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Sources, blood concentrations, and approaches for reducing exposure to lead: A critical appraisal on lead poisoning

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ABSTRACT

Lead, a non-essential metal, enters the body in various ways, making it a major public health issue. Painters and smelters report lead poisoning in children and staff. Mining and battery workers risk lead exposure. Traditional and cultural remedies may include dangerous quantities of lead, producing lead poisoning. These drugs must be properly understood and regulated to avoid toxicity. Lead poisoning symptoms vary by duration and severity. Lead first impairs cognition, development, and behaviour by damaging the neural system. Time degrades reproductive and haematological systems. Lead's quiet entry into the body makes it deadly. Acute lead nephropathy damages kidneys at 100mg/dL. Lead levels exceeding 150mg/dL may induce encephalopathy. Blood lead levels indicate lead poisoning severity. Lead levels over 10g/dL in children and 40g/dL in adults are hazardous. Lead toxicity affects various organs. Lead may induce hypertension and cardiovascular disease. It may also cause chronic kidney disease and renal failure. Lead exposure may impede fertility, cause miscarriages, and alter foetal development; hence the reproductive system is vulnerable. Symptoms and lead levels may be treated with different approaches. Lead chelation treatment is frequent. Other vitamins and medications may enhance

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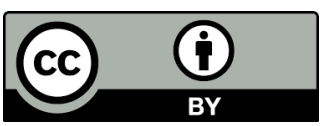

organ function and treat lead poisoning. Lead poisoning prevention requires widespread awareness. Strict standards and education regarding lead-contaminated products and conventional remedies should reduce occupational lead exposure. Regular blood lead level monitoring, especially in youngsters and lead workers, may help detect and treat lead poisoning early. Lead poisoning has serious health consequences. Understanding lead exposure pathways, identifying symptoms, and preventing lead poisoning is essential to public health and organ system protection.

1 Introduction

Lead, an abundant environmental metalthe most common industrial hazard, with a lengthy history reaching 360 B Lead reference levels in different media serve as critical benchmarks: blood lead levels should be less than 2 micrograms per decilitre, ambient air levels should be less than 1.5 to 3 micrograms per cubic metre, and paint levels should be less than 90 parts per million. The occurrence of increased lead levels in various mediums necessitates rapid medical treatment. Traditional treatments have been linked to many recorded instances of lead poisoning in India (Kute et al. 2013).

A source of lead found potentially everywhere is tap water, typically secondary to the presence of this metal in plumbing. In several nations where gasoline (leaded) is available, air contaminated with lead from emissions is a vital exposure source (Whitehead and Buchanan 2019; Halmo and Nappe 2023). Adults may be exposed to lead through a wide range of occupations and hobbies. The working parents may bring home lead where the children are exposed second-hand. The occupations and hobbies involving the highest risk include welding metal, manufacturing of battery, use of lead in firing range or instruction and bullet salvaging, smelting as well as refining lead, use of lead in construction work or painting, plumbing and fitting pipe, building ship and shipbreaking etc. Several other exposures that are less ubiquitous have been implicated in adults as well as children with the heightened concentrations of lead that, include ceramic dining ware (contaminated), spices as well as cosmetics imported, and ingestion of foreign bodies made up of lead and retained bullets that are led (Quail 2018; Egan et al. 2019; Halmo and Nappe 2023).

Lead poisoning has a wide-ranging effect on the body, impacting several systems. The central nervous system is the primary target, followed by the haematological, hepatic, and renal systems. This harms both systolic and diastolic blood pressure, as well as abnormalities in cellular processes and enzyme systems, culminating in severe diseases (Figure 1).

While acute lead poisoning is rare, chronic lead toxicity is prevalent, with blood lead levels commonly ranging between 40 and 60 micrograms per decilitre (Srinivasan et al. 2016; Estévez-García et al. 2022). Chronic vomiting, narcosis, dementia, seizures, and coma are all symptoms of lead poisoning. Apart from all these, due to lead toxicity, the nerve conduction may be slow, mood may swing, and there may be drowsiness and fatigue along with impairment of concentration. There also may be fertility disorders, reduced libido and constipation, and if the condition is severe, there may be encephalopathy. The illness may quickly develop and become deadly if not treated promptly (Nedelescu et al. 2022). Notably, the neurological system takes the brunt of lead's damage, with excessive lead deposition harming both the peripheral and central nervous systems.

Lead also directly affects the haematological system, interfering with haemoglobin formation by inhibiting important enzymes involved in the heme synthesis pathway, a vital stage in the process (Dsouza et al. 2022). Furthermore, lead weakens cell membranes, reducing the lifetime of circulating erythrocytes. Renal failure, including acute or chronic nephropathy, occurs when lead levels are above 60 micrograms per decilitre, adding to the previously described vascular and cardiac damage (Mabrouk 2021). Hypertension may develop even at low levels of lead exposure, providing a considerable health concern (Gajewska et al. 2021; Ramírez Ortega et al. 2021). This review emphasizes lead exposure sources, blood concentrations, and prevention techniques. Lead exposure may occur via lead-based paint, fuel, soil, and dust. Examining lead exposure and BLLs helps investigate primary, secondary, and tertiary lead prevention techniques. Lead is a potent neurotoxin that, particularly in children, may cause cognitive and behavioural difficulties, delayed growth and development, and an increased risk of cardiovascular disease and cancer. Notably, priority should be given to protecting children from pollution caused by heavy metals like lead (Hou et al. 2019). Because lead is a severe public health risk, the review study strongly urges reducing lead exposure, particularly in children. Lead exposure may have substantial and long-term effects on children's health and development, making it vital to prioritize prevention measures. This review also highlighted that reducing lead exposure should be a public health priority and offers preventative options.

