.01	<0.01	<0.01	<0.01	<0.01
Zinc	<0.01	0.05	<0.01	<0.01	<0.01
Lead	<0.005	<0.005	<0.005	<0.005	<0.005
Cadmium	<0.003	<0.003	<0.003	<0.003	<0.003
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic	<0.001	<0.001	<0.001	<0.001	<0.001
Beryllium	<0.01	<0.01	<0.01	<0.01	<0.01
Barium	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	<0.01	<0.01	<0.01	<0.01	<0.01
Lithium	<0.01	<0.01	<0.01	<0.01	<0.01
Magnesium	<0.01	<0.01	<0.01	<0.01	<0.01
Titanium	<0.01	<0.01	<0.01	<0.01	<0.01

Table 3: Migration of Lead and Cadmium (ppm)

Metal	Type of Utensil			
	Glass	Copper	Brass	
	Bowl	Cake Dome	Bowl	Tumbler
Lead	<0.05	0.37	897	985
Cadmium	<0.03	<0.03	<0.03	<0.03

4. Conclusions

4.1 Heavy Metals in Utensils

Metal utensils are commonly used in households, restaurants, and food industries. They are made of various materials such as iron, stainless steel, aluminum, copper, brass, and bronze. These materials can contain various heavy metals such as lead, cadmium, chromium, mercury, and arsenic. The presence of heavy metals in utensils can result from the manufacturing process or due to the use of low-quality materials. Additionally, some utensils may be coated with a layer of metal that can peel off over time, leading to increased heavy metal migration.

4.2 Heavy Metal Migration

Heavy metal migration occurs when metals leach from utensils into food during cooking or storage. The rate of migration is influenced by various factors such as pH, temperature, and the type of food being cooked or stored. Acidic foods, such as tomatoes and citrus fruits, are particularly prone to leaching heavy metals from utensils due to their high acidity levels. Additionally, prolonged heating and storage can increase the rate of migration. Once heavy metals enter the body through contaminated food, they can accumulate in tissues and organs, leading to long-term health effects.

4.3 Health Risks

The accumulation of heavy metals in the body can result in various health risks. Lead exposure, for instance, can cause anemia, cognitive impairment, and developmental delays in children. Cadmium exposure can lead to kidney damage, while arsenic exposure can increase the risk of cancer and cardiovascular disease. Mercury exposure can cause neurological damage, especially in developing fetuses and infants. Chromium exposure has been linked to lung cancer, while nickel exposure can cause dermatitis and lung cancer. The health risks associated with heavy metal exposure are often dose-dependent, and chronic exposure to low levels of heavy metals can also cause adverse health effects.

4.4 Impact of heavy metal exposure on family health

Exposure to heavy metals can have adverse health effects on humans, especially children, who are more vulnerable due to their developing bodies. Heavy metals can affect the central nervous system, leading to neurotoxicity, cognitive impairment, and behavioral changes. They can also cause damage to the liver and kidneys and increase the risk of cancer.

4.4 Prevention Strategies

To prevent heavy metal migration from utensils, it is essential to choose high-quality cookware made of materials that are less prone to leaching. Stainless steel and cast iron are good choices, while aluminum and copper should be avoided due to their high reactivity. Additionally, acidic foods should not be stored or cooked in metal utensils for an extended period, and metal utensils should be replaced when they show signs of wear and tear. It is also recommended to avoid using metal utensils with non-stick coatings, as these coatings can break down and increase heavy metal migration.

Based on the findings of this study, it is concluded that the industry that manufactures utensils need strict rules and quality control systems. As a result, customers won't be exposed to dangerously high levels of metal ions from utensils. This study also sheds light on the importance of electroplating in reducing the migration of heavy metal from utensils and highlights the need for more research in this area to better understand the dangers and potential negative effects on health posed by using metal utensils.

Statement of Data Availability

The data that supports the findings of this manuscript is available upon request. We understand the importance of data accessibility and transparency in scientific research, and we are committed to providing access to the data for the purpose of validation, replication, and further exploration.

Authors Contributions

Authors Deepak Kumar Sharma, Dr. Divya Tripathy, and Dr. Arvind Jain have made significant contributions to the manuscript. Deepak Kumar Sharma's expertise in the field of literature, experimental and writing has enriched the manuscript with his profound knowledge and exceptional storytelling abilities. His meticulous research and attention to detail have ensured the accuracy and credibility of the information presented in the manuscript. Dr. Divya Tripathy, with her profound understanding of the subject matter, has provided valuable insights and perspectives that have added depth and breadth to the content. Her expertise in the specific field of study has helped shape the manuscript into a comprehensive and well-rounded piece of work. Dr. Arvind Jain's contribution in the manuscript has been instrumental in providing a scientific and analytical perspective. His extensive knowledge and research in the field have brought forth a balanced and evidence-based approach to the content. Overall, the combined efforts of these authors have resulted in a manuscript that is informative, engaging, and credible, making it a valuable contribution to the field.

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Conflicts of Interest

The authors declare no conflict of interest.

Declarations

All authors have read, understood, and have complied as applicable with the statement on “Ethical responsibilities of Authors” as found in the Instrucations for Authors.

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Research Paper

MIGRATION OF METALS FROM UTENSILS: AN ASSESSMENT

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Abstract

Background: Heavy metal toxicity has proven to be a major threat to the society. Due to prolonged exposure of metal contaminated atmosphere & food and bioaccumulation nature of metals, there are numerous health risks associated with metal toxicity. One of the significant sources of metal contamination in food is through migration of metals from the utensils. Almost all types of utensils leach out the metals and there are various factors which include processing (e.g., heating) and nature of food (e.g. acidic) which plays important role in migration.

Objective: Determination of migration of metals from Stainless-Steel and Brass utensils.

Material and Methods: Stainless-Steel and Brass utensils (Plate, Tumbler and Bowl) were purchased from the local market of Moradabad. These utensils were of medium priced. The samples were analysed as per American Society for Testing and Materials (ASTM E1613-12 & ASTM C738-11) test methods based on Inductively coupled plasma mass spectrometry (ICP-MS) techniques. The composition was analysed through X-ray fluorescence (XRF). Leaching stimulant (4% Acetic Acid for 24 hours) is used for extraction process. Testing was performed in an accredited (in accordance with ISO/IEC 17025: 2017) laboratory.

Results: There is a growing trend for use of brass utensils not only at home but outside home such as restaurant also. From this study, it has been observed that brass utensils are leaching lead in to the food which ultimately entering in to the human body. Seventy-two samples were analysed to know the migration of metals from stainless-steel and Brass utensils. Migration of

metal (Lead) is observed from the brass utensils. Stainless-steel utensils are considered to be safe w.r.t. migration of metals.

Keywords: Heavy Metals contamination, Metal Toxicity, Metal Poisoning, Utensils

1. Introduction

Micro and Macro elements are necessary for human beings. Being toxic in nature, the metals beyond the permissible limits are dangerous to human beings. Metabolic functions in humans are troubled due to metal exposure mainly due to disruption in the functioning of vital organs [1]. Furthermore, the chelation effect of many metals affects the metabolism. Elevated levels of metals have been reported in the food chain. Environmental pollution, due to massive industrialization, is one of the primary reasons for heavy metal contamination of food and water bodies [2]. There have been various studies which have shown that the type and nature of cookware and cooking process can also lead to the increase of heavy metals contamination in food. Due to the leaching effect, utensils are a potential source for metal contamination [3, 4].

Various types of utensils are used throughout the world for the purpose of cooking, storing and eating food. Generally, locally made utensils were used. During investigations in Cameroon has indicated that the cookware made in informal manufactures by casting liquid aluminum melted from a collection of scrap metal [5, 6] Many other researches have reported about the potential leaching of metals from aluminum cookware in India, Egypt, China, Saudi Arabia, Syria, and Bangladesh [7, 8, 9].

In this study, we have evaluated the migration of metals from stainless-steel and Brass utensils to contribute to metal exposures. In spite of the fact that lead additives have been removed from gasoline more than decade ago in all but in a few countries, abundant reports established the prevalent persistence of elevated blood lead levels in low and middle-income countries [10-17. There is no safe level of lead exposure [18-20]. The toxic effects of lead are very well known to all. Lead exposures are linked to various implications including learning disabilities, attention related behaviours, deficits in intellectual development, high blood pressure, cardiovascular disease etc. The estimated worldwide toll from lead poisoning is 674,000 premature deaths annually [21] and economic costs approaching $1 trillion [22]. The tenacity of high blood lead levels

is of great concern for public health and economic development worldwide. The consumption of lead is growing rapidly due to fulfil the requirements of lead batteries for automobile and other related industries. The studies have shown that emissions from manufacturing and recycling unit of these batteries have contributed to lead exposures in adjacent populations [23]. Additionally, a wide variety of consumer products contain lead additives including lead paint which is commonly used in many countries around the world [24-25]. Many other consumer products that contain lead and are often unregulated include plastics, lipsticks, jewelry, solder, brass, and ceramic glazes [26-28]. Locally made utensils are a potential source of lead exposure that has largely been unheeded. This cookware is widely used in developing nations [5, 7, 29].

It is estimated that lead exposures from cooking is as high as 260 µg per serving and indicate a serious health hazard [30-36]. Additionally, simulated extraction in the laboratory released other metals also.

Our objective in this investigation is to explore how the potential health risks posed by Stainless-steel and Brass utensils will be in Moradabad region of India. We purchased 84 samples from the local market of Moradabad to study the migration of lead and other metals in laboratory conditions. We also conducted preliminary studies on possible means to reduce migration of the metals from utensils and subsequently reducing metal contamination.

2. Material and Methods:

2.1 Material

Eighty-four samples were purchased from the local market from Moradabad. These samples are of normally purchased by the common man as the price of these utensils were in normal range. All were manufactured in India.

Table 1: Sample Details

Material	Plate	Tumbler	Bowl	Total
Stainless-Steel	14	14	14	42
Brass	14	14	14	42
			Grand Total=	**84**

2.2 Composition analysis

The samples were analysed for composition of the material by X-ray fluorescence (XRF) using Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883). Internal quality checks were performed before analysis using traceable reference standard {NIST traceable BAS -England British Chemical Standard Certified Reference Material (BCSCRM)} is used. Instrumental QC samples are analyzed along with sample in order to ensure adequate instrumental performance.

2.3 Migration of Metal from Utensils (Leaching Test)

The cooking is an individual choice. There is no uniform cooking methodology adopted. To determine maximum leachability from any utensil, leaching stimulant (4%v/v Acetic Acid for 24 hours) was used. All utensils were cleaned and washed with soap and distilled water prior to conduct migration test.

The samples were filled with leaching stimulant (4%v/v Acetic Acid) and kept for 24 hours for leaching. After 24 hours, solutions were transferred in to volumetric flask for testing. The standard testing procedure was followed for testing.

2.4 Equipment Used: Inductively Coupled Plasma Mass Spectrophotometry (ICP MS)

Leaching solutions were analyzed by inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) (Thermo Scientific™ iCAP™ RQ ICP-MS Serial No. iCAP RQ01591). This analysis was conducted at Research Testing & Calibration Laboratory (A Division of Metal Handicrafts Service Centre), Moradabad. This laboratory is accredited in accordance with ISO/IEC 17025: 2017 “General requirements for the competence of testing and calibration laboratories” by National Accreditation Board for Testing and Calibration Laboratories (NABL) vide certificate number TC-6683 valid from 09/09/2020 to 08/09/2020.

2.4 Summary of Method

2.4.1 Principle

An aqueous sample is converted to aerosols with the help of nebulizer. The aerosols are transported to the inductively coupled plasma mass spectrophotometry which is a high temperature zone (8,000– 10,000ºC). The analytes are excited through heating to

different (atomic and/or ionic) states and produce characteristic optical emissions (lights). These emissions are separated based on their respective wavelengths and their intensities are measured. The intensities are directly proportional to the concentrations of analytes in the aqueous sample. The quantification is an external multipoint linear standardization by comparing the emission intensity of an unknown sample with that of a standard sample. Multi-element calibration standard solutions are prepared from multielement primary standard solutions.

2.4.2 Brief Procedure

Traceable primary standard is used to prepare working standard solutions. The freshly prepared working standard solutions are confirmed against old working standard solutions. As per routine practice, the ICP MS instrument is started, brought to operation conditions and stabilized. It is verified that the sample introduction mechanism working adequately and the wavelengths are tuned. The ICP MS instrument is standardized with the five working standard solutions (multi-point linear fitting). Samples are measured with standardization blanks, other kinds of blanks, drift control samples, and quality control/assurance samples. After the samples are tested, the data are processed to get desired results. Relevant correction w.r.t. blanks and drift correction in data is done and dilution factor is applied for calculation.

2.4.3 Environment, Health and Safety

All relevant environment, health and safety aspects are employed in the laboratory to ensure compliance.

2.4.4 Interference

This method covers the analysis of 23 elements in various types of samples by ICP MS. There is no interference observed.

2.4.5 Quality assurance (QA) and quality control (QC)

To ensure the proper functioning of ICP MS, quality assurance and quality control measures are employed. The in-house ICP MS working standards are prepared from primary standards (complying to metrological traceability). These working solutions are confirmed by using old working standards. A new batch of working standards are

prepared, checked and confirmed against a previous batch of working standards. The working standard solutions are confirmed by using ICPMS. Double distilled water and leaching stimulant are analyzed as blank each time after the instrument is standardized. The results of these measurements are confirmed against the expected values. The result of the double distilled water serves as a primary checking point against events such as clogged nebulizer, power abruption, low-argon gas supply, autosampler failure, etc. The samples after these events are re-analyzed. Samples are diluted to different ratios and analysed. The results are used to evaluate matrix effects and dynamic ranges. Samples are analyzed by using the calibration of internal standard addition. Identical samples are analyzed multiple times within one-day's acquisition sequence and are analyzed in different-day's acquisitions. The results are used to evaluate the repeatability of the analysis.

3. Results

3.1 Composition Test

3.1.1 Composition of steel samples

Eighteen samples (Six unit of each utensil i.e. six units of Glass, Plate and Bowl) are analysed for composition test. The composition test was performed by X-ray fluorescence (XRF) using Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883).

Table 2: Composition of Steel Samples (%)

Utensil Name	Chromium	Nickel	Manganese	Copper	Molybdnum	Lead	Cadmium
Plate	14.02	0.71	10.12	0.65	<0.1	<0.001	<0.001
Glass	13.6	1.2	9.64	1.43	0.14	<0.001	<0.001
Bowl	12.76	0.63	9.15	1.00	<0.1	<0.001	<0.001

3.1.2 Composition of Brass samples

Eighteen samples (Six unit of each utensil i.e. six units of Glass, Plate and Bowl) are analysed for composition test. The composition test was performed by X-ray fluorescence (XRF) using Helmut-Fischer Fischerscope XDAL-FD EDXRF Spectrometer (Serial No. 040004883).

