



e-ISSN: 2319-8753 | p-ISSN: 2320-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 10, Issue 3, March 2021

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

**Impact Factor: 7.512**

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# Exposure to Heavy Metals in the Environment and Its Health Implications

Mrs. Parveen Saini

Associate Professor in Zoology, Dr. Bhim Rao Ambedkar Govt. College, Sri Ganganagar, Rajasthan, India

**ABSTRACT:** Metal toxicity or metal poisoning is the toxic effect of certain metals in certain forms and doses on life. Some metals are toxic when they form poisonous soluble compounds. Certain metals have no biological role, i.e. are not essential minerals, or are toxic when in a certain form.<sup>[1]</sup> In the case of lead, any measurable amount may have negative health effects.<sup>[2]</sup> It is often thought that only heavy metals can be toxic, but lighter metals such as beryllium and lithium may also be in certain circumstances. Not all heavy metals are particularly toxic, and some are essential, such as iron. The definition may also include trace elements when abnormally high doses may be toxic. An option for treatment of metal poisoning may be chelation therapy, a technique involving the administration of chelation agents to remove metals from the body.

Toxic metals sometimes imitate the action of an essential element in the body, interfering with the metabolic process resulting in illness. Many metals, particularly heavy metals are toxic, but some heavy metals are essential, and some, such as bismuth, have a low toxicity. Most often the definition of toxic metals includes at least thallium, cadmium, manganese, lead, mercury and the radioactive metals.<sup>[3]</sup> Metalloids (arsenic, polonium) may be included in the definition. Radioactive metals have both radiological toxicity and chemical toxicity. Metals in an oxidation state abnormal to the body may also become toxic: chromium(III) is an essential trace element, but chromium(VI) is a carcinogen.

Toxicity is a function of solubility. Insoluble compounds as well as the metallic forms often exhibit negligible toxicity. The toxicity of any metal depends on its ligands. In some cases, organometallic forms, such as methylmercury and tetraethyl lead, can be extremely toxic. In other cases, organometallic derivatives are less toxic such as the cobaltocenium cation.

**KEYWORDS**-metal,heavy,environment,health,toxicity,pollution,implications

## I. INTRODUCTION

Decontamination for toxic metals is different from organic toxins: because toxic metals are elements, they cannot be destroyed. Toxic metals may be made insoluble or collected, possibly by the aid of chelating agents, or through bioremediation. Alternatively, they can be diluted into a sufficiently large reservoir, such as the sea, because immediate toxicity is a function of concentration rather than amount. Another method of decontamination of heavy metals in the soil is using a method called phytoremediation.<sup>[4]</sup> This method uses plants to extract and lower the concentration of toxic heavy metals in the soil.<sup>[4]</sup>

Toxic metals can bioaccumulate in the body and in the food chain.<sup>[5]</sup> Therefore, a common characteristic of toxic metals is the chronic nature of their toxicity. This is particularly notable with radioactive heavy metals such as radium, which imitates calcium to the point of being incorporated into human bone, although similar health implications are found in lead or mercury poisoning.

### Testing for poisoning

People are continually exposed to metals in the environment.<sup>[6]</sup> Medical tests can detect metals often, but this is to be expected and alone is not evidence that a person is poisoned.<sup>[6]</sup> Metal screening tests should not be used unless there is reason to believe that a person has had excessive exposure to metals.<sup>[6]</sup> People should seek medical testing for poisoning only if they are concerned for a particular reason, and physicians should consider a patient's history and physical examination before conducting tests to detect metals.<sup>[7]</sup>

### Treatment for poisoning

---

Chelation therapy is a medical procedure that involves the administration of chelating agents to remove heavy metals from the body. Chelating agents are molecules that have multiple electron-donating groups, which can form stable coordination complexes with metal ions. Complexation prevents the metal ions from reacting with molecules in the body, and enable them to be dissolved in blood and eliminated in urine. It should only be used in people who have a diagnosis of metal intoxication.<sup>[8]</sup> That diagnosis should be validated with tests done in appropriate biological samples.<sup>[9]</sup>

Chelation therapy is administered under very careful medical supervision due to various inherent risks.<sup>[10]</sup> Even when the therapy is administered properly, the chelation drugs can have significant side effects.<sup>[9]</sup> Chelation administered inappropriately can cause neurodevelopmental toxicity, increase risk of developing cancer, and cause death;<sup>[9]</sup> chelation also removes essential metal elements and requires measures to prevent their loss.