Anxieties about lead poisoning have been rising as of late because of the difficulty in diagnosing asymptomatic lead toxicity caused by prolonged exposure to low amounts of the metal. Appropriate investment in suitable environmental, nutritional, and medical resources is required to prevent and effectively cure lead

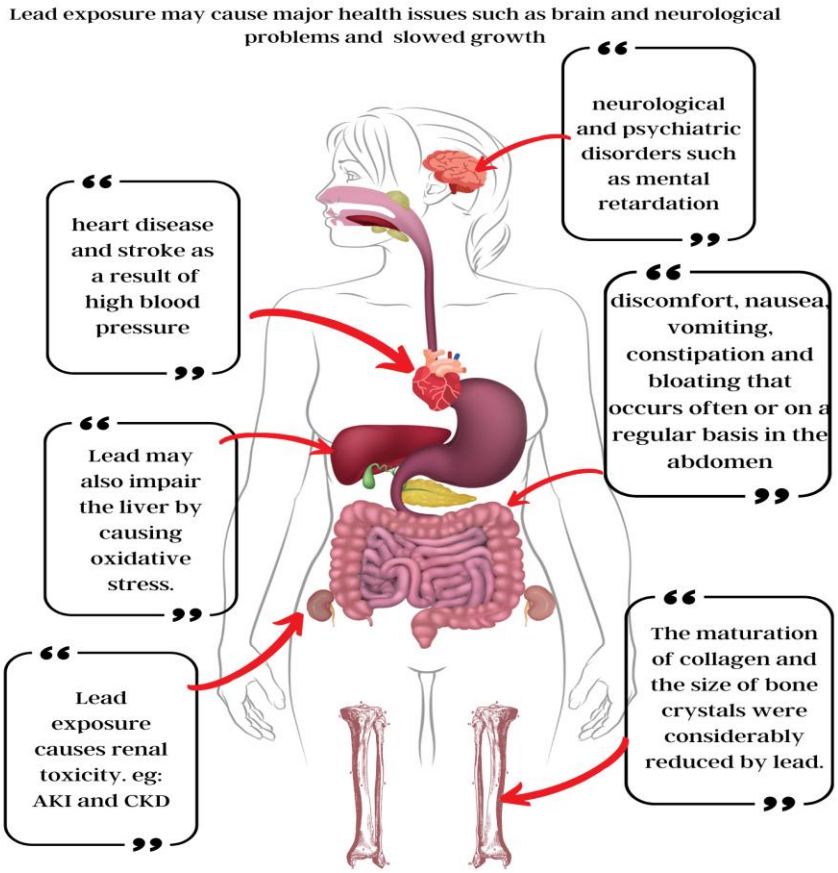

Figure 1 Illustrative scheme of lead exposure effect in various parts of the body

poisoning. Therefore, it is important to know where the lead came from to recognize the signs of lead poisoning in patients of varied ages and blood lead concentrations (Cantor et al. 2019; Lakka et al. 2023; Niu et al. 2023). The data provided by case reports is invaluable. Unfortunately, as far as we can tell, there aren't many reviews of lead poisoning case reports in the literature. An exhaustive literature review can shed light on the causes of lead poisoning that are currently unknown. It can help bring to light typical symptoms and realistic treatment options. In light of this, the current research reviewed published accounts of lead poisonings over the past decade, compiling data on exposure routes, symptoms, treatments, and preventative measures.

2 Lead exposure through Ayurvedic preparations

Ayurveda, an ancient Indian medical system, has received international acclaim for its holistic approach to treatment. Herbal medications, powders, and nutritional supplements are popular Ayurvedic formulations that enhance health and well-being (Gerritsen and Cleetus 2023). Concerns have been raised, however, about the presence of lead in several Ayurvedic medicines. Even though over 95 per cent of the exposure to lead is occupational, a potent source of lead poisoning is Ayurvedic medicine, which is responsible for 2 per cent of the non-occupational exposures (Yanamandra et al. 2020). This article aims to shed light on the subject by investigating the causes of lead pollution, possible health hazards, regulatory measures, and techniques to reduce exposure.

Several recent case reports of lead poisoning have been linked to using Ayurvedic supplements. A 58-year-old woman presented to the emergency room complaining of abdominal pain, anaemia, abnormal liver function tests, and elevated blood lead levels. For almost 6 weeks, the patient had been trying to control her diabetes with the help of Jambrulin, an Ayurvedic medicine. The chemical examination of the drug found dangerously high levels of lead. The patient's symptoms improved after she had chelation therapy. However, she developed chronic renal illness as a result of lead exposure. The risks of lead poisoning through Ayurvedic treatments are highlighted in this case study. We should know about the risks of lead poisoning before trying any Ayurvedic therapy (Ciocan et al. 2021).