Table 3: Composition of Brass Samples (%)

Utensil Name	Copper	Zinc	Nickel	Iron	Lead	Tin	Cadmium
Plate	62.26	37.56	<0.10	<0.10	<0.10	<0.10	<0.10
Glass	54.65	38.96	0.37	0.90	4.17	0.87	<0.10
Bowl	54.17	39.29	0.67	0.85	3.75	1.21	<0.10

3.2 Leaching Test (Lead and Cadmium)

Leaching solutions were analyzed by inductively coupled plasma spectrometry Mass Spectrophotometry (ICP MS) (Thermo Scientific™ iCAP™ RQ ICP-MS Serial No. iCAP RQ01591). The testing was conducted as per FDA guidelines. As per FDA guidelines, six samples are to be taken for testing. The results are mentioned below:

3.2.1 Leaching from Stainless-steel samples

Table 4: Migration of Lead and Cadmium from Stainless-steel samples (ppm)

Utensil Name	Lead	Cadmium
Plate	<0.05	<0.03
Glass	<0.05	<0.03
Bowl	<0.05	<0.03

3.2.2 Leaching from Brass samples

Table 5: Migration of Lead and Cadmium from Brass samples (ppm)

Utensil Name	Lead	Cadmium
Plate	<0.05	<0.03
Glass	985.00	<0.03
Bowl	897.00	<0.03

4. Discussion

4.1 Lead

Humans are prone to lead exposure due to various reasons. Environmental Pollution (Contaminated water, Air) is the major source of exposure. Occupational exposure (Auto repair works, battery making, glass manufacture, mining, plastics manufacture, ship building or ship breaking, smelting & refining, steel, welding & cutting, plumbing, pottery, printing, rubber industry, soldering (electronics)) is also observed. Certain industries and use of products such as Paints, Ceramicware, Cosmetics, Medicines, Pencils, Toys and Automobile exhaust are also equally responsible for lead exposure [1, 2].

Acquaintance to lead happens through inhalation, ingestion and sporadically by skin contact. Lead is absorbed through mucous membranes in the mouth, nose, and eyes and through breaks in the skin. Inorganic lead, found in food, paint and most lead-containing consumer products, are absorbed through inhalation and ingestion. In adults, about 35–40% of inhaled lead dust deposits in the lungs and about 95% of that goes into the bloodstream. Of ingested inorganic lead about 15% is absorbed in adults, but this percentage is higher in children, pregnant women and people with deficiencies of iron, calcium or zinc. Children and infants absorb about 50% of ingested lead.

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 bone. The estimated half-life of lead in bone is 20–30 years and bone can release lead into the bloodstream, long after initial exposure is gone. The half-life of lead in blood in men is about 40 days, but it is longer in children and pregnant women, as their bones are undergoing remodelling, which allows the lead to be continuously re-introduced into bloodstream. Lead in teeth, bones, hairs and nails is bound tightly and not available to other tissues and is harmless. In adults, 94% of absorbed lead is deposited in bones and teeth. In children, only 70% is stored in this manner and 30% remain in free form in the bloodstream, which may partially account for the more serious health impacts on children. If lead exposure takes place over years, clearance is much slower, partly due to the re-release of lead from bone. Other tissues such as the brain, spleen, kidneys, liver, and lungs also store lead to some extent.

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.

Use of stainless-steel and Brass utensils may also contribute in metal exposure. From this study, it has been observed that the lead exposure due to stainless-steel is minimum as migration is not observed from the stainless-steel utensils.

4.2 Cadmium

Cadmium exposure is happening through Contaminated Food, Water, Smoking etc. Occupational exposure (through inhalation of fine dust and fumes) is also one of the sources of cadmium toxicity.

Cadmium can accumulate throughout lifetime; this is the most treacherous characteristic of Cadmium. It 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. Cadmium bound to albumin is preferentially taken up by the liver. In the liver, cadmium induces the synthesis of metallothionein and a few days after exposure metallothionein-bound cadmium appears in the blood plasma. Because of its low molecular weight, cadmium-metallothionein is efficiently filtered through the glomeruli and thereafter taken up by the tubules. Cadmium accumulates in the human kidney over the entire lifetime.

Cadmium is widely distributed in the body, with the major portion of the body burden located in the liver and kidney. Liver and kidney cadmium concentrations are comparable after short-term exposure, but the kidney concentration exceeds the liver concentration following prolonged exposure.

The concentration of cadmium in the liver of occupationally exposed workers generally increases in proportion to intensity and duration of exposures to values up to 100 µg/g. The concentration of cadmium in the kidney rises more slowly than in the liver after exposure and begins to decline after the onset of renal damage at a critical concentration of 160-285 µg/g.

Most non-occupationally exposed people are exposed to cadmium primarily through the diet. Cadmium can be detected in virtually all tissues in adults from industrialized countries, with greatest concentrations in the liver and kidney. Average cadmium concentrations in the kidney are at birth near zero, and rise roughly linearly with age to a peak (typically around 40-50 µg/g wet weight) between ages 50 and 60, after which kidney concentrations plateau or decline. Liver cadmium concentrations also begin near zero at birth, increase to typical values of 1-2 µg /g wet weight by age 20-25, then increase only slightly thereafter.

Most cadmium that is ingested or inhaled and transported to the gut via mucociliary clearance is excreted in the faeces. Almost all faecal cadmium represents material that was not absorbed from the gastrointestinal tract. Most absorbed cadmium is excreted very slowly, with urinary and faecal excretion being approximately equal.

The placenta is only a partial barrier to foetal exposure to cadmium. Several studies have shown that in the general population urinary cadmium excretion increases with age, this increase coinciding with the increased body burden. Smokers have higher urinary excretion than non-smokers. The amount of cadmium excreted represents only a small fraction of the total body burden unless renal damage is present. Following oral exposure, the major proportion of administered cadmium is found in the faeces, because absorption is low.

Use of stainless-steel and Brass utensils may also contribute in metal exposure. From this study, it has been observed that the cadmium exposure due to stainless-steel and brass utensils is not observed. However, prolonged exposure to cadmium exposure from the stainless-steel utensils.

5. Conclusion

This paper presents the findings of an investigation of the migration of lead and cadmium from the stainless steel and brass utensils. This investigation demonstrates that utensils are source of metal contamination. It is observed that brass utensils are leaching lead. This study also demonstrates that stainless- steel utensils are comparatively safe with brass utensils as migration of Lead and Cadmium from stainless-steel is not significant.

From the findings of these studies, it is clear that utensils are a source of heavy metal toxicity. Heavy metal toxicity in food is one of alarming global menace. Excessive amount of heavy metals in food is linked to some disorders, especially of the nervous, cardiovascular and some chronic degenerative disorders. High concentrations of metals exceeding the permissible limit of daily intake leach into food vis-a-vis the use of some of these cooking utensils on regular basis. This may predispose humans to some chronic diseases or disorders.

Results from these studies brought to attention the metal contamination of food by the use of various utensils. The contamination of metals through different utensils suggests that there is a need to educate the populace against the use of utensils that are capable of causing increased levels of heavy metals in food, as their bioaccumulation may lead to chronic health diseases and disorders.

We conclude that exposure to lead from the leaching of brass utensils may pose significant public health risks throughout India. Our findings suggest that quality control measures should be deployed to control the migration of lead from brass utensils. These quality control measures may be in the form of product specifications issued by regulator(s). There may be other mechanism which may be explored to reduce migration of lead from brass utensils. However, it would be valuable to deliberate on different approaches in various markets to better assess the economic feasibility, cultural acceptance and practical reach of these alternative strategies. Research is instantly desirable to recognize safe and effective approaches that could improve the safety of the utensils.

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B. CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

C. SOURCE OF FUNDING

Nil

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Review Paper

METAL EXPOSURE FROM UTENSILS: RISK TO PUBLIC HEALTH- AN ILLUSTARTIVE REVIEW

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Abstract

Elements (micro and macro) are essential for humans. It has been established from various researches that concentration of heavy metals higher than permissible limits are harmful to humans due to their toxic nature. Metabolic functions in humans are disturbed due to heavy metal poisoning mainly due to disruption in the functioning of vital organs. Additionally, due to the chelation effect of certain heavy metals, the metabolism of essential elements is affected. Elevated levels of heavy metals have been reported in the food chain at several levels. Environmental pollution, due to massive industrialization, is one of the primary reasons for heavy metal contamination of food and water bodies. There have been various studies which have shown that the type and nature of cookware and cooking process can also lead to the increase of heavy metals contamination in food. Due to the leaching effect, cooking utensils are a potential source for contamination of heavy metals. Certain cookware leach out of heavy metals at high temperatures and changes in pH e.g. acidic foods such as tomatoes prepared in aluminium pots. In the present work, a comprehensive analysis of heavy metal toxicity due to cooking utensils has been reviewed. Focus has been on made on the leaching of metals from different types of utensils.

Keywords: Heavy Metals contamination, Metal Toxicity, Metal Poisoning, Utensils

1. Introduction

Cooking is a process in which food is prepared by using heat. The exact origin of cooking is not known but it is believed that at some point in the distant past, early humans conquered fire and started using it to prepare food. Richard Wrangham, a renowned anthropologist has said that cooking played an essential role in human evolution. Cooking makes the foods more digestible and helps to absorb the calories and nutrients from the food. Thus, cooking allowed early humans to tap a wider variety of food sources and gain more nutrition from them.

Around the world steps are taken to provide safe food/ environment/ water for the humans. Many lives are lost due to unsafe food/ environment/ water but the serious concern is when then the immediate impact of unsafe food/ environment/ water is not measured. One of the major concerns is to protect our food/ water/ environment from toxicity due to metals. Several studies have been done to prove that almost all metals are toxic in nature beyond a particular concentration. Heavy metals are naturally found on the earth and day by day the concentrations of these toxins are increasing due to various types of pollutions.

Due to enhanced awareness, safety of food, water and the environment in general. Food is one of the basic necessities for human beings. Metals not only occur naturally in food, mostly their levels increase due to further processing e.g. heating.

In India, generally cooked food is a preference hence the concentration of heavy metals due to cooking may be increased. Nowadays, hot food is also transported from one place to another place where the storage vessels are also one of the reasons for increasing metal toxicity. For cooking, different types of utensils are used; for example, iron, Aluminium, Steel, Stainless Steel, clay, among others. Hence the leaching of metals from these substances may occur and be variable.

2. Samples in metal toxicity studies

A study on cooking utensils as probable sources of heavy metal toxicity" was performed [1] wherein levels of few metals such as Iron, Zinc, Cadmium, Nickel, Manganese, Chromium, Cobalt, Lead, Copper and Aluminium was analysed in staple food, rice, cooked with different utensils such as Iron, Stainless Steel (Old & New), Aluminium (Old & New), and Clay pots (Old & New). New cooking utensils were purchased from the local markets of Nigeria while the old used ones were collected from homes in different areas within the city on random basis. The experiment was carried out in triplicate using each utensil. Three pots were used for each set of cooking utensils (i.e., 3 new pots, 3 old pots). The pots were cleaned with detergents and rinsed with distilled water**.** Distilled water (600mL) and rice (50g) were taken in utensils and boiled for 20 minutes. Thereafter, the water was drained, rice was dried in an oven, and later pulverised. The samples were analysed by using Atomic Absorption Spectrophotometer (Shimadzu AA-670). The results of the study are mentioned below.

Table 1: Concentration (mg/kg) of metals

Name of Metal	Utensils									
	Aluminium		Clay		Steel		Stainless Steel		Control	
	New	Old	New	Old	New	Old	New	Old	Raw uncooked rice	Beaker cooked Rice
Nickel	0.89	0.78	0.80	0.72	1.80	1.10	2.02	1.70	0.01	0.01
Manganese	2.92	2.10	3.00	2.11	2.80	2.01	3.53	2.60	0.02	0.03
Chromium	0.28	0.13	0.15	0.13	0.18	0.14	0.50	0.31	0.01	0.02
Cobalt	0.15	0.05	0.14	0.05	0.16	0.09	0.15	0.13	0.03	0.02
Lead	0.85	0.58	0.73	0.35	0.76	0.45	3.22	2.33	0.01	0.01
Iron	37.70	20.45	66.30	47.80	21.00	17.30	90.53	56.01	0.04	0.04
Cadmium	0.08	0.03	0.08	0.07	0.10	0.05	0.08	0.07	0.01	0.01
Copper	2.91	2.42	2.92	2.42	6.54	4.63	3.35	2.90	0.03	0.02
Zinc	8.90	8.80	11.40	10.50	8.64	5.01	17.93	8.12	0.02	0.04
Aluminium	440.00	259.00	195.00	132.00	241.00	187.00	295.00	289.00	0.02	0.01

To understand the impact of cooking utensils on trace metals level, another study was conducted by Emmanuel Udo Dan, Godwin Asukwo Ebong on the impact of cooking utensils on trace metal levels of processed food items [2] In this study, food items such as rice, beans, plantain fruit, and yam seeds were used. Rice and beans (1kg each) were cleaned with distilled water and divided into three equal parts each, two of which were cooked differently in aluminium pot and stainless-steel utensils, dried and crushed to fine powder. The uncooked samples were also dried, pulverised and digested for trace metal analysis. Yam and plantain were peeled manually, cut into pieces and cooked with distilled water in aluminium and stainless-steel pots respectively. These samples were dried and pulverised along with uncooked samples. Sample (1g), perchloric acid (4mL), conc. Nitric acid (25mL) and sulphuric acid (2mL) were taken in an Erlenmeyer flask and heated at 180-220^{o}C for about 35 minutes. After digestion, 40mL distilled water was added and re-boiled for 30 seconds. The resulting solution was filtered with and further analysis was performed by using Atomic Absorption Spectrophotometer. The results of the study are mentioned below:

Table 2: Level of Heavy Metals (mg/kg)						
Food Item	Cooking Utensils	Name of Metal				
		Iron	Aluminium	Copper	Chromium	Nickel
Rice	Uncooked	1.83	0.20	1.05	0.37	1.86
	Aluminium Pot	2.67	0.44	1.47	0.48	3.37
	Stainless Steel	3.46	0.10	1.14	0.98	4.32
Beans	Uncooked	2.12	0.09	4.34	0.31	1.44
	Aluminium Pot	2.88	0.16	7.26	0.52	2.62
	Stainless Steel	4.17	0.07	5.11	0.77	4.22
Yam	Uncooked	1.89	0.07	1.35	0.46	1.96
	Aluminium Pot	2.34	0.24	2.34	0.58	3.30
	Stainless Steel	2.98	0.05	2.24	0.78	4.65
Plantain	Uncooked	2.13	0.04	1.59	0.43	1.84
	Aluminium Pot	3.01	0.18	2.43	0.58	2.32
	Stainless Steel	4.45	0.06	1.85	0.97	5.29

3. **Migration of metals from utensils**

The migration law of lead and cadmium from utensils during cooking process has been investigated by Zhou, Liangbo et.al in Chinese pots during the cooking process" [3]. Ceramic pots, iron pots, and aluminum alloy pots were analysed for migration of lead and cadmium by using soybean oil. Distilled water, 15% ethanol, 4% acetic acid, and edible vegetable oil were used as the food simulation solutions, and the initial concentration of lead and cadmium in the four types of food simulation solutions was determined. The pots were soaked in solution for 2 h at 25°C. 1 L food simulation solution was taken in each pot, and the solution was boiled for 2 h at 100–200°C. Food simulation solution (25 mL) was sampled every 30 min, and 1 mL solution was sampled in case of oil. Each experiment was done in triplicates. The food simulation solution in the pot was replenished to reach the same volume every 0.5 h with the initial value prior to each sampling. A Graphite furnace atomic absorption spectrometer FS90 with an automatic sampler was used for measuring the concentrations of metals.