### Specific types of poisoning

---

#### Aluminium phosphide poisoning

Aluminium has no known biological role and its classification into toxic metals is controversial.

Acute aluminium phosphide poisoning (AAIPP) is a large, though under-reported, problem in the Indian subcontinent. Aluminium phosphide (ALP), which is readily available as a fumigant for stored cereal grains, sold under various brand names such as QuickPhos and Celphos, is highly toxic, especially when consumed from a freshly opened container.<sup>[11][12]</sup> Death results from profound shock, myocarditis and multi-organ failure.<sup>[13]</sup> Aluminium phosphide has a fatal dose of between 0.15 and 0.5 grams (0.0053 and 0.0176 oz).<sup>[14]</sup> It has been reported to be the most common cause of suicidal death in North India.<sup>[15]</sup> The very high toxicity of aluminium phosphide is attributed to the phosphine content and is not related to aluminium. Calcium phosphide and zinc phosphide are similar poisons.

#### Arsenic poisoning

Arsenic poisoning is a medical condition caused by elevated levels of arsenic in the body. The dominant basis of arsenic poisoning is from ground water that naturally contains high concentrations of arsenic. A 2007 study found that over 137 million people in more than 70 countries are probably affected by arsenic poisoning from drinking water.<sup>[16]</sup>

#### Beryllium poisoning

Beryllium poisoning is illness resulting from the toxic effect of beryllium in its elemental form or in various chemical compounds. The toxicity of beryllium depends upon the duration, intensity and frequency of exposure (features of dose), as well as the form of beryllium and the route of exposure (i.e. inhalation, dermal, ingestion). According to the International Agency for Research on Cancer (IARC), beryllium and beryllium compounds are Category 1 carcinogens; they are carcinogenic to both animals and humans.<sup>[17]</sup>

#### Cadmium poisoning

Cadmium is an extremely toxic metal commonly found in industrial workplaces. Due to its low permissible exposure limit, overexposures may occur even in situations where trace quantities of cadmium are found. Cadmium is used extensively in electroplating, although the nature of the operation does not generally lead to overexposures. Cadmium is also found in some industrial paints and may represent a hazard when sprayed. Operations involving removal of cadmium paints by scraping or blasting may pose a significant hazard. Cadmium is also present in the manufacturing of some types of batteries. Exposures to cadmium are addressed in specific standards for the general industry, shipyard employment, construction industry, and the agricultural industry.<sup>[18]</sup>

#### Copper toxicity

Copper toxicity, also called copperiedus, refers to the consequences of an excess of copper in the body. Copperiedus can occur from eating acidic foods cooked in uncoated copper cookware, or from exposure to excess copper in drinking water, as a side-effect of estrogen birth control pills, or other environmental sources. It can also result from the genetic condition Wilson's disease.

#### Iron poisoning

Iron poisoning is an iron overload caused by a large excess of iron intake and usually refers to an acute overload rather than a gradual one. The term has been primarily associated with young children who consumed large quantities of iron supplement pills, which resemble sweets and are widely used, including by pregnant women—

see overnutrition (approximately 3 grams is lethal for a 2 year old).<sup>[19]</sup> Targeted packaging restrictions in the US for supplement containers with over 250 mg elemental iron have existed since 1978, and recommendations for unit packaging have reduced the several iron poisoning fatalities per year to almost nil since 1998.<sup>[20][21]</sup> No known cases of iron poisoning have been identified that are associated with iron mining.