Karri et al. (2008) documented a 41-year-old man with hypertension who had memory loss, atrophy, and anhedonia. Except for Mahayogaraj-guggul, he was drug-free. He drank this

for almost 6 months since it is an ayurvedic drug that helps lower blood pressure. His examination revealed clinical indications of memory loss, significant disorientation, limb weakness with bilateral hypertonic and hyper reflexion, upgoing plantares, and spastic gait. His blood lead level was 161 µg/dL. The parasagittal occipital lobes had anaemia with basophilic stippling, bilateral focal hyperintensity, and similar lesions in the temporal, parietal, and frontal regions. His medical condition was chronic lead encephalopathy. The chelation therapy was administered in combination with stopping his Ayurvedic drug. This helped the client's clinical rehabilitation.

Similarly, these researchers reported a 9-month-old kid dying from lead encephalopathy convulsions after using Ghasard. Ghasard is a kind of traditional medicine. This medicine is provided to prevent constipation in neonates. His parents began supplementing his diet with conventional treatments when he was two months old. After eight months, the baby got drowsy and stopped moving. He also refused bottle feeding, had seizures, and died at nine months old. He started to suffocate and died two days later. The autopsy indicated that the victim had elevated lead amounts in his blood and other tissues. Lead lines were seen on long bone radiographs. All medications given to the youngster contained lead. Ghasard had the most lead by weight, at 1.6% (Karri et al. 2008).

Karri et al. (2008) described a 62-year-old man with arthritis and signs of status epilepticus with lead poisoning. He has been taking Mahayogaraj – guggul for over six years. It is an Ayurvedic drug used to treat arthritis. He wasn't on any other prescription drugs, and he wasn't working with lead. His blood lead level was found to be 89 ng/dL while being monitored for clinical indicators such as anaemia and status epilepticus. His diagnosis was acute and persistent lead encephalopathy. Many chelation procedures and chronic anti-convulsant medication were employed in this case to address the disease. It also caused anoxic brain damage from status epilepticus oppositely (Karri et al. 2008).

Geraldine and Venkatesh (2007) reported a 27-year-old Indian woman who resided in a non-polluted area of Bangalore and was diagnosed with HIV. She'd been utilizing herbal remedies for 13 weeks and complained of stomach aches, nausea, sleeplessness, giddiness, and constipation at the local hospital. IBS and mild hepatomegaly were diagnosed. Further, endoscopic testing confirmed antral gastritis. Her lead toxicity was examined at their facility. Her menstruation history and her husband's sperm count were within normal norms, yet she could not conceive for five years. She's been in the hospital since she refused to participate in follicular research and was advised to do an alternative medicine course. For a year, she was given three unbranded herbal treatments consisting of two types of brown powder and one kind of black pill, all provided randomly. In her interview, she disclosed that she began to experience moderate lead poisoning five weeks into this medicinal therapy. Their institution did a blood test for lead poisoning containing lead and zinc protoporphyrin. The lead levels in the blood and the three herbal drugs were tested using a portable X-ray fluorescence analyzer. She took one teaspoon of each brown powder, two black tablets, and one teaspoon of each white powder once daily.

As a consequence, herbal medications were shown to cause this lead poisoning. After a month of therapy with D-penicillamine (25–35 mg/kg body weight/day), her blood lead and ZPP levels were dramatically decreased, suggesting that she had received successful treatment. The patient's clinical indications indicated lead toxicity; blood lead levels were tested to confirm lead poisoning. As a result of lead poisoning, the haematological and hepatic systems were affected(Geraldine and Venkatesh 2007).

A 45-year-old software expert was poisoned by lead at work, according to Raviraja et al. (2010). He was sent to a Bangalore hospital twice in 10 days due to weakness, vomiting, and stomach pain. Both times the treatment failed to help him. So far, he had used twelve different Ayurvedic remedies, all of which were natural. These were used to relieve stress and maintain health. He bought all drugs without an Ayurvedic physician's prescription. His blood pressure was 120/84 mm Hg, his haemoglobin was 14.2 g/dl, and his BLL was 122.4 g/dl, all indicating lead poisoning. He was also chelated with 250 mg D-penicillamine three times a day for two months, following which he was instructed to discontinue using all ayurvedic drugs. Prescribed were calcium pills, B-complex tablets, and plenty of water. After chelation, two months of medication effectively relieves stomach pain. A year later, his blood lead level was 27.4 ng/dl, and he was no longer in pain. When all twelve ayurvedic products were tested, 75% had lead, arsenic, and mercury levels, several orders of magnitude greater than the daily permissible limits (Raviraja et al. 2010). These researchers also documented a 36-year-old male wing commander from Bangalore, India, who had been diagnosed with lead poisoning. He was admitted to the Air Force Command Hospital in Bangalore due to stomach ache, headache, insomnia, weakness, facial pallor, and joint pain. The study revealed a haemoglobin level of 8 g/dl and significant internal bleeding. The patient had an endoscopy, colonoscopy, and barium meal to establish the origin of internal bleeding. He said he went to a vaidya in Pune, Maharashtra, for psoriasis, a skin condition that affects the hands and feet. According to the local vaidya, Gulkand (Mukta Bhasma, Sapta Ratna, Kumar Kalyan ratna, and Sal Bhaskar ratna) is an efficient arthritic cure. He had to take 2 tablespoons of Gulkand for two months before breakfast and dinner. On examination, the peripheral blood picture exhibited basophilic stippling, suggesting a basophilic stippling infection. Doctors suspected lead poisoning and sent the case to the NRCLPI for a blood lead test, which came

back at 115 ng/dl. He was advised to cease taking Gulkand. After chelation therapy with 2 g calcium disodium EDTA in 500 mL saline, the patient's liver and kidney functions and blood calcium and phosphorus levels returned to normal. He had no known risk factors for lead poisoning at the time. The lead content of Gulkand was 11,798 g/g(Raviraja et al. 2010).