To understand the effect of pH, acetic acid food simulation solutions with concentrations of 4%, 1%, and 0.1% were prepared. The pH value and initial lead and cadmium concentration of the three types of food simulation solutions and distilled water were measured. Food simulation solution (1L) was taken in each aluminium alloy pot and boiled for 2 hours. To evaluate the effect of ethanol concentration, ethanol food simulation solutions with concentrations of 10%, 15%, and 20% were prepared. The initial lead and cadmium concentration of the three types of food simulation solutions was measured. Food simulation solution (1L) was taken in each aluminium alloy pot and boiled for 2 hours. Similar sampling and analyses methods were used in these cases as done earlier

To determine lead and cadmium in food stimulation solution, a total of 1mL oil and turbid solution was sampled and poured into the digestion tube, 7mL concentrated nitric acid was added. After 15 minutes at room temperature, the tube was sealed and digested by microwave. The initial temperature was raised to 120°C in 5 minutes before being held constant for 3 minutes; then, the temperature was raised to 160°C in 5 minutes before being held constant for 3 minutes; finally, the temperature was raised to 180°C for 8 minutes before being held constant for 20 minutes [4]. After completing the process, the digestion solution was cooled to room temperature and then transferred to a 25mL volumetric flask and diluted with 0.5% nitric acid followed by testing of sample (25 mL). The test was conducted using graphite furnace atomic absorption spectrometry. The results are mentioned below:

Table 3: Migration (µg /L) of Heavy Metals from Utensil

Name of Metal	Test Condition	Type of Utensil								
		Ceramic			Iron			Aluminium		
		Simulation Solution								
		Water	4% Acetic Acid	15% Ethanol	Water	4% Acetic Acid	15% Ethanol	Water	4% Acetic Acid	15% Ethanol
Lead	Initial con.	Not Detected	0.038	Not Detected	Not Detected	0.038	Not Detected	Not Detected	0.038	Not Detected
	Soaked at 25°C for 2 hours	Not Detected	0.160	0.034	Not Detected	0.749	0.412	Not Detected	0.605	0.125
	Boiled at 100°C for 2 hours	0.117	1.956	0.12	1.500	5.641	2.837	0.790	3.627	1.139
Cadmium	Initial con.	Not Detected	0.026	Not Detected	Not Detected	0.026	Not Detected	Not Detected	0.026	Not Detected
	Soaked at 25°C for 2 hours	Not Detected	0.126	0.015	Not Detected	0.525	0.093	Not Detected	0.394	0.024
	Boiled at 100°C for 2 hours	0.022	0.408	0.065	0.065	0.911	0.624	0.027	0.565	0.094

In developing countries, traditional cooking utensils such as aluminium & clay pots are still used. A study was conducted by Lar Uriah et.al to determine if locally made utensils could be a potential source of heavy metal contamination of water [5]. Aluminium and clay pots were washed with distilled water and distilled water was boiled in the pots for 2 hours. After cooling, the water was stored in a polythene bottle for further analysis. Two drops of concentrated nitric acid were added to the samples to prevent any absorption and precipitation of ions. The samples were analysed by using inductively coupled plasma optical emission spectrometry (ICP-OES).

In another study, ceramic and glass utensils were tested for the release of lead, cadmium, zinc and copper [6]. In this study, migration of lead, cadmium, copper and zinc from the surface of ceramic and glassware into a food simulant with 4% acetic acid for 24 ± 0.5 hour at 22 ± 2°C was conducted, according to the test procedure specified in European Standards EN 1388-1 and EN 1388-2 [7, 8]. The pots were filled with acid up to 1mm below the overflow edge and placed in a dark at a temperature of 22 ± 2°C and left for 24 hours.

Migration of metals such as nickel and chromium into food during cooking, from stainless steel (SS) utensils was studied by Kamerud et al [9]. SS are widely used in the food and beverage

industry due to various advantages such as thermal conductivity, resistance to corrosion, among others. SS grades 304 and 316 are the most usually used in the food and beverage industry [10]. These SS grades differ in their chemical compositions having different concentrations of nickel and chromium. SS grade 304 contains approximately 18–20% mass fraction chromium, and 8–12% nickel, whereas SS grade 316 contain approximately 16–18% chromium, and 10–14% nickel; other metals may also vary within the grades [11]. SS sauce pan was washed with water and soap prior to use. Four types of tomato sauces from different manufacturers were evaluated. The acidity of the tomato sauces tested ranged between pH 4.17–4.30. Samples were digested and analysed by using inductively coupled plasma mass spectrometry (ICP-MS).

Weidenhamer et al studied the migration of metal from aluminium cookware [12] where, dilute acetic acid (4%v/v) was boiled for 2 hours in the utensils and used as a simulator. The solution was analysed by ICP-MS.

Excessive amount of heavy metals in food is linked to some disorders, especially of the nervous, cardiovascular and some chronic degenerative disorders [13]. It has also been demonstrated that lead in glazed cookware and storage containers can leach with test acidic solutions and increase with duration of contact [14] Chromium and lead leaching into acetic acid solutions has been shown to increase with stainless steel surface area [15]. Metal leaching from stainless steel has been found to be dependent on the ratio of surface area of the stainless steel to the volume of solution it is in direct contact with [15].

Health risk assessment was performed taking into account current reference doses for elements introduced by EFSA and JECFA [16, 17, 18, 19, 20] and the highest obtained results for migration of tested elements.

4. Conclusions

It has been observed that the cooking process leads to migration of heavy metals. The migration of metals was also affected by acidity during the cooking process. In particular, the released amounts of lead and cadmium were high when the acidity was high. Alcohol strength also affected the migration of lead and cadmium during the cooking process. Moreover, when the ethanol concentration increased, the migration of lead and cadmium was inhibited. All these findings show that the migration of lead and cadmium in pots presented a regular law during the cooking process, and this migration was subject to many factors. The findings can provide theoretical basis and technical guidance for future in-depth study on the migration of heavy metals during the cooking process. Though the type of food (properties of condiments and food) plays an important role in migration of metals (acidic food stimulates the leaching process) from cooking utensils, migration of metals will occur irrespective of the food item. The studies have also shown that the different cooking utensils which are used in food processing have different impacts on the metal levels of different food stuffs processed. Quality of the utensils and properties of food also plays a vital role in migration of metals. Considering the fact that the heavy metals are migrated from cooking utensil and further due to bioaccumulation, the concentration of the heavy metals may increase up to such level wherein it may cause health hazards.

From the findings of these studies, it is clear that cooking utensils are a source of heavy metal toxicity. Heavy metal toxicity in food is one of alarming global menace. Excessive amount of heavy metals in food is linked to some disorders, especially of the nervous, cardiovascular and some chronic degenerative disorders [13]. High concentrations of metals exceeding the permissible limit of daily intake leach into food vis-a-vis the use of some of these cooking utensils on regular basis. This may predispose humans to some chronic diseases or disorders.

Results from these studies brought to attention the metal contamination of food by the use of various utensils. The contamination of metals through different utensils suggests that there is a need to educate the populace against the use of utensils that are capable of causing increased levels of heavy metals in food, as their bioaccumulation may lead to chronic health diseases and disorders.

This review paper summarized the findings of investigation done by various researchers of the leaching characteristics of cooking utensils. From the various researches, it has been revealed that different foods have different potential of accumulating heavy metals depending on the type of utensil used, food and process applied. It can be concluded that the different types of utensils, migrate metals in the food during cooking process. The continuous use of such type of utensils may pose serious threat to human health especially the children. Suitable legislation to control the quality of utensils should be made and implemented. To ensure human health safety, it is essential to include the safe limits of metals which can be released from the utensils.

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B. CONFLICT OF INTEREST DISCLOSURE

The authors declare no conflict of interest.

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D. REFERENCES

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Review Article

Barium Poisoning with Analytical Aspects and its Management

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A B S T R A C T

Barium is a non-essential nutrient to terrestrial organisms and reported to be toxic at elevated concentrations. Barium is a heavy divalent alkaline earth metal. It is denoted by the symbol Ba and has an atomic number 56. Barium occurs in nature as baryte ore (Barium Sulphate, $BaSO_4$) and witherite ore (Barium Carbonate, $BaCO_3$). Barium is used in various industrial processes. The common-mode is accidental ingestion and the common compound is barium carbonate. Barium carbonate is a highly toxic substance used in the past as Rodenticides. The insoluble form of barium, such as Barium Sulphate, commonly used in radiographic procedures is harmless whereas soluble salts of barium such as barium carbonate are highly toxic. Weakness, paralysis, and hypokalemia being the characteristics signs of the barium poisoning. The clinical features of barium poisoning along with the appropriate diagnosis has been discussed in this paper. The analytical techniques such as Voltammetry, AAS, ICP-OES, NAA, UV-Vis Spectrophotometry can be routinely used to analyze biological and non-biological samples from poisoning as well as overdose cases. This paper can assist officials, toxicologist, physicians and researchers, understand barium poisoning and its management in a much simpler way.

Keywords: Barium Poisoning, Hypokalemia, Sodium Potassium ATPase Enzyme, AAS etc.

Introduction

Barium is named after the Greek word 'Barys' meaning 'heavy' and is a relatively dense and reactive earth metal. The element is chemically represented by the symbol 'Ba' with atomic number '56' with atomic weight 137.4 and a melting point of 1000K (1). It is a divalent cation in its compounds. Physically Barium metal has a soft, silvery-white appearance, with a slight golden shade when ultrapure. On exposure to air, the silvery-white appearance rapidly oxidizes to the dark grey oxide layer. Like the other members of the group, barium reacts violently with water to produce hydrogen gas, so it is normally stored in kerosene, petroleum, mineral oil, or in an argon rich atmosphere to prevent reaction with oxygen and moisture in the air. Barium, owing to its high reactivity does not occur free in nature rather it occurs mostly as Sulphate (baryte) and Carbonate (witherite) ores and other natural minerals (2). It is the fourteenth most abundant element in the earth's crust, with its abundance estimated to be 0.034% (3).

In the early 1600s, Vincenzo Casciarolo, an alchemist, of

Bologna, Italy, found some unusual pebbles near volcanic rocks in Italy which if heated to redness during the day, would shine during the night for years. He named the pebble as 'Bologna stone'. When these Bologna stones, as it became known, was investigated by Carl Scheele in 1774, he realized that it was the sulfate of an unknown element, which were later identified to be mineral Barite (Barium Sulfate, $BaSO_4$). Meanwhile, a mineralogist, Dr. William Withering, had found another curiously heavy mineral in a lead mine in Cumberland which was not a lead ore. He named it 'Witherite'; which was later identified to be Barium Carbonate, $BaCO_3$. Neither the sulfate nor the carbonate yielded up the pure metal itself using the conventional process of smelting with carbon (4). However, Sir Humphry Davy, an English Chemist at the Royal Institution in London in 1808isolatedthe pure metal by doing electrolysis of molten barium salts such as Barium Hydroxide ($Ba(OH)_2$) (5). But due to its reactivity to air, barium cannot be found in its pure form but rather extracted from its mineral, Barite.

Two forms of barium occur naturally in the environment, barium sulphate (Baryte) and barium carbonate (Witherite) and often in underground ore deposits. These salts can be commonly found as white orthorhombic crystals or powder. These forms of barium are not very soluble in water 0.020g/ litre (at 20°C) for barium carbonate and 0.001 15g/litre (at 0°C) for barium sulphate. The presence of other salts of barium in water and soil is chiefly attributed to dumping and contamination by waste sites (6,7). Other barium salts like barium chloride, barium nitrate, and barium hydroxide are manufactured from barium sulphate.

Barium can be found in trace amounts in both igneous and sedimentary rocks. The water-soluble Barium salts like acetate, carbonate, chloride, fluoride, hydroxide, nitrate, and sulfide are highly toxic, whereas the insoluble salts like barium sulphate are considered comparatively nontoxic because it is poorly absorbed through oral route (8). Very uncommon, but Barium poisoning results from accidental contamination of food & water sources, suicidal ingestion, or occupational inhalation exposure (9). The ingestion of soluble barium salts can produce effects such as hypokalemic paralysis leading to respiratory and cardiac arrest (10). Barium isn't carcinogenic and does not bioaccumulate, but on inhalation of insoluble compounds, it can accumulate in the lungs to cause a benign condition called 'Baritosis'. It is widely known that barium is a 'Muscle Poison' and effects on skeletal and smooth muscle and Myocardial excitability and may cause significant Hypokalemia, Malignant arrhythmia, and Secondary respiratory paralysis, in serious consequences.

Major Uses of Barium

- Barium is used in oil and gas industries to manufacture drilling muds.
- Barium sulphate is used in making soaps, bricks, paints, glass, tiles, rubber (11).
- Barium compounds such as Barium Carbonate, Barium Hydroxide, and Barium Chloride are used in making ceramics, insecticides, and rat poison.
- Barium has its uses in plastic, rubber, electronics, textiles, sugar-refining, seal-nuts, and paper manufacturing.
- Barium has its presence in many products, like depilatories and fireworks, ceramic grazes (12).
- Barium nitrate and chlorate are added to firecrackers which emit green colour on ignition.
- The modern use of barium is in radiodiagnosis. It is used by doctors to perform medical tests and X-ray photographs of the stomach and intestine.
- Barium can be used for diagnosis of cancer, ulcers, Crohn's disease, irritable bowel syndrome, and treat dropsy (edema).
- Barium styphnate has been used in detonators.