#### Lead poisoning

Lead poisoning, also called Plumbism is a medical condition in humans and other vertebrates caused by increased levels of the heavy metal lead in the body. Lead interferes with a variety of body processes and is toxic to many organs and tissues including the heart, bones, intestines, kidneys, and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders. Symptoms include abdominal cramping, constipation, tremors, mood changes, infertility, anemia, and toxic psychosis.<sup>[22]</sup>

#### Lithium poisoning

Lithium is used in some medications, specifically to treat bipolar disorder. The level of "sufficient" medication is thought by many physicians to be close to toxic tolerance for kidney function. Therefore, the patient is often monitored for this purpose.<sup>[23][24]</sup>

#### Manganese poisoning, or manganism

Manganism or manganese poisoning is a toxic condition resulting from chronic exposure to manganese and first identified in 1837 by James Couper.<sup>[25]</sup>

#### Mercury poisoning

Mercury poisoning is a disease caused by exposure to mercury or its compounds. Mercury (chemical symbol Hg) is a heavy metal occurring in several forms, all of which can produce toxic effects in high enough doses. Its zero oxidation state  $Hg^0$  exists as vapor or as liquid metal, its mercurous state  $Hg_2^{2+}$  exists as inorganic salts, and its mercuric state  $Hg^{2+}$  may form either inorganic salts or organomercury compounds; the three groups vary in effects. Toxic effects include damage to the brain, kidney, and lungs. Mercury poisoning can result in several diseases, including acrodynia (pink disease), Hunter-Russell syndrome, and Minamata disease.

Symptoms typically include sensory impairment (vision, hearing, speech), disturbed sensation and a lack of coordination. The type and degree of symptoms exhibited depend upon the individual toxin, the dose, and the method and duration of exposure.

## II. DISCUSSION

#### Silver poisoning (Argyria)

Argyria or argyrosis is a condition caused by inappropriate exposure to chemical compounds of the element silver, or to silver dust.<sup>[27]</sup> The most dramatic symptom of argyria is that the skin turns blue or bluish-grey. It may take the form of generalized argyria or local argyria. Generalized argyria affects large areas over much of the visible surface of the body. Local argyria shows in limited regions of the body, such as patches of skin, parts of the mucous membrane or the conjunctiva.<sup>[28]</sup>

#### Thallium poisoning

Thallium and its compounds are often highly toxic.<sup>[29]</sup> Contact with skin is dangerous, and adequate ventilation should be provided when melting this metal.<sup>[30]</sup> Many thallium(I) compounds are highly soluble in water and are readily absorbed through the skin. Exposure to them should not exceed 0.1 mg per m<sup>2</sup> of skin in an 8-hour time-weighted average (40-hour work week). Thallium is a suspected human carcinogen.<sup>[30]</sup>

#### Tin poisoning

Tin poisoning refers to the toxic effects of tin and its compounds. Cases of poisoning from tin metal, its oxides, and its salts are "almost unknown"; on the other hand certain organotin compounds are almost as toxic as cyanide.<sup>[31]</sup>





Zinc toxicity

Even though zinc is an essential requirement for a healthy body, excess zinc can be harmful, and cause zinc toxicity. Such toxicity levels have been seen to occur at ingestion of greater than 225 mg of zinc.<sup>[32]</sup> Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to bacteria, plants, invertebrates, and even vertebrate fish.<sup>[33][34][35]</sup>

Society and culture

It is difficult to differentiate the effects of low level metal poisoning from the environment with other kinds of environmental harms, including nonmetal pollution.<sup>[36]</sup> Generally, increased exposure to heavy metals in the environment increases risk of developing cancer.<sup>[37]</sup>

Without a diagnosis of metal toxicity and outside of evidence-based medicine, but perhaps because of worry about metal toxicity, some people seek chelation therapy to treat autism, cardiovascular disease, Alzheimer's disease, or any sort of neurodegeneration.<sup>[9]</sup> Chelation therapy does not improve outcomes for those diseases.<sup>[9]</sup>