Raut et al. (2021) described dual cases of lead encephalopathy because of the intake of ayurvedic medication for a long time. The first case was a female aged 54 years who was taking long-term medication and presented with a confusional state (acute) and disturbances of memory with pain in the abdomen. Magnetic resonance imaging (MRI) of the brain revealed symmetric basal ganglia, signal changes in the cortex, and edema. The presence of lead was in the blood at an elevated level significantly. The second case was a female aged 45 years taking ayurvedic medicine for high blood pressure. She presented with headaches and deterioration in the sensorium rapidly, leading to coma and death. MRI of the brain revealed cerebral edema (diffused), signal changes in basal ganglia and elevated blood level of lead. These two cases have highlighted the requirement for heightened awareness that certain medicines (Ayurvedic) may contain lead potentially at a harmful level, and people using them have the risk of developing toxicity associated with fatality.

Roy et al. (2022) and Jain and Roy (2022) have documented an incidence of toxicity induced by lead in a child suffering from type 1 diabetes mellitus due to *naga Bhasma* (Jain and Roy 2022; Roy et al. 2022). Now it is required to be told in this context that scientific studies reveal that during *naga bhasma* preparation quenching, trichuration along with calcinations of the crude lead is repeatedly done, thereby transforming it into the least toxic lead sulphide, which is nanocrystals. Other organic contents and various nutrient elements that come from the herbs are also used to prepare *naga bhasma*. The shortcomings in preparing *naga bhasma* and its use in an injudicious manner are alarming and may be responsible for the lead toxicity in the child suffering from type 1 diabetes mellitus (Varghese et al. 2022).

3 Lead exposure at the workplace

Lead is a dangerous metal that may cause many health issues, including learning and behavioural issues, lower IQ, and even death. Further exposure to lead may be associated negatively with weight at birth. Lead exposure may occur via many routes, including inhaling lead dust, consuming lead-contaminated food or drink, or exposure to lead-based paint (Dettwiler et al. 2023; Ramadan et al. 2023).

In their research, Ghanwat et al. (2016) evaluated 36 male employees aged 20 to 60 from lead battery plants in Western Maharashtra. The researchers gathered demographic, occupational, and clinical data from healthy male volunteers who did not drink or smoke. Paraesthesia, intermittent stomach discomfort, lack of appetite, nausea, diarrhoea, and constipation were among the symptoms encountered by these employees (Ghanwat et al. 2016). According to the research, the interaction between lead-oxyhaemoglobin and oxygen-free radicals in red blood cells resulted in the production of reactive oxygen species in the circulation. The copper deficit induced by high blood lead levels resulted in increased oxidative damage to red blood cells and reduced superoxide dismutase function (Gwozdzinski et al. 2021). Furthermore, the research discovered that lead exposure impeded heme synthesis and iron absorption enzymes, resulting in a lower heme pool and catalase activity. The researchers used vitamin C supplementation for one month to reduce blood lead levels (Sanders et al. 2009). Although the supplementation reduced lipid peroxidation and nitrite levels, the impact was insignificant. However, antioxidant status markers such as erythrocyte superoxide dismutase and catalase levels increase (Kurutas 2016).

Awasthi et al. (1996) tested pregnant women from Lucknow slums to discover whether lead might be passed to the foetus during pregnancy. The researchers separated 500 pregnant women from 70 slums into four groups depending on gestational age. Personal interviews were done to gather information about age, reproductive history, menstrual cycle, and other possible sources of lead exposure (Awasthi et al. 1996). The researchers determined that 26 women had blood lead levels of more than 20 micrograms per deciliter, averaging 35 micrograms per deciliter. Age, weight, height, haemoglobin levels, or reproductive history did not affect lead exposure (Fadrowski et al. 2010). However, the research found that lead exposure in pregnant women caused nutritional deficiencies and raised the likelihood of infant developmental disorders, particularly when associated with poor nutrition, infectious illnesses, and other poverty-related concerns (Awasthi et al. 1996). Kute et al. (2013) published a case study of a guy who used Sindoor, a traditional cosmetic containing lead, for religious motives. Severe stomach colic, constipation, nausea, vomiting, and other symptoms plagued the 44-year-old guy. A bluish-grey thin line at the gingival tooth edge and lead nephropathy were discovered during the testing. Lead exposure was connected to proximal tubular damage, interstitial nephritis, and chronic kidney disease, all impacting tubular function and vascular reactivity(Al-Naimi et al. 2019). Chelation therapy was part of the patient's treatment (Kute et al. 2013).