Major Routes of Exposure To Barium

- People who work in industries that manufacture barium compounds or use them are at maximum risk of exposure.
- Barium (barium chloride or barium hydroxide) can be introduced in the body through breathing its dust or by getting them in contact with the skin.
- Barium carbonate would be harmful if eaten accidentally as it will dissolve in acids within the stomach.
- Exposure to barium near dangerous waste sites.
- Exposure of barium can occur by using water, soil or plant polluted with it, usually near the waste sites.

Pharmacokinetics of Barium

Barium is not considered to be an essential element for human nutrition. An average adult contains about 22 mg of barium salts in his body which are introduced naturally by foods and drinks like carrots, onions, beans, and cereal grains (13). Low levels of barium up to serve no biological role and are not harmful in any way. However, large quantities of salts up to can be toxic and even cause death. If someone has been exposed to barium or its salts several factors will determine its toxicity. These factors include the dose, duration, route of exposure, age, sex, genetics, lifestyle, and state of health. Barium carbonate can be harmful if ingested through the oral route as it can be dissolved by acid in the stomach, unlike barium sulphate which his insoluble in the stomach. Major routes of administration of barium and its salts can be breathing, eating, drinking, or application across mucous membranes. The barium compound most commonly used in toxicology studies is barium chloride (water solubility at 375 g/litre at 20°C).

Absorption

Soluble barium salts are absorbed rapidly (5–30%) into the

blood through the digestive mucosa. The absorption rate barium compounds are barium chloride > barium sulfate > barium carbonate (14). Large doses of barium sulfate do not increase the uptakes of this salt because it has low solubility. Oral or inhalant exposure can create systemic toxic effects. Barium sulfate is commonly used as a radiopaque as a contrast compound to visualize the digestive tract for diagnosis of cancer, ulcers, Crohn's disease, irritable bowel syndrome, and dropsy (edema) (15). Barium sulfate is often considered to be otherwise very poorly absorbed in the systemic circulation.

Distribution

A rapid distribution phase is followed by a slow decrease in concentration. The highest concentrations of barium in humans are found in the bones and teeth. Approximately 91% of the total body burden is in the areas of active bone growth (8). A small amount of barium is found in soft tissues i.e., aorta, brain, heart, kidney, spleen, pancreases, lung, etc. A high concentration of barium is sometimes found in the eye, primarily in the pigmented structures. Additionally, quantification of levels of barium in skeleton muscles and kidneys were reported to be higher than whole blood suggesting the ability of soft tissues to concentrate the metal more than blood.

Bauer et al., 1957 in his study reported for the first time that barium accretion rates for the whole skeleton, tibia, and incisors were 1.4–2.4 times greater than accretion rates for calcium suggesting that deposition rates of barium were on a faster rate than calcium (4). In bones, the half-life of barium is found to be up to 50 days.

Metabolism

The mechanisms of barium metabolism are not well characterized. However, the general patterns of uptake are similar to the uptake of calcium and strontium in the body (16).

Excretion and Elimination

Barium is excreted majorly in the urine and faces following oral, inhalation, parental exposure. The faeces are a major route for the excretion with 90% excretion through this route and 10–28% reported to be excreted in the urine. Barium can be irreversibly stored in the bone.

Systemic Effects on the Body

The quantity of barium which is detected in water and food is generally not that much high to become a health concern. The maximum contaminant level of Ba in drinking water has been set at 2 mg/Lby the USEPA (13). People who work in barium industries are at greatest risk to barium exposure. Most of the risk to the health that they can face is inhaling the air contaminated with barium carbonate or barium sulfate. Exposure to barium can be designated as acute (<14days), intermediate (15–365days), or chronic (more than 1year). The health effect depends upon the solubility of compounds in water. In large amounts of water-soluble barium may cause paralysis but in some cases death and small amounts of water-soluble barium can cause breathing difficulty, high blood pressure, heart rhythm, change in nerve reflexes, muscle weakness, swelling in brain, kidney, liver and heart damage (16). No case of barium causing cancer has been seen till date in humans, and also no proof of barium causing infertility or birth defect has been found so far.

In Case of Acute Exposure

Most human exposure to toxic barium salts occurs via ingestion or inhalation. Diagnostic radiographic examination in gastrointestinal mucosa can be performed by comparing it with radiopaque barium sulfate, which is used worldwide because of its very low water solubility and lipid solubility. Absorption of barium sulfate does not generally occur. Suicidal or accidental poisoning with barium containing household or medical products includes nitrate, sulfide, carbonate, chloride of barium.

Gastrointestinal

Gastrointestinal tract effects such as abdominal cramps, gastric pain, diarrhea, nausea, vomiting are common symptoms of barium poisoning in humans exposed to a large amount of barium and barium compound by ingestion, inhalation exposure.

Cardiovascular

Cardiovascular abnormalities such as changes in heart rhythm and increased or decreased blood pressure have been observed after exposure to large amounts of barium and its compound which are soluble by ingestion or inhalation. The cardiovascular effects could be hypokalemia (a reduction in blood k^+ levels)(17)which may lead to significant hypokalemia and have serious consequences. This paper reports a case of unprecedented barium intoxication in which the patient, who suffered from depression, swallowed at least 3.0 g barium chloride to commit suicide. On admission, the patient presented with nausea, vomiting, stomach burning feeling, dizziness, and weakness. Emergency biochemical testing showed that the patient was suffering from severe hypokalemia (K\n +\n 1.7 mmol/L.

Musculoskeletal

Musculoskeletal effects like muscle weakness, numbness, or paralysis may occur due to exposure to a high level of barium or its soluble compounds either by inhalation or by ingestion (16). These effects are somewhat similar to that of hypokalemia.

Neurological

Tremors, seizures, and mydriasis may occur severe poisoning.

In Case of Chronic Exposure

High chronic exposure to barium or its soluble compound can cause extreme renal effects. When inhaled action of barium sulfate or baryte causes a pulmonary reaction involving mobilization of polymorphone nuclear leukocytes, macrophages and radiographic changes are seen in the lungs (baritosis). These effects can be much more serious to children due to their potential for a life span longer than adults.

Carcinogenicity

The US EPA has concluded that barium does not cause cancer to humans by oral exposure and after inhalation exposure, its carcinogenic potential could not be determined.

Reproductive and Developmental effects

The potential of barium induced reproduction or developmental effect has not been assessed in humans.

Mechanisms of Toxicity/Action

The specific toxic mechanism of barium is a blockade of passive transmembrane Potassium (K+) conductance in excitable cells by the barium ions. The characteristic systemic effects of barium poisoning are violent contraction of smooth, striated and cardiac muscles.

Barium induces hypokalemia by following two mechanisms

- It competitively blocks potassium channels. It is associated with sodium-potassium pump (Na^+-K^+ - ATP enzyme).
- The Na^+-K^+-ATP enzyme is involved in transmembrane, transport of K^+ against concentration in intake within the cell. After a barium chloride intake, Ba^+ activity of Na^+ - K^+ - ATP enzyme can be increased by Ba^+ and it can block potassium (K^+) channel to introduce in passive K^+ diffusion, which is leading to a continued decreased in extracellular potassium and leads to:
- Depolarization and paralysis.
- It also increased vascular resistance, reduced blood flow and is the likely mechanisms for hypertension and lactic acidosis.

Hypokalemia is a major cause of paralysis and muscle weakness is related to barium concentration instead of potassium concentration.

Onset and Duration of Action

Symptoms of barium poisoning are evident mostly after 12 hours of administration through the oral route. The quantity of barium that may cause poisoning depends on the age group, duration, and amount of exposure. Usually in acute barium poisoning conditions can cause ventricular dysrhythmias. Symptoms of barium poisoning have been observed in the kidney of several adult cases.

Fatal Dose and Fatal Period

Ingestion of 3 gm results in moderate symptoms. Ingestion of more than 3.8 gm causes severe toxicity and leads to morbidity and mortality within 12 hours of ingestion (18–20).

Normal/Reference values

The reference and normal dose value depend upon sub-chronic and chronic. In case of sub-chronic oral reference value 0.07 mg/kg/day and in case of chronic oral reference value 1- 0.07 mg/kg/day (13, 21). These reference values are based upon a weight of evidence approach using sub-chronic to chronic human drinking water.

Table 1.Normal Reference Value of Ba in Biological Material

Matrixes	Normal Level	Toxic Level
Blood	7.15 ± 2.05 µg/L	150 ± 12 µg/L
Serum	12.07 ± 1.70 µg/L	20.45 ± 3.15 µg/L
Urine	12.07 ± 0.25 µg/L	10.50 ± 5.20 µg/L

Management/Treatment

Household Remedies

Thorough washing should be done if skin is contaminated with barium carbonate, barium chloride, or barium nitrate. Mild detergent or soap should be used while washing if the contaminant is barium carbonate. If route is oral, then, water can be given as it can dilute the contaminant.

Pre- hospital management

Hot Zone

Proper training and appropriate attire are necessary for rescuers who are entering the hot zone. A properly equipped response organization can be called upon if proper equipment or trained rescuers are not available.

Removal of Victim

Those victims who can walk can be mobilized from hot zone to decontamination zone. backboards, gurneys can be utilized to carry those victims who are unable to walk; carefully carry or drag victims to safety if needed.

Decontamination Zone

Victims can be transferred immediately to the support zone that have only inhalational exposure of barium and have no skin or eye irritation. Decontamination of other patients can be as described below:

ABC Reminders

The airway should be quickly established; ensure breathing

and circulation. If trauma is suspected, stabilize the cervical spine with a collar and a backboard. Administer supplemental oxygen as required. Bag-valve-mask device assisted ventilation can be used if needed.

Basic Decontamination

- With assistance, self-decontamination can be tried. Remove clothing which is contaminated and all personal belongings packing them into a double bag.
- The exposed skin and hair have to be washed with copious amounts of water.
- If eyes have irritation, flush with tepid water for 20 min. Contact lenses should be removed without causing additional trauma to the eyes.
- Neutralization should not be attempted as it causes an exothermic reaction. Do not induce emesis in cases of ingestion. Soluble sulfates, if administered orally, will precipitate an insoluble form of barium (barium sulfate) and may limit the absorption of barium. In victims who are conscious and able to swallow, 5 mL/kg up to 200 mL of water for dilution can be administered. Magnesium sulfate (250 mg/kg up to 30 g maximum single dose) can be given orally for reducing the absorption of barium from the gastrointestinal tract. Decontamination can be delayed if the victim is symptomatic. Wait until other emergency measures have been instituted.

Hospital Management

Gosselin et al. describe the oral lethal dose in humans as1–15 g (22). A research chemist attempted suicide by ingesting a teaspoon (approximately 13 g) of $BaCl_2$. He was rushed to a hospital and survived after treatment with $MgSO_4$ and KCl. Barium has no antidote. Treatment consists of respiratory and cardiovascular support and regulation of serum potassium levels. The speed of potassium supplementation can be slowed after the serum potassium level increases to 3.0 mmol/L in the initial 3 hours. The serum potassium level should be monitored every two hours by performing blood chemistry testing. Changes in the ECG and urine volume should be taken care of to prevent high potassium levels. Aerosolized bronchodilators such as albuterol can be used in patients who have bronchospasm. Consider that barium poisoning may include tachycardia and hypertension, in which case the use of bronchodilators that are known as cardiac sensitizing agents may pose an enhanced risk. Hypotension, seizures, ventricular arrhythmias should be treated conventionally. In the first 24 hours post-exposure, Serum potassium, CBC, glucose, and electrolyte should be monitored. Chest radiography, pulse oximetry (or ABG measurements), peak-flow and/or spirometry may be required by patients who have respiratory complaints (17,23)which may lead to significant hypokalemia and have serious consequences. This paper reports a case of unprecedented barium intoxication in which the patient, who suffered from depression, swallowed at least 3.0 g barium chloride to commit suicide. On admission, the patient presented with nausea, vomiting, stomach burning feeling, dizziness, and weakness. Emergency biochemical testing showed that the patient was suffering from severe hypokalemia (K\n +\n 1.7 mmol/L.

Clinical Appearance/ Symptoms in Barium Poisoning

Clinical appearances/ symptoms in case of barium poisoning depend upon different forms of barium and amount of doses taken.

In case of acute toxicity

- Gastrointestinal effects.
- Nausea, abdominal pain, vomiting, diarrhea occur within 60 minutes of ingestion.
- Esophagitis.
- Hemorrhagic gastritis.

In case of chronic toxicity

Signs and symptoms associated with hypokalemia.

- Lactic acidosis.
- Ventricular dysrhythmia.
- Hypophosphatemia.
- Respiratory failure.
- Intense flaccid muscle weakness
- Rhabdomyolysis
- Basal ganglia manifestations.

Diagnostic Investigation in Case of Barium Poisoning

Barium can be diagnosed via many techniques such as:

- ICP-MS which can quantitate barium present in urine and blood.
- Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS) can be useful to identify barium level in biological materials.
- The acute exposures, serum electrolytes of patients should be measured hourly while performing continuous ECG monitoring.
- Generally, barium levels more than 0.2 mg/l values are abnormal.
- Barium might be shown by plain abdominal radiograph but the specificity and the sensitivity of radiography have not checked for barium poisoning.
- Toxicological etiologies for flaccid paralysis like hypermagnesemia, botulisms and the neuromuscular blockers administration also should be considered.
- CBC, glucose, and electrolyte determinations, particularly serum potassium levels for the first 24 hours post exposure.
- Patients who have respiratory complaints may require

pulse oximetry, chest radiography, and peak-flow and/or spirometry.

Chemical Tests for Barium Poisoning

Atomic Absorption Spectroscopy (AAS), Inductively Coupled Plasma- Atomic Emission Spectrometry (ICP-AES), and ICP-Mass Spectrophotometry (ICP-MS) is the most commonly used analytical methods for measuring low levels of barium and its compounds in the air, water, geological and various other non-biological and biological materials (24). The other analytical techniques include the less sensitive methods of X-ray Fluorescence Spectroscopy and Neutron Activation Analysis and the less commonly used methods of Scintillation Spectroscopy, and Spectrography. In general, analytical procedures measure total barium ion present and do not allow for speciation of barium compounds.

Qualitative Chemical Analysis

Potassium Dichromate Test(25)

Residue obtained by dry digestion is dissolved in 2 ml of conc. Hydrochloric acid, boiled and filtered.