Heavy metals enter plant, animal and human tissues via air inhalation, diet, and manual handling. Motor vehicle emissions are a major source of airborne contaminants including arsenic, cadmium, cobalt, nickel, lead, antimony, vanadium, zinc, platinum, palladium and rhodium.<sup>[20]</sup> Water sources (groundwater, lakes, streams and rivers) can be polluted by heavy metals leaching from industrial and consumer waste; acid rain can exacerbate this process by releasing heavy metals trapped in soils.<sup>[21]</sup> Transport through soil can be facilitated by the presence of preferential flow paths (macropores) and dissolved organic compounds.<sup>[22]</sup> Plants are exposed to heavy metals through the uptake of water; animals eat these plants; ingestion of plant- and animal-based foods are the largest sources of heavy metals in humans.<sup>[23]</sup> Absorption through skin contact, for example from contact with soil, or metal containing toys and jewelry,<sup>[24]</sup> is another potential source of heavy metal contamination.<sup>[25]</sup> Toxic heavy metals can bioaccumulate in organisms as they are hard to metabolize.<sup>[26]</sup>

III. RESULTS

Heavy metals "can bind to vital cellular components, such as structural proteins, enzymes, and nucleic acids, and interfere with their functioning".<sup>[27]</sup> Symptoms and effects can vary according to the metal or metal compound, and the dose involved. Broadly, long-term exposure to toxic heavy metals can have carcinogenic, central and peripheral nervous system, and circulatory effects. For humans, typical presentations associated with exposure to any of the "classical"<sup>[28]</sup> toxic heavy metals, or chromium (another toxic heavy metal) or arsenic (a metalloid), are shown in the table.<sup>[29]</sup>

Element	Acute exposure usually a day or less	Chronic exposure often months or years
Cadmium	Pneumonitis (lung inflammation)	Lung cancer Osteomalacia (softening of bones) Proteinuria (excess protein in urine; possible kidney damage)
Mercury	Diarrhea Fever Vomiting	Stomatitis (inflammation of gums and mouth) Nausea Nephrotic syndrome (nonspecific kidney disorder) Neurasthenia (neurotic disorder) Parageusia (metallic taste) Pink Disease (pain and pink discoloration of hands and feet) Tremor
Lead	Encephalopathy (brain dysfunction) Nausea Vomiting	Anemia Encephalopathy Foot drop/wrist drop (palsy) Nephropathy (kidney disease)
Chromium	Gastrointestinal hemorrhage (bleeding) Hemolysis (red blood cell destruction)	Pulmonary fibrosis (lung scarring) Lung cancer



	Acute renal failure	
Arsenic	Nausea Vomiting Diarrhea Encephalopathy Multi-organ effects Arrhythmia Painful neuropathy	Diabetes Hypopigmentation/Hyperkeratosis Cancer

### History

The toxic effects of arsenic, mercury and lead were known to the ancients but methodical studies of the overall toxicity of heavy metals appear to date from only 1868. In that year, Wanklyn and Chapman speculated on the adverse effects of the heavy metals "arsenic, lead, copper, zinc, iron and manganese" in drinking water. They noted an "absence of investigation" and were reduced to "the necessity of pleading for the collection of data".<sup>[30]</sup> In 1884, Blake described an apparent connection between toxicity and the atomic weight of an element.<sup>[31]</sup> The following sections provide historical thumbnails for the "classical" toxic heavy metals (arsenic, mercury and lead) and some more recent examples (chromium and cadmium).

#### Arsenic

Arsenic, as realgar (As<sub>4</sub>S<sub>4</sub>) and orpiment (As<sub>2</sub>S<sub>3</sub>), was known in ancient times. Strabo (64–50 BCE – c. AD 24?), a Greek geographer and historian,<sup>[32]</sup> wrote that only slaves were employed in realgar and orpiment mines since they would inevitably die from the toxic effects of the fumes given off from the ores. Arsenic-contaminated beer poisoned over 6,000 people in the Manchester area of England in 1900, and is thought to have killed at least 70 victims.<sup>[33]</sup> Clare Luce, American ambassador to Italy from 1953 to 1956, suffered from arsenic poisoning. Its source was traced to flaking arsenic-laden paint on the ceiling of her bedroom. She may also have eaten food contaminated by arsenic in flaking ceiling paint in the embassy dining room.<sup>[34]</sup> Ground water contaminated by arsenic, as of 2014, "is still poisoning millions of people in Asia".<sup>[35]</sup>