Palaniappan et al. (2011) investigated blood lead levels and their consequences in children aged three to seven attending schools in the Chennai area of India. The research was divided into four zones with differing levels of industry and traffic. All 76 youngsters tested positive for blood lead levels over the national average, with half surpassing 10 micrograms per deciliter. The research discovered that higher blood lead levels affected these children's IQ and general cognitive development (Palaniappan et

al. 2011). Menezes et al. (2003) described a case study of a 10-year-old child labourer who had joint and epigastric discomfort while working in a battery recycling factory. The youngster has been exposed to lead for a long time owing to poor industrial safety practices. The investigation uncovered the consequences of persistent lead exposure (Menezes et al. 2003).

A total of 107 children from three schools in Mangalore and Dakshin Kannada were tested for lead poisoning by Kuruvilla et al. (2004). The X-ray Fluorescence Analyzer was used to determine the amount of lead in the soil of the schools, playgrounds, and households. They found that 11 of the 107 children, mostly from low-income schools, had 40 g/dl or higher blood lead levels. The assessment found lead spray on the tulsikatte (holy basil platform), peeling paint on playground equipment, yellow paint on the railing of a rice mill, and paint and traditional treatments used in homes(Kuruvilla et al. 2004). Thirty automotive workers in Bijapur were found by Dongre et al. (2011) to have significantly higher lead levels in their blood and urine compared to a control group. The study participants who worked in the automotive industry reported experiencing muscle pain, fatigue, irritation, and decreased haemoglobin and red blood cell counts after prolonged exposure to lead (Dongre et al. 2011). The effects of lead exposure on the health of people who work in the printing industry were the subject of a case study by Ji et al. (2014). Symptoms, including convulsions, diarrhoea, anaemia, colic, nephritic discomfort, and leg pain, were linked to prolonged exposure to lead dust in printing presses. The research highlighted the significance of dust management technologies and the need of fostering appropriate hygiene practises in these settings (Ji et al. 2014). Workers in Calcutta, electrical accumulator firms, were exposed to greater levels of lead due to inadequate protective gear and poor sanitary practices, according to a study by Ghosh et al. (1952). The study highlighted the importance of modern tools, exhaust ventilation, and efficient safety measures in reducing the risks of lead poisoning in the workplace. Goswami (2013)'s study has also linked using Surma, an ore powder, as an eyeliner to an increased risk of lead poisoning in children. The research highlighted that lead may enter the body via many channels, including the eyes and mouth, and identified improper Surma preparation as a critical component in lead poisoning. These studies highlight the need of identifying and controlling lead exposure sources to maintain public health (Goswami 2013).

A major concern for professionals who provide training or work with firearms regularly is exposure to lead. Such professionals include military personnel or people from law enforcement departments. In the study conducted by Schenk et al. (2021) on the military personnel of the Swedish armed forces, it was found that the instructors have more chances of airborne exposure to lead compared to the cadets while training with ammunitions that are led (Schenk et al. 2021). Those instructors who closely supervise the training programme with leaded ammunitions have increased blood lead level (BLL) geometric mean (GM) compared to other instructors. Widyantoro et al. (2021) found that the pipe repair place could expose people to heavy metals like lead exceeding the quality standards (Widyantoro et al. 2021).

4 Lead poisoning and counteracting measures for reducing exposure to lead – critical discussion

Lead, a soft, silvery grey metal, has unique properties that make it essential in various sectors. However, in addition to its positive features, lead seriously threatens human health and the environment (Iqbal et al. 2023). Lead's contradictory nature raises severe concerns about its ubiquitous usage and the possible risks related to its presence in daily things. We will examine the dual nature of lead in this creative debate, emphasizing its numerous uses and the hazards it presents in various circumstances (Cedergreen and Streibig 2005).

Lead's properties, such as corrosion resistance, high density, and low melting point, have made it a sought-after commodity in various sectors. Lead acid batteries, commonly employed in automotive applications, depend on effective electrical energy storage and conversion (Charkiewicz and Backstrand 2020). The jewellery industry favours lead for its malleability, which allows for creating elaborate patterns. Lead's durability and tolerance to the severe maritime environment make it a perfect option for various uses in shipbuilding. Its usage in petrol additives also improves engine performance (Tandon et al. 2001).

While lead has valuable industrial characteristics, its toxicity concerns human health. Lead-based paint, lead-soldered pipes, and polluted air and soil are frequent causes of lead pollution that may harm many organs (Mielke and Egendorf 2023). The customary use of unregulated pharmaceuticals, cosmetic goods, and hand-crafted ceramics adds to the risk of lead exposure. Lead-containing components used in mining, processing, recycling, and disposal may pollute the environment, exacerbating the problem (Abalansa et al. 2021).

Lead contamination is a major problem; lead accidentally enters the food chain via numerous methods (Kumar et al. 2020). Elevated lead levels in cultivated vegetables, cookware, and other food products may be caused by soil contamination, industrial and agricultural pollution, and food processing. Higher soil contaminations around the lead smelters, mines, and vehicular traffic centres have been reported, harming crops planted in such areas. Milk samples from cows grazing near roadways and industrial zones may also have increased lead levels, providing a health concern to humans (Levin et al. 2021).