The acidified test solution is boiled with a few drops of concentrated nitric acid. It is made alkaline by adding ammonium chloride and ammonium hydroxide solutions.

Filter it, if required and add an excess of ammonium carbonate appearance of white ppt indicates presence of Barium.

- Precipitate is dissolved in acetic acid and is divided into 3 portions.
- To '1' portion, add sulfuric acid it gives white ppt, which is insoluble in Nitric acid& Hydrochloric acid.
- To '2' portion, add few drops of potassium chromate solution, which gives yellow precipitate of barium chromate.
- The third portion is evaporated to dryness and the residue is dissolved in water. A drop of it is spotted on the filter paper and dried. A drop of sodium rhodizonate is added on the spot. Brown or brownish-red color spot on paper is obtained, which confirms the presence of barium.

Flame Test

- Dry residue obtained after dry digestion is coated on a platinum wire and heated on a flame.
- A persistent apple green flame is observed confirmatory for presence of barium.

Quantitative Analysis

UV-Vis Spectroscopy method

Barium can be detected quantitatively by using UV-Vis spectroscopy (26,27). Barium can form a complex organic compound which will give absorbance at a specified wavelength.

Atomic Absorption Spectrophotometric method

It is a good technique to determine barium in the biological method. Graphite Furnace Atomic Absorption Spectroscopy (GF-AAS) can be useful to quantify barium. The absorption of the standard solution is plotted against the concentration. The concentration of barium is obtained from the calibration curve. Flame AAS and graphite furnace AAS determine levels of barium in water and wastewater from 200 µg/L (28). Plamboeck et al. (2003) have developed a sensitive method for determination of barium in water, bone, and liver-based on Flow Injection Analysis and Flame Atomic Emission Spectrometry (FIA-FAES) with a detection limit of 0.8µg/L (21).

Ion chromatography

Ion chromatography is another important technique for the quantitative estimation of barium in biological material such as tissue, hair, urine, blood and gastrointestinal tract (29).

Voltammetry/Polarography method

This method is another technique for the quantitative analysis of barium in any biological material. The instrumentation presents a reliable, cost-effective, rapid, and in-filed voltammetric determination of barium. Glassy carbon (GCE) has been the most commonly employed electrode in combination with a linear sweep or differential pulse mode for potential delivery (30–33).

ICP-AES/ICP-MS method

Inductively Coupled Plasma-Atomic Emission Spectroscopy and Inductively Coupled Plasma - Mass Spectroscopy is an analytical technique that uses the emission spectra/mass spectra to quantify the trace metal barium. It is a screening technique in acute poisoning. This technique is the latest advanced technique for the determination of heavy metals in micrograms, nanograms, and picogram levels. This is an instrument by which multiple elements can be determined simultaneously. By use of ICP-MS, detection limits have been reported for analysis of barium in the urine of 1µg/L and water of 0.001µg/L (2,34–36).

Neutron Activation Test (NAA)

This technique is used for the low level of barium in blood, in explosives and gunshot residue (37–39). The interaction of the nucleus of the barium atom with irradiation neutrons results in the emission of x-rays forms the basis of this technique. The advantages of NAA technique includes minimum preparation of the sample and the fact that destruction of the sample is not needed to conduct the analysis.

Conclusion

Barium is a naturally occurring element, non-essential for human nutrition. The toxicity of its compounds

depends on their salt form, their solubility, and mode of administration. The free ion can be readily absorbed from the lung or gastrointestinal tract, but barium sulphate will comparatively remain unabsorbed. Barium poisoning is easy to be misdiagnosed and this has a direct effect on treatment methodologies. Therefore, timely and accurate diagnosis is crucial for the treatment of acute barium poisoning. If poisoning occurs, wash hands, affected skin, and drink plenty of water and electrolytes. The victim should be promptly monitored as dangerous hypokalemia can develop which can even cause death. Radiographic methods that use barium as contrast can also rarely lead to complications. Ingestion of certain forms of barium (e.g., barium carbonate or barium fluoride) in toxic amounts can lead to gastrointestinal signs and symptoms (e.g., vomiting, abdominal pain, and watery diarrhea). Within 1–4 hours of ingestion, profound hypokalemia, and generalized muscle weakness can develop which may progress to paralysis of the limbs and respiratory muscles. Severe hypokalemia induced by barium toxicity can cause ventricular dysrhythmias. Barium sulfate is not absorbed when taken by mouth and therefore is commonly used as a contrast agent for radiographic procedures.

At high concentrations, barium causes vasoconstriction by its direct stimulation of the arterial muscle, peristalsis as a result of the violent stimulation of smooth muscles and convulsions and paralysis following stimulation of the central nervous system. Depending on the dose and solubility of the barium salt, death may occur in a few hours or a few days. The acute toxic oral dose is between 3 and 4 g. Repeated exposures to barium chloride in table salt are believed to have caused recurrent outbreaks of "pa-ping" disease (a transient paralysis resembling familial periodic paralysis) in China, but recovery was usually rapid. Barium induces hypokalemia in two ways one is by competitively blocks potassium channels, which is associated with a potassium pump and the other is the sodium-potassium-ATP enzyme involved in trans-membrane. Barium can increase the activity of the ATPase enzyme. It can direct effect on either skeletal muscle or neuromuscular transmission.

Traditional methods of chemical analysis although require time-consuming sample preparation, are easy to do in any lab setup. The results of chemical analysis are qualitative in form of colour changes of the products. Barium being an elemental heavy metal can be easily analyzed using sophisticated instruments like AAS, ICP-OES, NAA, Polarography & Voltammetry, Ion Chromatography. The sensitivity of these techniques can be achieved as low as 0.11mg/ml, well below any limit recommended by environmental guidelines (36). The technique requires less sample preparation and can be easily prepared otherwise by acid digestion or microwave digestion.

This mini-review can assist officials, toxicologists, physicians and researchers understand barium poisoning and its management in a much simpler way. Forensic pathologists, physicians should be aware of the clinical presentations of barium compound poisoning and especially look for any evidence of hypokalemia (40). Other health conditions, for example, botulism and Guillain-Barre´ syndrome, which present with very similar signs and symptoms as barium intoxication must be excluded using analytical techniques (41).

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REVIEW ARTICLE

IRON POISONING WITH ANALYTICAL ASPECTS AND ITS MANAGEMENT

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ABSTRACT: Iron is a naturally occurring element found in the nature. It is denoted by the symbol Fe and has an atomic number 26. Iron is one of the most common metals occurring on earth. It occurs in a variety of oxidation states.Out of all the states ferrous (II) and ferric (III) are the most common states and ferrous iron is absorbed better in the body than ferric iron.This is the reason it is used in many iron supplements. Iron is found in many over-the-counter (OTC) multivitamins. Iron toxicity from intentional or accidental ingestion is a common poisoning. Life-threatening toxicity is associated with pediatric ingestion of potent adult preparations, such as prenatal vitamins. Serious iron ingestion in adults is usually associated with suicide attempts. The exposure to iron can be in various forms including metal, salts (ferrous sulfate) and organic compounds. Organs that are affected by iron toxicity are pancreas, liver, kidneys, central nervous system and joints. The clinical features of iron poisoning along with the appropriate diagnosis has been discussed in this paper. The hospitalization and post-hospitalization management would help in the proper care of the patient along with the treatment that canbe done along with analytical techniques like Inductively coupled plasma-mass spectrometry (ICP-MS), Atomic absorption spectroscopy (AAS) and Voltammetry.

KEY WORDS: Iron toxicity, Metal poisoning, Inductively coupled plasma-mass spectrometry (ICP-MS), Atomic absorption spectroscopy (AAS).

INTRODUCTION:

Iron is a naturally occurring element found in the nature. It is denoted by the symbol Fe and has an atomic number 26. Iron is one of the most common metals occurring on earth. It occurs in a variety of oxidation states but out of all the states +2and +3 are the most common states. Out of the two ferrous iron is absorbed better in the body than ferric iron and this is the reason it is used in many iron supplements. Iron occurs in the form of metal, oxides, organic and inorganic forms. It plays a crucial role in the formation of different complexes with oxygen in hemoglobin and myoglobin

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(oxygen transporters). Iron is widely used in preparation of foods and medicines, micronutrients for the plants and also has vast applications in the field of automobiles.it occurs in four distinct crystalline forms and dissolves readily in dilute acids. It is a very crucial component of different metalloproteins and plays a crucial role like oxygen sensing and transport, electron transfer and catalysis.[1,2]

Iron toxicity from intentional or accidental ingestion is a common poisoning. Life-threatening toxicity is associated with pediatric ingestion of potent adult preparations, such as prenatal vitamins. Serious iron ingestion in adults is usually associated with suicide attempts. The exposure to iron can be in various forms including metal, salts (ferrous sulfate) and organic compounds. Organs that are affected by iron toxicity are pancreas, liver, kidneys, central nervous system and joints. The clinical features of iron poisoning along with the appropriate diagnosis and treatment is extremely important in iron toxicity cases. [3]

SOURCES OF IRON

Iron occurs in various forms namely

- It is alloyed with carbon, nickel, chromium to form cast iron.
- It is used in magnets.
- It is used in toys and sports goods.
- It is sued in food supplements and medicines.
- Iron catalysts are used in the haber process for producing ammonia.
- It is used in architecture, bearings, cutlery and surgical instruments.
- Iron sulfate is used as a fungicide.
- Iron oxalate is used in the development of photographs.
- Iron chloride and nitrate are used as mordents and industrial reagents in the dye industry.

EXPOSURE OF IRON

1. Iron contamination is common in air, water and soil in iron producing areas.
2. Exposure to iron can be caused by iron catalysts used in the Haber process for producing ammonia.
3. Exposure to iron dust and fumes from welding, smelting, grinding can cause a risk of lung cancer to the workers.
4. Other sources of iron exposure can be drinking water, iron pipes and cook wares.
5. Iron overdose is very common and dangerous in children as they may eat too much multivitamins.

PHARMACOKINETICS OF IRON

Absorption

Iron absorption is a complex process that occurs in the proximal small bowel and consists of a series of step. 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. In case of therapeutic dosing 10-35% is absorbed, but in iron deficiency this increases to 80-95%.Peak serum concentrations occur approximately 4 -6 h after the ingestion of an overdose. The absorption of iron is dependent on body iron stores, hypoxia and rate of erythropoiesis. Dietary absorption of iron takes place at duodenum and upper jejunum.

Distribution

Distribution of iron is very rapid. Entry of iron into tissues is an active process involving specific transferrin receptors and endocytosis. Liver can passively absorb iron and this is one of the reasons it is a target organ in iron poisoning. Half-life of iron after therapeutic dosing is approximately 6 hours as well as in case of overdose.

Excretion

Excretion of iron after an overdose is insignificant as the body doesn't have any effective means of excreting it from the body.

MECHANISM OF TOXICITY/ACTION

Iron has the ability to produce oxygen free radicals under aerobic conditions. Overproduction of reactive oxygen species such as superoxide and hydroxyl ion may lead to cellular damage. Organs exposed to high concentrations of iron are the gastrointestinal epithelium, cardiovascular system and the liver. Five clinical phases are known namely- Gastrointestinal Toxicity, Relative Stability, Circulatory Shock and Acidosis, Hepatotoxicity and Gastrointestinal Scarring.

ONSET AND DURATION OF ACTION

Symptoms of iron poisoning are evident mostly after 6 hours of administration through oral route. The amount of iron that may cause poisoning depends on the age group and the mg/kg bodyweight. Symptoms may also occur in respect to the different available oral forms. After the early symptoms the serious complications may develop within 48 hours after the overdose.

FATAL DOSE AND FATAL PERIOD

Ingestion of 20 mg/kg to 60 mg/kg results in moderate symptoms. Ingestion of more than 60 mg/kg can cause severe toxicity and lead to morbidity and mortality within 6 hours of ingestion.

NORMAL AND REFERENCE VALUES

In unexposed individuals the level of iron in blood is usually between 500- 2000µg/l and toxic level more than 3500μg/l. In acute toxicity the level remains high whereas in case of urine the normal levels is 65µg /gand in toxicity level it is more than 65µg /g[4-6].

Table 1: Normal/ Reference and Toxic values of iron[4-6]

Matrixes	Normal level	Toxic level
Blood	500-2000µg/l	more than 3500 µg/l
Urine	65µg/g	more than 65 µg/g

SYSTEMIC EFFECTS ON THE BODY

Iron toxicity is classified as corrosive or cellular. Ingested iron can cause direct caustic injury to the gastrointestinal mucosa, resulting in nausea, vomiting, abdominal pain, and diarrhea. Significant fluid and blood loss can lead to hypovolemia. Hemorrhagic necrosis of gastrointestinal mucosa can lead to hematemesis, perforation, and peritonitis. At the cellular level, iron impairs cellular metabolism in the heart, liver, and central nervous system. Free iron enters cells and concentrates in the mitochondria. This disrupts oxidative phosphorylation, catalyzes lipid peroxidation, forms free radicals, and ultimately leads to cell death.

Central Nervous System

Iron accumulating in cells plays a significant role for initiating neurodegeneration by promoting free radical formation (Fenton chemistry). Ferrous iron (Fe2+) gets catalyzed to ferric iron (Fe3+) in a chemical reaction mediated by hydrogen peroxide (H2O2) formed as a byproduct of oxidative stress leading to formation of hydroxide radical. Depletion in antioxidants level inside the cell fails to scavenge hydroxide radicals and causes neurotoxicity. Iron toxicity contributes to neurodegenerative disorders like Parkinson's disease and Alzheimer's disease by increasing the brain oxidative stress status.

Cardiovascular system

Iron-mediated generation of noxious reactive oxygen species is believed to be the most important pathogenetic mechanism causing cardiomyocyte damage, the initiating event of a pathologic progression involving apoptosis, fibrosis, and ultimately cardiac dysfunction.

Reproductive system

Iron toxicity induces ovarian dysfunction syndrome in females. Low ovarian reserve is associated with low chances for spontaneous pregnancy and poor response to hormonal stimulation. Excess of iron element leads to defective spermatogenesis, reduced *libido*, and oxidative damage to the testicular tissue and spermatozoa, ultimately leading to fertility impairmentin males.