#### Mercury

The first emperor of unified China, Qin Shi Huang, it is reported, died of ingesting mercury pills that were intended to give him eternal life.<sup>[36]</sup> The phrase "mad as a hatter" is likely a reference to mercury poisoning among milliners (so-called "mad hatter disease"), as mercury-based compounds were once used in the manufacture of felt hats in the 18th and 19th century.<sup>[37]</sup> Historically, gold amalgam (an alloy with mercury) was widely used in gilding, leading to numerous casualties among the workers. It is estimated that during the construction of Saint Isaac's Cathedral alone, 60 workers died from the gilding of the main dome.<sup>[38]</sup> Outbreaks of methylmercury poisoning occurred in several places in Japan during the 1950s due to industrial discharges of mercury into rivers and coastal waters. The best-known instances were in Minamata and Niigata. In Minamata alone, more than 600 people died due to what became known as Minamata disease. More than 21,000 people filed claims with the Japanese government, of which almost 3000 became certified as having the disease. In 22 documented cases, pregnant women who consumed contaminated fish showed mild or no symptoms but gave birth to infants with severe developmental disabilities.<sup>[39]</sup> Since the Industrial Revolution, mercury levels have tripled in many near-surface seawaters, especially around Iceland and Antarctica.<sup>[40]</sup>

#### Lead

The adverse effects of lead were known to the ancients. In the 2nd century BC the Greek botanist Nicander described the colic and paralysis seen in lead-poisoned people.<sup>[41]</sup> Dioscorides, a Greek physician who is thought to have lived in the 1st century CE,<sup>[42]</sup> wrote that lead "makes the mind give way". Lead was used extensively in Roman aqueducts from about 500 BC to 300 AD.<sup>[43]</sup> Julius Caesar's engineer, Vitruvius, reported, "water is much more wholesome from earthenware pipes than from lead pipes. For it seems to be made injurious by lead, because white lead is produced by it, and this is said to be harmful to the human body."<sup>[44]</sup> During the Mongol period in China (1271–1368 AD), lead pollution due to silver smelting in the Yunnan region exceeded contamination levels from modern mining activities by nearly four times.<sup>[45][n 1]</sup> In the 17th and 18th centuries, people in Devon were afflicted by a condition referred to as Devon colic; this was discovered to be due to the imbibing of lead-contaminated cider. In 2013, the World Health Organization estimated that lead poisoning resulted in 143,000 deaths, and "contribute[d] to 600,000

new cases of children with intellectual disabilities", each year.<sup>[47]</sup> In the U.S. city of Flint, Michigan, lead contamination in drinking water has been an issue since 2014. The source of the contamination has been attributed to "corrosion in the lead and iron pipes that distribute water to city residents".<sup>[48]</sup> In 2015, the lead concentration of drinking water in north-eastern Tasmania, Australia, reached a level over 50 times the prescribed national drinking water guidelines. The source of the contamination was attributed to "a combination of dilapidated drinking water infrastructure, including lead jointed pipelines, end-of-life polyvinyl chloride pipes and household plumbing".<sup>[49]</sup>

#### Chromium

Chromium(III) compounds and chromium metal are not considered a health hazard, while the toxicity and carcinogenic properties of chromium(VI) have been known since at least the late 19th century.<sup>[50]</sup> In 1890, Newman described the elevated cancer risk of workers in a chromate dye company.<sup>[51]</sup> Chromate-induced dermatitis was reported in aircraft workers during World War II.<sup>[52]</sup> In 1963, an outbreak of dermatitis, ranging from erythema to exudative eczema, occurred amongst 60 automobile factory workers in England. The workers had been wet-sanding chromate-based primer paint that had been applied to car bodies.<sup>[53]</sup> In Australia, chromium was released from the Newcastle Orica explosives plant on August 8, 2011. Up to 20 workers at the plant were exposed as were 70 nearby homes in Stockton. The town was only notified three days after the release and the accident sparked a major public controversy, with Orica criticised for playing down the extent and possible risks of the leak, and the state Government attacked for their slow response to the incident.<sup>[54]</sup>