Plumbing systems polluted with lead contribute to the dispersion of lead in drinking water. The presence of lead is often revealed during the first flush of the plumbing system. Industrial operations such as smelting and cremation and lead-based businesses greatly increase airborne lead concentrations (Jarvis et al. 2018). When lead-based paints on walls and chalking from woodwork and toys are breathed, they become significant sources of lead absorption for newborns. Lead crystal glasses, ceramic glazes, and other glazed food storage, preparation, or serving items may also bring lead into everyday life (Fralick et al. 2016).

A success concerning public health is the removal of lead from gasoline. By eliminating lead from gasoline, several nations have achieved mean (population) blood lead levels (BPb) of 1 µg/dL or less. Such actions have made life safe, enhanced children's intelligence and created enormous economic benefits in nations globally. There has also been a reduction in the incidence of exposure to lead at higher doses by eliminating lead in household paints (Angrand et al. 2022; Eastman and Tortora 2023).

Omeljaniuk et al. (2018) conducted a study to determine lead concentration in the blood and tissue of the placenta of women who suffered from miscarriages. Total 83 women who have experienced miscarriage formed the study group. The control group comprised 35 women either after the child's birth or in the first three months of pregnancy. It has been found that the average concentration of lead in the blood of women who miscarried is more significant when compared to the level of lead in the blood of the control group's women (Omeljaniuk et al. 2018). Similarly, in the placental tissue of women who suffered from miscarriages, the average lead content is greater when compared to the concentration of lead in the placental tissue of the control group's women. Therefore, monitoring the lead level is essential in women planning pregnancy.

Aside from the more well-known causes of lead exposure, many cultural practices unwittingly expose people to lead poisoning (Wani et al. 2015). Surma, a traditional cosmetic ore used as eyeliner, is applied to the conjunctival surface of the eyelids and may be absorbed or ingested if it comes into touch with the mouth (Goswami 2013). Folk medicine and the use of lead in Ayurvedic remedies offer hazards, especially if used over time. Sindoor, a red powder used as a cosmetic and in religious ceremonies, may cause lead poisoning if swallowed incorrectly as a food component (Shah et al. 2017).

Correct diagnosis is a crucial first step in preventing lead poisoning and toxicity. A complete diagnosis requires investigating all potential entry points. The inquiry should focus on the patient's medical history and symptoms. Clinical toxicologists and other medical specialists can aid in making a correct diagnosis and developing an appropriate treatment plan. A major sign of lead toxicity is basophilic stripping. This stripping makes the microscopical visualization of red blood cell specks possible. Lead poisoning can be detected with a thorough blood film evaluation for such symptoms (Samarghandian et al. 2021). Anaemia caused by a lack of iron is linked to lead poisoning. Erythrocyte protoporphyrin (EP) levels in the blood are another method for diagnosing lead poisoning. When blood lead levels are elevated, EP tends to rise a few weeks later. Nonetheless, increased blood lead levels below 35 µg/dL cannot be detected with just the EP level. Lead exposure detection with EP has fallen in use because of its higher detection threshold and because EP levels rise in iron deficiency (Cantor et al. 2019; Sadiku and Rodríguez-Seijo 2022). Lead concentrations in the blood only reflect recent or ongoing exposure to lead, not the total load carried by the body. Indicative only of recent lead exposure, a blood lead level test does not accurately account for lead already present in the body. Non-invasive X-ray fluorescence measurement of lead in bones provides a possible optimal method for gauging total body exposure and load. Foreign objects, such as paint chips containing lead and lodged in the digestive tract, may be visible on an X-ray (Charkiewicz and Backstrand 2020).

Lead poisoning is treated with a combination of dimercaprol and succimer. Given the long-term effects of lead poisoning on children's brain development, the metal's use must be curtailed on a massive scale (Mitra et al. 2017). Chelating salts, such as calcium edentate, the disodium salt of ethylene-diamine-tetraacetic acid (EDTA), are commonly used to treat lead poisoning. These chelating compounds have a high concentration of the solvent they are meant to remove. Because the lead chelating agent is more attracted to lead than calcium, the lead chelate is generated by an exchange reaction. This is then eliminated by the urinary tract, leaving behind only innocuous calcium. As a chelating agent, succimer has been found to minimize BLL and improve cognitive development in children exposed to lead (Lakka et al. 2023). Antioxidants, in particular, are thought to mitigate the harmful effects of substances like lead and its derivatives. Improved biodistribution and bioavailability of poorly soluble medicines may be possible with a novel technology termed nano-encapsulation of antioxidants. Curcumin encapsulated in a pluronic block copolymer was found to have anticancer efficacy on par with free curcumin and a delayed and sustained release profile. These novel approaches can potentially improve treating many human ailments (Niu et al. 2023). N-acetylcysteine (NAC) has been shown in a recent study on a group of lead-exposed employees to lower blood lead levels significantly. Furthermore, it was shown that glutamate dehydrogenase activity increased dramatically in all NAC-treated groups. It was also found that oxidative stress was reduced, and homocysteine levels were normalized after treatment with NAC. As a result, NAC was found to be a viable alternative treatment option for chronic lead toxicity in humans (Kumar and Singh 2023). Various sources of lead poising and its management and prevention measures are presented in Table 1.