CHEMICAL TESTS FOR IRON POISONING

QUALITATIVE ANALYSIS [7]

The biological sample should be digested with acid or mixture of acid in microwave digestion system

Iron is detected using Reinsch test. It is applicable to urine, stomach contents and scene residues. It acts as an initial indicator to detect the presence of heavy metals. Shiny black stain on the copper is interpreted as iron .10-15 g of gastric contents or tissue homogenate is used for the test. 3 ml of concentrated hydrochloric is added and then a copper wire spiral is inserted. It is then gently heated for two hours. Silvery deposit indicates mercury whereas shiny black is iron. Gutzeit test is the confirmatory test, and they can even be quantified.

a. Reinsch's Test

1. In a China crucible, 5 ml of test solution is taken.
2. Few drops ofHClare added to it.
3. Then small piece of cleaned copper strip is added to it and heated in a water bath.
4. Now the presence of iron is indicated by a gray deposit on the copper strip.
5. The pieces of dried shining copper strip are slowly heated in a Reinsch's tube after necessary cleaning.
6. Non-sublimation of copper strip on heating in Reinsch's tube is indicative of the presence of iron.

b. Potassium Iodide-Cinchonine Test

1. In a spotted tile, a portion of stained copper strip from the Reinch's test is taken.
2. To dissolve the deposit, a few drops of Nitric acid are added.
3. The solution is then evaporated and the residue is divided into two portions.
4. One drop of potassium iodide solution is added to one portion, followed by a drop of acidified aqueous cinchonine solution.
5. Appearance of orange color is indicative of the presence of iron.

QUANTITATIVE ANALYSIS [7]

a. UV-Visible Spectroscopy method

Iron can be detected quantitatively by using UV-Visible spectrophotometry. Iron can form complex with organic compounds which will give absorbance at specified wavelength.

b. Atomic Absorption Spectrophotometry method (AAS)

Atomic absorption spectrophotometry is good technique for the determination of iron in biological materials. The absorbance of the standard solutions is plotted against the concentration of iron. The concentration of iron is obtained from the calibration curve.

c. Ion Chromatography

Ion chromatography is another important tool for the quantitative estimation of iron in biological materials such as blood, urine, tissue, hair, nail etc.

d. Voltammetry/ Polarography method

Voltammetry/Polarography is another tool for quantitative analysis of iron in biological materials.

e. ICP-OES/ICP- MS Method

Inductively Coupled Plasma Optical Emission Spectroscopy/ (ICE-OES) is an analytical technique that uses the emission spectra to quantify the trace metal iron. It is a screening technique in acute poisoning. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is latest advance technique for determination of heavy metals in microgram and nanogram and picogram levels. This is the instrument by which multiple elements can be determined simultaneously.

CLINICAL APPEARANCES/ SYMPTOMS IN IRON POISONING

Clinical appearances/systems in case of iron poisoning depend upon different forms of iron and the amount of doses taken.

A. In case of acute toxicity

Stage 1- Gastrointestinal Effects

- Nausea
- Vomiting
- Gastrointestinal bleeding lead to hematemesis or bloody diarrhea
- Local corrosion leads to the formation of gastric antral and pyloric strictures.

Stage 2- Systemic Effects

Signs of hypoperfusion

- Cold extremities
- Tachycardia
- Tachypnea
- Hypovolemic shock
- Acidosis

B. In case of chronic poisoning

- Myocardial dysfunction
- Heart failure
- Lactic acidosis
- Cardiogenic shock leads to hypoperfusion
- Hepatic necrosis
- Abnormalities in coagulations and inhibitory effects on clotting factors.

DIAGNOSTIC INVESTIGATION IN CASE OF IRON POISONING

1. 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.

2. Abdominal radiographic examination can be useful to identify iron.
3. Laboratory tests should include serum electrolytes, blood urea nitrogen(BUN), aniline and aspartate aminotransferases and bilirubin.

4. Venous or arterial blood concentrations are monitored in moderately or severely poisoned patients.
5. Prothrombin and partial thromboplastin time should be determined.

MANAGEMENT/TREATMENT [8]

Exposure to all forms of iron should be treated as soon as possible. Delay of confirmatory test can cause irreversible damage.

Criteria of Management in Iron poisoning

A. Observation at home: Ingestion of single and small amount of Iron is unlikely to cause systemic toxicity and the asymptomatic patient may be observed at home.

B. Observation in hospital: Ingestion of large amount of Iron should be evaluated in hospital. Patient with symptoms of acute or chronic intoxication should be referred to health care facility.

C. Criteria for admission in hospital: The patient with persistent vomiting or evidence of systemic toxicity should be admitted in hospital for supportive measures.

D. Criteria for toxicologist consultation: If any patient develops systemic toxicity of Iron then the treating physician should consult a medical toxicologist or nearby poison control center.

HOSPITAL MANAGEMENT [9]

1. 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. The treatment of Iron overdose starts with attention to supportive care and adequate fluid resuscitation. [10]

2. 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. Abdominal radiography such as straight X-Ray abdomen and Contrast enhanced CT scan of abdomen should be done.

3. Gastrointestinal decontamination

- Any patient with probable and confirmed significant exposure should have whole bowel irrigation.
- Polyethylene glycol- electrolyte solution at a rate of 0.5 L/h for children or 2 L/h for adolescents should be done.
- Whole bowel irrigation is continued until effluent is cleared.

4. Patients with minimal gastrointestinal symptoms should have abdominal radiographs, an arterial blood gas and electrolyte tests. A serum level concentration less than 350μg/dL would support it as a low risk patient. He may be discharged home with close follow up or kept under observation if necessary.

5. Patients with altered mental status, shock or acidosis should receive chelation therapy and remain admitted to the hospital.

6. Activated charcoal and gastric lavage is generally not recommended in case of iron toxicity. After acute ingestion, gastric lavage should be considered only if the patient presents within one hour.

7. Mechanical ventilation and sedation may be required for severe agitation and myoclonus.

8. Correction of hypovolaemia and metabolic acidosis is done urgently.

9. Chelation therapy is done with Desferrioxamine (DFO) or Deferiprone, which is a chelator with high affinity and specificity for Iron. After chelating with iron, it forms a stable compound ferrioxamine that is excreted in the urine. [11]

10. Desferrioxamine binds 8.5 mg of elemental iron per 100 mg of the chelate. [12]

11. Continuous arteriovenous hemofiltration (CAVH) can also be applied in severe poisoning. [13]

CHELATION THERAPY

This is indicated in these circumstances [9]:

i. Several episodes of vomiting or diarrhea.
ii. Severe abdominal pain, hypovolaemia or metabolic acidosis.
iii. Multiple radio-opaque areas in abdominal radiographs.
iv. Serum Iron level is more than 350 µg/dl.

It can be given by the following doses[10]:

1. **Intravenous Dose:** administered at a continuous infusion at a rate up to 15 mg/kg/hr. In patients with severe overdoses, the dose can be increased up to 35 mg/kg/hr.
2. **Intramuscular Dose:** administered at a dose of 90 mg/kg, up to maximum of 1000 mg/kg, thrice daily.
3. **Total Daily Dose:** the total dose should not exceed 6 grams/day.
4. **Duration of infusion:** in moderate toxicity, infusion is given for 8—12 hours, while in severe intoxication, the patient is infused for 24—36 hours with the chelator.
5. **Therapy endpoint:** urine is monitored for characteristic colour change from pink to orange red, indicating excretion of chelated iron from body.Chelation therapy should be given throughout until there is significant resolution of systemic toxicity, especially acidosis and shock.
6. Chelation therapy with Desferrioxamine may have adverse effects such as sepsis, ocular toxicity, ototoxicity, pulmonary toxicity and nephrotoxicity in few patients.

CONCLUSION:

It is extremely important to avoid the exposure of iron, for which the following steps should be taken. 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.Laboratory tests should include serum electrolytes, blood urea nitrogen(BUN),aniline and aspartate aminotransferases and bilirubin. Patients with altered mental status, shock or acidosis should receive chelation therapy and be admitted to the hospital.

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Review Article

Magnesium poisoning with analytical aspects and its management

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ABSTRACT

Magnesium is an alkaline earth metal represented as Mg and has atomic number 12 and atomic mass 24. It is one of the most abundant metal found in the atmosphere of the earth and sea water. Magnesium acts as cofactor to various enzymes in the biological system and is very essential part of diet, several medications and health supplements. High concentration of magnesium and its compound in the blood serum results into toxicity and hypermagnesemia. Such condition is generally common in people with renal defects, hypothyroidism or accidental exposure to huge amount of magnesium and its salts. Magnesium poisoning can cause severe health issues including depression of CNS, neuromuscular and cardiovascular manifestation, with other symptoms including vomiting, nausea, paralysis etc. This paper discusses the general features, techniques of analysis, clinical diagnosis, symptoms and treatments related to the magnesium poisoning.

1. Introduction

Magnesium is a greyish white alkaline earth metal, represented by symbol Mg. It ranks eighth in the series of most abundant element found in earth's crust and is third most abundant element found in sea water.[1] Naturally occurring magnesium generally occurs in combined forms with other compounds and exists in +2 oxidation state, whereas the free elemental state of the metal can also be produced artificially which is comparatively more reactive. Magnesium is one of the key elements found in living cells and is known to act as cofactor for more than 300 enzymes. Several biological processes such as glycolysis, oxidative phosphorylation, phosphate transfer reactions, ATPase activity etc. requires magnesium as a direct or indirect factor. Magnesium also has a very important role in maintaining nucleotides during RNA and DNA synthesis.[2]

Exposure of human beings to magnesium is very common and obvious. It is naturally present in various fruits, vegetables, nuts, dairy, sea food etc. It is also consumed in several health supplements and medicines such as laxatives and antacid. Processes such as mining, production of magnesium alloys is also a source of human exposure to magnesium. Several experimental studies suggest that the blood level of magnesium more than 2.6mg/dl leads to hypermagnesemia, which have toxic effects on the body and lead to severe health problems. There is a need to understand the probable exposure of magnesium in order to take preventive measures. Also, proper techniques of analysis and management is required in order to avoid further damage.

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2. Sources of Mgnesium

Magnesium being an essential element of living cells and very abundant in earth's crust, make its occurrence very common in nature. Some of the sources of magnesium has been listed and discussed below.

1. Magnesium is found in many foods such as green leafy vegetables, legumes such as kidney beans, soy products.
2. Nuts such as cashew, peanuts and almonds and grains are also a good source of magnesium.
3. Magnesium is present in sea water.
4. It is present in earth crust as magnesium ores such as magnesite, dolomite and carnallite.
5. It is also present in mantle of earth.
6. Industries deals with magnesium alloys in order to make various parts of automobiles and aircraft.
7. It is also present in several household appliances.
8. Several compounds of magnesium such as magnesium hydroxide, sulphate and chloride are used in several medicines and agents for laxative and antacids.
9. It is also is a part of magnesium supplements.
10. It is used in blasting compositions, incendiaries, pyrotechnics and signal flares.

3. Exposure of Magnesium

1. Intake of high dosage of magnesium supplements or medicines which contain magnesium as one of the components.
2. Taking high amount of magnesium rich diet can also cause hypermagnesemia.
3. Occupational exposure to magnesium and its compounds is very common in industries related to metallurgy, electronic industry, manufacturing or processing of the magnesium and its compounds.
4. Use of magnesium in agriculture industries, fertilizer, construction material, pulp and paper industry results in their direct release to atmosphere.[3]
5. Being a part of various blasting compositions, blasting flares and pyrotechnics it is released to the atmosphere.
6. Oxides of magnesium is also released into atmosphere naturally as mineral periclase.[4]

4. Pharmacokinetics of Magnesium

4.1. Absorption

Magnesium and its compounds when taken orally get dissociated into magnesium cations (Mg^{2+}) due to acidic pH of the stomach. Nearly 15% of the Mg^{2+} are absorbed in the small intestine, by solvent drag mechanism and intercellular diffusion. Absorption of these cations is also dependent on the type of food and its ability to form complex. Several studies in human suggest that the absorption of magnesium is also dependent on the type of magnesium compound and availability of other factors. Magnesium chloride, citrate and lactate are known to get absorbed more rapidly as compared to magnesium hydroxides and oxides due to their solubilities.[5,6] Various studies, also suggests role of vitamin D is very important in absorption of magnesium. Absorption of the magnesium in intestine is dependent upon the magnesium concentration of the body and not on the amount ingested. In case of intravenous administration, the effect is observed immediately and last for about 30-60 min.

4.2. Distribution

Human body contain approximately 26 g of magnesium, out of which nearly 60% is found in bones, followed by 20% in skeletal muscles, 19% soft tissues, and nearly 1% in extracellular fluid. Kidney has a key role to play in maintaining plasma magnesium levels. The serum magnesium level is regulated via renal magnesium reabsorption.[7] Most of the absorbed magnesium is stored in bone.

4.3. Excretion

Excretion by urine is the main method of elimination of magnesium from body, which accounts for 80-90% of Mg^{2+}ion excretion. Some hydroxides of magnesium and unabsorbed magnesium ions are directly eliminated in feces.[8]

5. Mechanism of Toxicity

Compound of magnesium such as magnesium sulphate act as a depressant of CNS and respiratory system. Mild dosage cause flushing, sweating and vasodilation, whereas high dosage results into blockage of neuromuscular transmission and hypotension.

6. Onset and Duration of Action

The appearance of symptoms may be within few days to few weeks depending upon the compound magnesium and dose of uptake. In case of acute poisoning symptoms may appear within hours, however in chronic poisoning the appearance of symptoms may take several months or years.

7. Fatal Dose/ Fatal Period

Several studies suggest that oral fatal dose of magnesium for human ranges from 0.5 to 5 g/kg for a healthy adult. The symptoms may vary from mild to severe depending upon the age, sex, health condition and various internal as well as external factors.[9]

8. Normal and Reference Value

Normal and toxic level of magnesium are discussed in Table 1.

Table 1: Showing normal and toxic levels of magnesium.

Matrixes	Normal level	Toxic level
Blood	1.7-2.2 mg/dl	More than 2.6 mg/dl
Serum	2.2-2.7 mg/dl	More than 7.0 mg/dl
Urine	3.0-4.3 mg/dl	More than 5.0 mg/dl

9. Systemic Effects on Body

Poisonous effect of magnesium is very uncommon because kidneys are efficient in eliminating excess magnesium from the body. Hypermagnesemia is usually found in patients with undergoing health issues or accidental ingestion of large amount of sea water. Some common reasons for hypermagnesemia include intake of large amount of magnesium salts or drugs with impaired renal function and undergoing dialysis. Studies suggests that the rectal administration of the magnesium medication are also a common cause for magnesium poisoning. Patients with Addison's disease and hypothyroidism are also reported with slightly high levels of magnesium in the plasma. Some of the effects of the hypermagnesemia has been discussed below. [10]

9.1. Neuromuscular manifestation

Several evidences suggest that the serum levels of calcium higher than 2mmol/L, results into neuromuscular blockage and vasodilation. Higher concentration of magnesium ions results into inhibition of presynaptic acetylcholine release from neuromuscular and sympathetic junction. Prolong effects include sleepiness and loss of tendon reflexes. [11]

9.2. Cardiovascular manifestation

Hypotension is the commonly observed symptom in case of hypermagnesemia. Initial symptoms show reduction in supine and erect blood pressure. Studies show that with increase in the blood magnesium concentration other conditions such as asystole, blockage of heart, paradoxical bradycardia can be observed.