#### Cadmium

Cadmium exposure is a phenomenon of the early 20th century, and onwards. In Japan in 1910, the Mitsui Mining & Smelting Company began discharging cadmium into the Jinzū River, as a byproduct of mining operations. Residents in the surrounding area subsequently consumed rice grown in cadmium-contaminated irrigation water. They experienced softening of the bones and kidney failure. The origin of these symptoms was not clear; possibilities raised at the time included "a regional or bacterial disease or lead poisoning".<sup>[55]</sup> In 1955, cadmium was identified as the likely cause and in 1961 the source was directly linked to mining operations in the area.<sup>[56]</sup> In February 2010, cadmium was found in Walmart exclusive Miley Cyrus jewelry. Wal-Mart continued to sell the jewelry until May, when covert testing organised by Associated Press confirmed the original results.<sup>[57]</sup> In June 2010 cadmium was detected in the paint used on promotional drinking glasses for the movie *Shrek Forever After*, sold by McDonald's Restaurants, triggering a recall of 12 million glasses.<sup>[58]</sup>

### IV. CONCLUSIONS

In humans, heavy metal poisoning is generally treated by the administration of chelating agents.<sup>[60]</sup> These are chemical compounds, such as  $\text{CaNa}_2\text{EDTA}$  (calcium disodium ethylenediaminetetraacetate) that convert heavy metals to chemically inert forms that can be excreted without further interaction with the body. Chelates are not without side effects and can also remove beneficial metals from the body. Vitamin and mineral supplements are sometimes co-administered for this reason.<sup>[61]</sup>

Soils contaminated by heavy metals can be remediated by one or more of the following technologies: isolation; immobilization; toxicity reduction; physical separation; or extraction. Isolation involves the use of caps, membranes or below-ground barriers in an attempt to quarantine the contaminated soil. Immobilization aims to alter the properties of the soil so as to hinder the mobility of the heavy contaminants. Toxicity reduction attempts to oxidise or reduce the toxic heavy metal ions, via chemical or biological means into less toxic or mobile forms. Physical separation involves the removal of the contaminated soil and the separation of the metal contaminants by mechanical means. Extraction is an on or off-site process that uses chemicals, high-temperature volatilization, or electrolysis to extract contaminants from soils. The process or processes used will vary according to contaminant and the characteristics of the site.<sup>[62]</sup>

Some elements otherwise regarded as toxic heavy metals are essential, in small quantities, for human health. These elements include vanadium, manganese, iron, cobalt, copper, zinc, selenium, strontium and molybdenum.<sup>[63]</sup> A deficiency of these essential metals may increase susceptibility to heavy metal poisoning.<sup>[64]</sup>