Table 1 Various sources of lead poising, It's Management and Prevention

S. N.	Source of lead	Symptoms	Management	Outcome	Ref
1	a sindoor powder consumed for 11 years at 5–10gm	Nephropathy caused by lead poisoning, combined with gingivitis, gout, and high blood pressure	Treatment for lead levels between 50 and 100 mcg/dL (DMSA/Calcium EDTA) may be used	Sindoor lead exposure among Indians	Kute et al. 2013
2	Adult and child use of lead-based glazes	Neurotoxic and Nephrotoxic	Chelation (DMSA/Calcium EDTA).	Promoting Lead free glazes	Estévez-García et al. 2022
3	Romanian Pre-schooler's and School-Aged Children (4-6, 8-11 years) in Industrial and Mining Regions	Neurological dysfunction	preserve human health by limiting or eliminating exposure to heavy metals	After being evacuated from an exposed environment, the health of the youngsters has improved	Nedelescu et al. 2022
4	Necessary minerals ameliorated lead-induced changes in haematological parameters in male Wistar albino rats	There is a decrease in blood haemoglobin and an increase in urine -amino levulinic acid dehydratase (ALAD)	Lead toxicity and speciation may be altered by eating a mineral-rich diet	Lead inhibits -ALAD in leached workers, most likely at zinc-binding sites. -ALAD is required to synthesize porphobilinogen from two -ALA molecules	Dsouza et al. 2022
5	Adult male Wistar rats were studied for lead-induced hematotoxicity	However, the RBC, HGB, HCT, and PLT levels all reduced, although WBC levels increased	TQ, the primary active ingredient in Nigella sativa seeds volatile oil, was effective in treating lead-intoxicated rats	Thymoquinone may be used to treat lead-induced hematotoxicity as well as other poisons and infections	Mabrouk 2021
6	Case report-Traditional Ayurvedic Medicines uses	Acute and chronic Lead encephalopathy	Chelation therapy and discontinuation of ayurvedic medicines	Patient recovered clinically and lesions on MR imaging resolved	Karri et al. 2008
7	Case report- lead-based manufacturing unit	Leg Fatigue & Weakness of Forearm Extensor Muscles Peripheral Neuropathy	D-penicillamine chelation therapy were used to treat his lead poisoning	Chronic exposure to lead requires a series of treatment regimens	Geraldine and Venkatesh 2007
8	Case report-Ayurvedic medicines manufactured using lead based bhasmas	General weakness and significant stomach discomfort are all symptoms of psoriasis	D-penicillamine, and/or Ca-Na2EDTA, and/or environmental intervention, appropriate diet, and enough hydration and education are all necessary components of a comprehensive treatment plan	Discontinue any Ayurvedic medications and drink a lot of water	Raviraja et al. 2010
9	Western Maharashtra battery workers (20-60years)	Some of the side effects include nausea and diarrhoea; constipation; headaches; paresthesia; and myalgia	Vit-C and Iron Intake	Vitamin C does not lower blood lead levels on a monthly basis. Catalase and superoxide dismutases are also enhanced by the supplement	Ghanwat et al. 2016
10	water supply, surma usage, and lead paint	spontaneous abortions, stillbirths, and premature births	Low iron, calcium, or zinc levels during pregnancy may increase intestine absorption and mobilization of bone lead	More research is needed on pregnancy and lead	Awasthi et al. 1996
11	Gasoline	visual-motor, visual-spatial (Drawing task) (Matching task) Peek-a-boo pegboard)	Regulations pertaining to the environment and the workplace are being implemented	Urban Indian children with poor visual-motor integration are more likely to have elevated blood lead levels	Palaniappan et al. 2011
12	Battery-recycling unit.	Osteoarthritis, epigastric pain, and a little rise in ALT and hepatomegaly are all symptoms	Dimercapto succinic acid and penicillamine were the first chelators used in chelation treatment	Small-scale industrial employees must be taught about the hazards of lead poisoning and lead poisoning	Menezes et al. 2003
13	Occupationally and nonoccupationally exposed lead poisoning cases	Constipation, diarrhoea, vomiting, and other symptoms of an upset stomach	Chelation therapy with D-penicillamine	Eating healthful foods, avoiding painted toys and unbranded medications, and taking showers at work may help reduce exposure	Mani et al. 2020