9.3. Hypocalcaemia

With increased concentration of the magnesium in blood serum the levels of the calcium decreases. Decrease in the levels of calcium in turn lead to further deficiencies and a series of symptoms.

9.4. Miscellaneous

Other common effects of increased magnesium concentration include nausea, vomiting, dilation of pupils, facial flushing, paralysis and coma.

10. Analytical Tests for Magnesium Poisoning

10.1. Qualitative analysis

10.1.1. Sodium hydrogen phosphate test

1. It is detected by usual group analysis with sodium hydrogen phosphate.
2. White ppt is obtained with sodium hydrogen phosphate.

10.1.2. Cobalt nitrate test

1. A drop of test solution is mixed with cobalt nitrate on charcoal.
2. Rosy pink incrustation confirms the presence of magnesium.

10.1.3. Triazine dye test

1. Drop of solution containing magnesium is taken in spot plate
2. Above solution is acidified with HCl
3. Few drops of titan yellow solution is added to it
4. Few drops of NaOH is added to the mixture and mixed well
5. Red flocculent precipitate is appeared which confirm the presence of magnesium

10.1.4. Caustic soda test

1. A drop of test solution is taken in a test tube.
2. Titan yellow reagent and a drop of 0.1N caustic soda solution are added to it.
3. Orange or red color is obtained, which confirms the presence of magnesium.

10.2. Qualitative analysis

10.2.1. Titration with EDTA

Magnesium ion reacts with electron pair donors compounds in order to form coordination compound or complex ion called chelated, which can be used for quantitative analysis. EDTA is commonly used for the process of chelation and analysis. For titration of Mg^{2+} the solution is firstly buffered at pH 10 and the end point is determined by addition of Eriochrome black T which results into formation of a coloured chelate with Mg. The colour is again changed when the Mg^{2+} is released in order to form complex with EDTA.

10.2.2. Scanometric method

This technique is based on the procedure of scanning a solution which contain pink-coloured complex produced by

combination of Titan yellow and the magnesium ion. This is a highly sensitive method and can be used for wide variety of sample. [12]

10.2.3. Atomic absorption spectrometry (AAS)

It is a very conventional technique used for analysis of trace metals in different samples. Solution containing sample is aspirated as aerosols into flame. The gaseous atoms of the molecule absorb electromagnetic radiations in order to produce measurable signals. These signals are then amplified and detected using detectors. [13]

10.2.4. Inductively coupled plasma mass spectrometry (ICPMS)

It is commonly used method for ultra-trace analysis of metals. Here, the sample is atomized and small polyatomic ions are created which are further detected as compared to AAS this technique is more accurate and has great speed and sensitivity.

10.2.5. Spark source atomic emission spectrometry (SPAES)

This method does not require dissolution of the sample and best used by conductive samples. An electric spark is passed into the sample, which results into excitation of the metal atoms present in the sample. The energy released then can be detected by various detectors.

10.2.6. X-ray fluorescence spectrometry (XRF)

This technique measures absorption, emission, fluorescence, as well as diffraction and scattering of the given sample. It is a non-destructive technique which relies on bombarding sample with high energy X-rays, which results into ionization of electrons of innermost shell.

11. Clinical appearances/ Symptoms in Magnesium Poisoning

High amount of magnesium in serum due to magnesium rich diet is very uncommon. This condition is generally observed in people with intake of high magnesium supplement or having health issues such as kidney failure. Inhalation fumes of compounds containing magnesium can also lead to certain specific symptoms.

11.1. In case of acute toxicity

1. Lethargy.
2. Nausea.
3. Vomiting.
4. Facial flushing.
5. Stomach cramps.
6. Depressed reflexes.

11.2. In case of chronic toxicity

1. Respiratory paralysis.
2. Hypotension.
3. Circulatory collapse.
4. Heart block.
5. Asystole.
6. Hypocalcaemia.

12. Diagnostic Investigation

Following diagnostic investigations are very useful in case of magnesium poisoning.

1. Recording medical history of the patient is necessary in order to have correct diagnosis.
2. Diagnosis such as arterial blood, CBC, X ray of chest, pulmonary function test can be carried out in order to get clear idea about the exposure. [14]
3. Elevated levels of magnesium in urine, plasma and serum.

13. Management/ Treatment

All types of exposures to magnesium in levels higher than accepted should be taken seriously and treated according to the severity of the symptoms.

13.1. Observation at home

Ingestion or inhalation of small amount of compound with mild symptoms can be treated at home. Keeping patient away from the further exposure. In case of dermal exposure and irritation in eyes, multiple washing with water or saline is usually carried out.

13.2. Hospital management

Patient with normal kidney function (glomerular filtration rate (GFR) over 60 ml/min) and mild asymptomatic hypermagnesemia require no treatment. But higher magnesium levels should be taken seriously and treated according to the severity of the symptoms.

13.3. Decreasing absorption

1. After acute exposure of magnesium either ingestion or inhalation, one should immediately remove the patient from further exposure.
2. External exposure and irritation in eyes require frequent washing and irrigation with water or saline.
3. Decontamination done by gastric emptying with a nasogastric tube for large recent ingestions. Activated charcoal is not effective in case of magnesium toxicity. Do not administer a cathartic.

In more severe cases, close monitoring of the ECG, blood pressure, and neuromuscular function and early treatment

are necessary:

13.4. Supportive measures

1. Maintain an open airway and assist ventilation if necessary.
2. Replace fluid and electrolyte losses caused by excessive catharsis.
3. Treat hypotension with intravenous fluids and dopamine.

13.5. Chelation therapy

1. In severely poisoned patients the presence of acute renal failure often limits the potential for antidotes.
2. There is no specific drugs and antidotes for hypermagnesemia. However, administration of intravenous 10% calcium gluconate or chloride solution (10 ml iv repeatable over 5 minutes) can serve as an antidote. It alleviates respiratory depression, hypotension, and arrhythmias.

13.6. Enhanced elimination

1. Hemodialysis rapidly removes magnesium and is the only route of elimination in anuric patients.
2. Hemoperfusion and repeat-dose charcoal are not effective.
3. Forced diuresis using intravenous furosemide and normal saline enhance Mg elimination.

14. Conclusion

Magnesium and its compounds are one the abundantly found compounds in nature and human body. It has a important role to play in the functioning of various enzymes and processes. Use of magnesium in various industries, food supplements, and medication is very common which makes human susceptible to overdose and poisoning. There is a need to understand the underlying symptoms, diagnostic features and related treatment regarding the same. Any symptom mild or severe in patients, must not be ignored and should rush for immediate medical help for further treatment.

15. Source of Funding

None.

16. Conflict of Interest

None.

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Review Article

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TIN Toxicity with Analytical Aspects and its Management

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Abstract

Tin is a silvery-white metal, naturally occurring as cassiterite. It is denoted by symbol Sn, has an atomic number 50 and atomic weight 118.71u. The two commonly found oxidation states of tin are Sn (IV) called stannic and Sn (II) called stannous with approximately equal stabilities. Tin has been extensively used for storing food and beverages, transportation, construction industries, in paints, as heat stabilizers, and biocides. Several anthropogenic and natural processes release tin and its compounds into the environment posing a severe toxicological threat to living beings. Several studies prove absorption and accumulation of tin in the various parts of the body such as lungs, kidney, and spleen resulting in impairment of respiratory system, degenerative changes in kidney, central nervous system and reproductive system. The clinical features of tin poisoning along with appropriate diagnosis has been discussed in this paper. The identification of tin and its compounds using various advanced analytical techniques will help in better dealing with the toxic effects of the same. Also, the hospitalization and post-hospitalization management will help to understand the proper care and treatment required by the patient.

Keywords: Tin toxicity; Poisoning; Tin; Biocides; Analytical techniques etc.

Introduction

Tin is a chemical element that belongs to group 14 in the periodic Table. It is represented as Sn, which stands for the Latin word 'stannum'. Tin is a silvery metal that occurs in two stable oxidation states +2 and +4 and is also 49th most abundant element on earth, which is mainly obtained from mineral cassiterite. Tin is globally used to preserve the canned food and beverages; other well-known uses of tin are in the transportation sector and various electrical appliances. Industries use both organic and inorganic forms of tin common examples of organotin includes agrochemicals, biocides, Polyvinyl chloride and some catalysts.[1,2]

Studies suggest no biological significance of tin in the living organisms, however, various research establish the toxic aspects of the tin if consumed regularly. Dosage of tin more than 130 mg/kg is known to get accumulated in kidneys, bones, and spleen. The inorganic form of tin and certain salts are known to cause severe effects on the gastrointestinal system, respiratory system, reproductive and renal system.[3] Symptoms of mild toxicity includes nausea, vomiting, diarrhea and irritation of the upper respiratory tract. Severe effects include irreversible damage to renal tubules and various neurodegenerative changes leading to disorientation, confusion, memory loss with severe epileptic seizures in many cases. Therefore, proper

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management is required in case of Sn poisoning along with proper treatment in order to avoid further damage.

Sources of TIN

The concentration of the tin in earth crust is approximately 0.0006%, the main sources of tin exposure to humans are anthropogenic in nature. Some of the common sources of tin exposure are discussed below.[4]

1. Tin present in the soil is released to the atmosphere due to the process of weathering.
2. Certain biocides and antifouling paints contain compounds of tin such as Tributyltin and triphenyltin.
3. Canned food and beverages are a major source of tin.
4. Disposal of products made of tin leads to its leaching in the ground.
5. Industries dealing with manufacturing and processing any form of tin are a source of occupational exposure.
6. The process of mining is known to release metallic tin in the environment, which is further converted into the inorganic compounds of tin.[5]
7. Tin also gets accumulated in various fishes and plants which grow near high in concentration.

Human Exposure of TIN

There are three commonly known methods of the exposure of tin, most common being ingestion followed by inhalation and dermal absorption. Some of these are discussed in detail below.[6]

1. Consumption of canned food and beverages is known to administer tin in the body. The actual concentration of tin in canned food is governed by various factors such as storing temperature, the acidity of the food, the presence of oxidizing agents, lacquered or unlacquered can, etc.
2. Inhalation of the tin particles near landfills or industries dealing with the manufacturing of tin products.
3. Eating seafood which has high levels of tributyltin and triphenyltin.
4. Dermal absorption is a common occupational exposure and is commonly seen in the case of organotin compounds.
5. Regions, where polyvinyl compounds are used for water distribution, are known to have a high concentration of mono-and dibutyltin and Mono-and dimethyltin.

Pharmacokinetics and Metabolism

Absorption

Studies suggest organic tin compounds are absorbed much faster as compared to inorganic tin compounds in the body. It is observed, with an increase in the dosage of tin in the body the gastrointestinal absorption decreases. Tin incorporated in the food naturally is readily absorbed than stannous chloride present in some food. 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 body.[7]

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. A trace amount of inorganic tin is known to cross the placental barrier.

Excretion

Most of the ingested inorganic tin remains unabsorbed and is readily excreted in urine and feces and a small amount in bile. Organotin compounds generally degrade via dealkylation and de-arylation through the liver and finally discharged from the kidney, saliva, digestive tract, respiratory tract.[8]

Mechanism of Toxicity

There are few studies stating the possible bioalkylation of tin via reductive Cobalt-Carbon bond cleavage of alkyl cobalamines. Although there is no direct experimental study present on the topic. Some salts of tin such as stannous chloride are shown to cause genotoxicity by damaging the DNA and causing chromosomal aberrations. Stannous ions are known to reduce hydrogen peroxide and produce reactive oxygen species.

Onset and Duration of Action

In the case of tin poisoning appearance of symptoms depends upon the dose of exposure. The occurrence of symptoms appears depending upon the form of the tin compound and its mode of exposure. Usually in case of acute poisoning symptoms may appear within hours, however, in chronic poisoning, the appearance of symptoms may take several months or years.

Fatal Dose / Fatal Period

The fatal dosage of tin varies greatly depending upon the compound of tin and its mode of exposure. According to the World Health Organization, the intake of 200 mg/kg in salt is fatal in humans.[9] The fatal period varies a lot depending upon several factors, in general, it can be estimated as an incubation period of 15 minutes to 14 hours. Triphenyltin acetate if consumed orally in dosage 260 mg/kg is fatal in humans. Triethyltin if consumed about 90 mg/day for 7–8 days is highly toxic and lethal.[10]

Normal and Reference Values

Table 1: Showing normal and toxic levels of tin.

Biological Matrixes	Normal level	Toxic level
Blood	Less than 0.005 µg /mL	More than 0.009 µg/ml
Urine	1 – 20 µg/L	More than 30 µg/ml
Hair	Less than 0.30 µg/g	More than 0.32 µg/g

Systemic Effects on Body

Studies suggest that the metallic form of tin is not very toxic due to its poor absorption by the body. However acute intake of inorganic compounds of tin has some adverse effects like nausea, vomiting, irritation in skin or eyes and various gastrointestinal issues. Organic compounds of tin such as $(CH_3)_3Sn$ (trimethyltin) and $(C_2H_5)_3Sn$ (triethyltin) are known to interfere with the nervous system and immune system in certain animals.[11,12] Very few experimental data available regarding the effect of tin and its compound on human health, the majority of the studies were carried out in animals.

Respiratory effects

Prolong exposure to dust of stannic oxide gets deposited in the lungs and is known to cause stannosis in humans. Tributyltin oxide is known to produce irritation of the upper respiratory tract with symptoms of pain and tightness in the chest, further exposure can lead to difficulty in breathing and coughing. Certain inflammatory changes such as bronchitis, lung edema, and hyperemia were observed in some animals such as rats and rabbits.

Gastrointestinal effects

Studies suggest that ingestion of trimethyltin chloride and tributyltin oxide produce severe nausea, vomiting, diarrhea followed by substernal and epigastric burning. Continuous pain and burning can persist even after 2–3 months of exposure.

Renal effects

Several experimental studies conducted on animals reveals proximal tubule degeneration and high level of tin in the urine. Further necropsy studies suggested damage to glomeruli, as well as collecting tubules. Extensive congestion in the kidney along with swelling in the renal tubular epithelium was also observed.