### REFERENCES

1. Dewan 2008
2. ^ Dewan 2009
3. ^ Poovey 2001

4. ^ Zhang, Hongling; Walker, Tony R.; Davis, Emily; Ma, Guofeng (September 2019). "Ecological risk assessment of metals in small craft harbour sediments in Nova Scotia, Canada". *Marine Pollution Bulletin*. 146: 466–475. doi:10.1016/j.marpolbul.2019.06.068. PMID 31426182. S2CID 201095843.
5. ^ Srivastava & Goyal 2010, p. 2
6. ^ Brathwaite & Rabone 1985, p. 363
7. ^ "10 chemicals of public health concern". [www.who.int](http://www.who.int). Retrieved 2020-10-09.
8. ^ Wright 2002, p. 288
9. ^ Qureshi, Shabnam; Richards, Brian K.; McBride, Murray B.; Baveye, Philippe; Steenhuis, Tammo S. (2003). "Temperature and Microbial Activity Effects on Trace Element Leaching from Metalliferous Peats". *Journal of Environmental Quality*. 32 (6): 2067–75. doi:10.2134/jeq2003.2067. PMID 14674528.
10. ^ "Fear In The Fields -- How Hazardous Wastes Become Fertilizer -- Spreading Heavy Metals On Farmland Is Perfectly Legal, But Little Research Has Been Done To Find Out Whether It's Safe".
11. ^ <https://hazwastehelp.org/ArtHazards/glassworking.aspx> Art Hazards
12. ^ Harvey, Handley & Taylor 2015
13. ^ Howell et al. 2012; Cole et al. 2011, pp. 2589–2590
14. ^ Finch, Hillyer & Leopold 2015, pp. 849–850
15. ^ Aggrawal 2014, p. 680
16. ^ Di Maio 2001, p. 527
17. ^ Lovei 1998, p. 15
18. ^ Perry & Vanderklein 1996, p. 336
19. ^ Houlton 2014, p. 50
20. ^ Balasubramanian, He & Wang 2009, p. 476
21. ^ Worsztynowicz & Mill 1995, p. 361
22. ^ Camobreco, Vincent J.; Richards, Brian K.; Steenhuis, Tammo S.; Peverly, John H.; McBride, Murray B. (November 1996). "Movement of heavy metals through undisturbed and homogenized soil columns". *Soil Science*. 161 (11): 740–750. Bibcode:1996SoilS.161..740C. doi:10.1097/00010694-199611000-00003.
23. ^ Radojevic & Bashkin 1999, p. 406
24. ^ Guney, Mert; Zagury, Gerald J. (4 January 2014). "Bioaccessibility of As, Cd, Cu, Ni, Pb, and Sb in Toys and Low-Cost Jewelry". *Environmental Science & Technology*. 48 (2): 1238–1246. Bibcode:2014EnST...48.1238G. doi:10.1021/es4036122. PMID 24345102.
25. ^ Qu et al. 2014, p. 144
26. ^ Pezzarossa, Gorini & Petruzelli 2011, p. 94
27. ^ Lanids, Sofield & Yu 2000, p. 269
28. ^ Neilen & Marvin 2008, p. 10
29. ^ Afal & Wiener 2014
30. ^ Wanklyn & Chapman 1868, pp. 73–8; Cameron 1871, p. 484
31. ^ Blake 1884
32. ^ Dueck 2000, pp. 1–3, 46, 53
33. ^ Dyer 2009
34. ^ Whorton 2011, p. 356
35. ^ Notman 2014
36. ^ Zhao, Zhu & Sui 2006
37. ^ Waldron 1983
38. ^ Emsely 2011, p. 326
39. ^ Davidson, Myers & Weiss 2004, p. 1025
40. ^ *New Scientist* August 2014, p. 4
41. ^ Pearce 2007; Needleman 2004
42. ^ Rogers 2000, p. 41
43. ^ Gilbert & Weiss 2006
44. ^ Prioreshi 1998, p. 279
45. ^ Hillman et al. 2015, pp. 3353–3354
46. ^ Hillman et al. 2015, p. 3349





47. ^ World Health Organization 2013
48. ^ Torrice 2016
49. ^ Harvey, Handley & Taylor 2015
50. ^ Barceloux & Barceloux 1999
51. ^ Newman 1890
52. ^ Haines & Nieboer 1988, p. 504
53. ^ National Research Council 1974, p. 68
54. ^ Tovey 2011; Jones 2011; O'Brien & Aston
55. ^ Vallero & Letcher 2013, p. 240
56. ^ Vallero & Letcher 2013, pp. 239–241
57. ^ Pritchard 2010
58. ^ Mulvihill & Pritchard 2010
59. ^ Cs uros 1997, p. 124
60. ^ Blann & Ahmed 2014, p. 465
61. ^ American Cancer Society 2008; National Capital Poison Center 2010
62. ^ Evanko & Dzombak 1997, pp. 1, 14–40
63. ^ Bánfalvi 2011, p. 12
64. ^ Chowdhury 1987



**INNO**  **SPACE**  
SJIF Scientific Journal Impact Factor

**Impact Factor:  
7.512**

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
**INDIA**



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details