Neurological effects

Several studies suggest neurobehavioral changes in humans due to long-term exposure to organotin compounds, common effects include headache, impaired memory, deafness, cognitive dysfunction, and neuropsychiatric behavior, in some of the serious cases, epileptic seizures were also observed. Swelling in the brain and spinal cord along with degeneration of myelin can be seen in some cases.[13]

Reproductive effects

Experimental studies done on rat suggests, acute and intermediate exposure of compounds such as tributyltin bromide and dibutyltin dibromide reduce pregnancy rates. Some impairment was also seen in the female reproductive function, but these changes looked reversible once the exposure was reduced.

Analysis

There are several analytical techniques available in order to detect tin and its compounds, some of these commonly used techniques are listed below.

Qualitative test

1. *Cacotheline test:* A Whatman filter paper is moistened with a saturated solution of cacotheline and dried at room temperature. A drop of test solution containing tin is put on the above filter paper. Development of violet colour indicates the presence of tin.[14]
2. *Meissner's flame test:* the sample containing tin is mixed with zinc and HCl, then a test tube containing water is dipped in the above solution and immediately held over a flame of Bunsen burner. The appearance of blue coloured flame proves the presence of tin. Production of this flame is due to $SnCl_4$ (which is volatile in nature) and its reduction to SnH_4.[15]

Quantitative analysis

1. *Polarography or Voltammetry method:* Voltammetry method for analyzing tin uses the varying degree of the electric potential in the solution containing metal, this method is very sensitive detecting 1 to 1000 parts per million.
2. *Potentiometric titration:* This method measures the variations in the redox potential when the solution containing tin is titrated against the potassium iodate solution. Such a method is generally used for estimating stannous (tin II) present in radiopharmaceutical vials sealed in inert gases or nitrogen. Stannous estimation by potentiometric titration is not possible in vials with antioxidants such as ascorbic acid.
3. *Flame atomic absorption:* Determination of tin in biological materials such as blood, urine, fecal matter, etc. requires a series of extraction processes followed by separation and detection.[16] Commonly used techniques in the case of biological material are spectrophotometry and photometry. It is seen that the determination of tin is usually done both as total metal and organotin analysis. Flame atomic absorption is the direct method for determining tin in any sample, this method uses the absorption of optical radiation by the free gaseous atoms of the tin in any given sample.
4. *Gas Chromatography (GC):* Determination of the organotin compound is preferentially done by gas chromatography (GC) due to its high resolution. This process requires some preparatory steps such as extraction, derivatization, separation, and detection. Extraction is carried out using organic solvent or various ion-exchange methods. Extraction is followed by derivatization, which includes the formation of alkyl, ethyl or hydride derivatives using respective chemical agents. The next step in the series is separation using variations in the boiling point of the compounds, once the atoms are separated identification is done using MS (mass spectrometry) and AAS (atomic absorption spectrometry).[17]
5. *Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP- AES):* Multielement analysis of tin in drinking water, canned food, air, and waste is done using this method. This method requires dilution of the test sample with HCl, which is then pumped to a nebulizer in order to produce an aerosol. Very fine aerosol particles are then allowed to pass the plasma using the cyclonic spray chamber. This method is considered one of the most precise methods to analyze tin using a quantitative approach.[18]

Clinical Appearances/Symptoms in Tin Poisoning

Clinical appearances and symptoms in case of tin poisoning depends upon the amount of substance, form of tin (organic/inorganic), mode of exposure and duration of the exposure.[19]

A. In case of acute toxicity

i. *Gastrointestinal effects*
- Nausea
- Abdominal pain and burning
- Vomiting
- Diarrhea
- Irritation in esophagus

ii. Systemic effects
- Lacrimation and severe conjunctivitis
- Upper respiratory tract irritation
- Irritants to the skin and mucous membranes
- Headache
- Subacute lesions

B. In case of chronic toxicity

- Proximal tubule degeneration
- Congestion of kidney and
- Swelling of renal tubules
- Memory loss
- Cognitive dysfunction
- Epileptic seizures

Diagnostic Investigation

- It is necessary to know and record the medical history of the patient, exposed to any form of tin poisoning.
- The physical examination is equally important where forced vital capacity (FVC) posteroanterior chest roentgenogram, and forced expiratory volume per sec (FEV1) is performed. Patients are also subjected to eye examination which includes various tests for visual activity and pupillary reaction.
- For the detailed investigation, kidney function test, urine albumin, glutamate-oxaloacetate transaminase test is also performed for a hepatic function test.
- X-ray of chest and blood tests are common in the case of organotin compounds.

Management and Treatment

All kinds of tin exposure should be taken seriously and treated as soon as possible. Delay in the identification of the symptoms and treatment can cause severe irreversible damage. Criteria for management of tin poisoning are

1. ***Observation at home:*** Ingestion of a very small amount of tin or its compound is unlikely to cause any systemic toxicity, an asymptomatic patient can be observed at home.
2. ***Observation in hospital:*** Intake of a large amounts of tin in any form should be evaluated in the hospital. A person with any acute or chronic symptoms of poisoning should be referred to a healthcare facility.
3. ***Criteria for toxicological consultation:*** If any systemic toxicity of tin is observed in the patient, then the physician should consult a medical toxicologist or nearby poison control center.

4. ***Hospital management***

1. The history of exposure of a patient to tin or its compound is noted to get a clear idea about the type and mode of poisoning.
2. Signs and symptoms of the patient, along with liver function, urine test, blood potassium and ammonia levels, MRI, CT scans are closely monitored.
3. In the case of mild poisoning symptomatic treatment is preferred.
4. In very severe patients few dosages of glucocorticoids are administered. Potassium glutamate and sodium glutamate is given intravenously in order to reduce blood ammonia. Oral administration of potassium is also helpful in order to normalize intractable hypokalemia and sodium bicarbonate is administered for metabolic acidosis; some sedatives are also helpful in controlling twitches and spasm.[20]
5. In some cases, gastrointestinal decontamination is carried out, patient with a confirmed significant amount of inorganic tin exposure is made to undergo whole bowel irrigation until the effluent is cleared. Decontamination is done by subjecting patients to electrolyte solution of polyethylene at a rate of 2L/h for normal adults.
6. Chelation therapy using EDTA- Patients with severe tin poisoning are intravenously administered with EDTA diluted with physiological saline solution (0.9% NaCl) at a very slow rate; this method is very effective for removing the tin and its compounds from the body. It is the property of EDTA to bind with toxic metals and in turn form, the stable complexes, later these complexes are eliminated from the body via urine.[21]

Conclusion

Tin and its compounds are known to show toxic effects in case of acute and chronic exposure to the body. People working in industries dealing with tin should take special care and should be subjected to periodic testing of blood, renal function test, urine albumin and another test to monitor levels of tin in the body. Consumption of canned food and beverages is a very common mode of tin exposure that should be taken care of.

Any symptom mild or severe in patients, must not be ignored and should rush for immediate medical help for symptomatic treatment.

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Profile Summary:

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- **PG Diploma in Intellectual Property Rights** (2007) – 60.1% from Bioinformatics Institute of India, Noida.
- **Diploma in Naturopathy and Yoga** (2002) **–** 60.3% from National Academy of Naturopathy, New Delhi.
- **Diploma in Computer Application** (2001) – 72.8% from RCSM, Aligarh.

Career Achievements:

- "Special recognition in QA" for the year 2012 at **Pfizer**.
- Successful transfer of about 75 Technology Transfer Documents (TTDs) to manufacturing plant in India and Abroad.

International Visit:

- Visited our Manufacturing Unit based at **"China"** to review its documentation and Quality Systems.
- Visited **"Slovenia"** to attend 9th workshop on Proficiency Testing in Analytical Chemistry, Microbiology and Laboratory Medicine.
- Visited **"Uzbekistan"** to attend ISO/IEC 17011:2017 and Risk Management Training conducted by Asia Pacific Accreditation Cooperation (APAC).

Work History / Experience:

DESIGNATION	FROM	TO	ORGANISATION
Chief Operating Officer	Apr 2023	Till date	Metal Power Private Limited
General Manager	Sep 2022	Mar 2023	Metal Power Private Limited
Deputy Director	May 2021	Aug 2022	Quality Council of India (Board: NABL)
Assistant Director	Jan 2017	Apr 2021	Quality Council of India (Board: NABL)
Accreditation Officer- Grade I	Aug 2014	Dec 2017	National Accreditation Board for Testing and Calibration Laboratories **(NABL)**
Junior Accreditation Officer	Nov 2013	July 2014	National Accreditation Board for Testing and Calibration Laboratories **(NABL)**
Research Scientist- Documentation	July 2007	Oct 2013	Pfizer Limited, New Delhi.
Analytical Chemist- Microbiologist	Sep 2004	Jun 2007	Analytical Testing Services Pvt. Limited, New Delhi

Responsibilities Handled:

Operation:

- Handling operations of following divisions of Metal Power Private Limited:
    - Testing Laboratories,
    - Proficiency Testing, and
    - Reference Material Producers.
- Implementing strategies to enhance revenue from each division.
- Setting and maintaining highest quality standards.
- Exploring and developing new business avenues.

Laboratory Accreditation:

- Well versed with the Laboratory Accreditation Process (starting from initial scrutiny to grant of Accreditation)
- Dealing with laboratories of following field-
    1. Testing Laboratories as per **ISO/IEC 17025** and
    2. Medical Laboratories as per **ISO 15189**
- Maintaining and Tracking Laboratory Accreditation Cycle.

Documentation:

- Preparatory work for **Technology Transfer Documents (TTD)** and Technical Dossiers.
- Review all existing documents, supporting data in various departments and bring them to the level of international standards.

- **Critically review** and evaluate data to devise on its suitability and adequacy for registration.
- Study the nature of the query and provide a suitable reply with supportive technical documents.
- Support and provide all the necessary regulatory registration documents to enable the company to establish in regulated markets regulatory liaison for coordinating with customers, regulatory agents & regulatory authorities towards all technical communications.
- Collect, review, compile & prepare quality data towards Dossier requirements as per international regulatory requirements.
- **Establish Quality Systems** to meet international regulatory requirements.
- Prepare **analytical method transfer protocol** for Drug Substances and Drug Products.
- **Preparation and review of SOPs**.
- Review and approvals of master documents from various departments.
- Review of documents related to **stability analysis**.
- ePALMs (Electronic Pfizer Artwork and Label Management System)

Audit:

- Internal self-auditing, external auditing of raw and packing materials, towards compliance, everything concerned to the quality of product entering in to regulatory markets to match the international regulations.

Handling of Market complaint:

- Investigation of root causes and implementation of corrective and preventive actions.

Handling of Quality Notifications:

- Investigation and Handling of Deviations, Non-conformances, Out of Specification, Out of trend and Change Controls.

Training Programs Attended:

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Analysis of Different Pharmaceutical Samples	Research & Development Center, Ranbaxy Laboratories Limited, Gurgaon	2004
LAL methodologies	Cambrex India Private Limited	2005
Laboratory Quality Systems, Management and Internal Audit	National Institute of Training for Standardization, Bureau of Indian Standards	2006
Professional Development Program	Indian Pharmaceutical Association, Delhi	2008
BET Testing	Charles River Laboratories India Pvt. Ltd.	2012
Effectively Using the Pharmacopeia	Indian Pharmacopeia Commission and **United State Pharmacopeia**	2012
Laboratory Assessor Course as per **ISO/IEC 17025: 2005**	National Accreditation Board for Testing & Calibration Laboratories, New Delhi	2014
Awareness Program on Reference	National Accreditation Board for	2014

Material Producers Accreditation as per **ISO Guide 34: 2009**	Testing & Calibration Laboratories	
Reference Material Producers Assessors Course as per ISO Guide 34: 2009	National Accreditation Board for Testing & Calibration Laboratories	2016
Graphical PT Tools in ISO 13528	Eurachem	2017
PT Language and PT Report	Eurachem	2017
Sophisticated PT Statistical Techniques	Eurachem	2017
Basic PT Statistics	Eurachem	2017
Proficiency Testing in Analytical Chemistry, Microbiology and Laboratory Medicine	Eurachem	2017
ISO/IEC 17025: 2017	National Accreditation Board for Testing & Calibration Laboratories	2018
CGMP	Quality Council of India	2018
Introduction to Measurement and Metrology	National Physical Laboratory, UK	2020
Introduction to Measurement Uncertainty		2020
Understanding Uncertainty Budgets		2020
Understanding and Evaluating Measurement Uncertainty		2020
Dimensional Measurement User		2020
Metrology for Biogas		2020
Portable 3D Metrology		2020
Introduction to Geometrical Tolerancing		2020
Radionuclide Calibrator		2020
Uncertainty Analysis for Earth Observation		2020
Training Programme on Water Resources Management & Sustainable Habitat for Scientists & Technologists, Government of India	Indian Institute of Public Administration, New Delhi	2021
ILAC Inspection Committee (ILAC IC)	International Laboratory Accreditation Cooperation (ILAC)	2021
CIPM-ILAC Joint Webinar: Digital Transformation in the context of Accreditation	CIPM-ILAC	2021
Standards on Drinking Water	BIS	2021
Seminar on "Disaster Management in Drinking Water Supply"		
Third Meeting of Services Sector Division Council SSDC- Seminar on "Disaster Management in Drinking Water Supply System"		
Magnetic Nanoparticles Standardisation and Biomedical Applications	NPL, UK	2022
Seminar on "Importance of Standardization on Greenbelt	BIS	2022

Development"		
Webinar on quality and transparency in procurement of goods and services	EURACHEM/ CITAC	2022
Terminology and Content of the EURACHEM/CITAC Guide		
Qualitative Chemical Analysis		
Qualitative Forensic Analysis		
Why Accreditation Matters	NATA	2022
IAF MD 25 Criteria for Evaluation of Conformity Assessment Schemes	Gitchia Institute of Global Certification	2022

Publications:

- *Iron Poisoning with Analytical Aspects and its Management*- International Journal of Medical Laboratory Research
- *TIN Toxicity with Analytical Aspects and its Management*- International Journal of Forensic Science
- *Barium Poisoning with Analytical Aspects and its Management*- International Journal of Advanced Research in Medicinal Chemistry
- *Magnesium Poisoning with Analytical Aspects and its Management*- Indian Journal of Forensic and Community Medicine
- *Heavy Metal Toxicity: Impact on Human Health- A Review*- Indian Journal of Forensic Medicine and Pathology
- *Impact Assessment of Electroplating in the Leaching of Harmful Metals from Utensils*- Macromolecular Symposia

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