S. N.	Source of lead	Symptoms	Management	Outcome	Ref
14	Lead levels on painted surfaces such as windows, flooring, gates, doors, door frames, walls, shelves, containers, cabinets, playground equipment, etc.	Asymptomatic	Create public awareness	Field Portable XRF instrument	Kuruvilla et al. 2004
15	Exposure to car mechanics (spray painters, radiators, and batteries) India's Bijapur city	Inflammation of the muscles and other symptoms such as itching and moderate tiredness are all signs of an overactive immune system	Create public awareness	For occupational lead exposure screening, a full hemogram, urine ALA and other biomarker activity such PBG and erythrocyte delta-ALAD, and blood pressure readings are helpful	Dongre et al. 2011
16	Bone lead concentration- patella and tibia	Hypertension, heart disease, diabetes mellitus, and cancer	Supporting therapy to minimize symptoms	As occupations were added, they helped to reduce the bone lead and education categories	Ji et al. 2014
17	The environmental air of Two Electrical Factory people	Asymptomatic	Industrial danger may be reduced by using modern scientific methodologies	Scientific ways for preventing lead poisoning are available	Ghosh et al. 1952
18	Traditional eye cosmetics' Surma - Black, brown, orange, grey and white usage by Childrens	Anaemia and convulsions	The use of lead free 'Surma' is suggested. (White)	Decreases in Hb with increasing values of blood lead levels	Goswami 2013
19	The battery recycling and manufacturing people (Western Maharashtra)	nausea, vomiting, diarrhoea, and cramping are all symptoms of irritable bowel syndrome	Chelating with adjacent therapy	Workers in the battery production industry show less indication of serious impairment of liver and renal functions	Kshirsagar et al. 2015
20	Medication, food, cooking utensils, bullet wounds, and water to drink that haven't been labelled	Abdominal discomfort, dizziness, cognitive impairment, and other symptoms may occur	Cuprimine (D-penicillamine, 3-mercapto D-valine) Chelating treatment	No patient had a blue gum line or basophilic stippling. Chelation treatment does not substitute remediation or lead prevention	D'souza et al. 2011
21	Lead poisoning from herbal diabetes medicines	upper abdominal pain, anaemic, icteric, and pyrexial	Calcium ethylenediamine tetra acetate (EDTA) infusion (2.4 g) for 5 days	Diabetic men may have been treated with lead contain an Ayurvedic aphrodisiac may cause severe side effect. Better to avoid	Keen et al. 1994
22	Inhabiting and living	Abdominal pain, bilateral symmetric sensorineural hearing loss with descending configuration, stapedial reflex bilaterally present, speech intelligibility asthenia, paresthesia in upper limbs, progressive hearing loss	Calcium ethylenediamine tetra acetate (EDTA) infusion (2.4 g) for 5 days	Patients recovered clinically and lesions on MR imaging resolved	Kumar and Singh 2023
23	Foreign body	Increased blood pressure, normocytic normochromic and regenerative anemia, transitory headache, reactive anisocoria, asthenia, visual hallucinations, transient aphasia episodes, left pyramidal syndrome, memory impairment and psychomotor retardation, worsened generalized tonic-clonic seizures and altered consciousness, interstitial nephropathy	Chelation therapy with D-penicillamine	Eating healthful foods, avoiding painted toys and unbranded medications, and taking showers at work may help reduce exposure	Lelievre et al. 2020
24	Lead poisoning from medication	Pale conjunctiva, exertional dyspnea, hypochromic microcytic anemia, anisocytosis with basophilic stippling	Traditional Chinese herbal medicine (Qushangjieyu-san powder) - chelation therapy	Patient recovered clinically	Samarghandian et al. 2021

Conclusion and Future Prospects

The paradox of lead displays a complicated interaction between its desirable features and the risks it poses to human health and the environment. The versatile metal is widely used in various sectors, allowing for novel uses and economic advantages. However, the possibility of lead contamination, whether from industrial methods, environmental exposure, or cultural practises, presents serious concerns. As a society, we must balance enjoying the advantages of lead's adaptability and enacting tight laws, safe handling practises, and spreading awareness to reduce exposure dangers. Only then can we properly walk the narrow line between the beauty and danger of lead. Consequently, lead serves no purpose in the body and is hence unnecessary. If lead enters the body, it may stay there indefinitely and cause injury and even death. Lead poisoning accounts for about 0.6 percent of the global disease burden. Because of the toxicity of lead, workers exposed to it experience more severe repercussions than the general population. Various groups, as well as the government and the media, are now striving to increase awareness of lead poisoning by interacting with and educating people who have been exposed to it and the general public about the health dangers connected with it.

Lead poisoning seems to be more common than other heavy metal poisonings. Lead's widespread and historically attested toxicity has led to widespread concern for its safety. It has been adopted globally due to the significance of its physicochemical features. As the industrial revolution began in the seventeenth century, its use skyrocketed, as did its toxicity to humans. Having lead-related industries close to playgrounds increases the danger for children. There is an elevated risk of lead poisoning for those exposed to lead in the workplace. Young children of parents with lead-related occupations should have their blood lead levels monitored often. The available research shows that lead is very hazardous and interferes with virtually every bodily process. Damage to the digestive, neurological, respiratory, reproductive, and other systems results from lead poisoning. To add insult to injury lead inhibits enzyme function. Disabling impairments in the skeleton directly results from lead's interference with the normal DNA transcription process.

Toxic effects can occur at deficient lead concentrations, and the body has no physiologic need for lead. Fortunately, there are methods available today that can reverse the damage and lower lead levels in the body. Chelation therapy, nano-encapsulation, and N-acetylcysteine (NAC) stand out among these. In addition to a variety of antioxidants, they aid in the elimination of lead from the body. The best course of action is to avoid exposure to toxins in the first place, even when effective treatments are available. Parents should also teach their children about the dangers of lead poisoning and how to protect themselves and their families from exposure. Genetic, environmental, and dietary variables all contribute to the fact that not everyone responds the same way to the same treatment.

Abbreviations

BLL: Blood Lead Level

IBS: Irritable Bowel Syndrome

NRCLPI: The National Referral Center for Lead Poisoning Prevention in India

XRF: X-ray fluorescence

ZPP: Zinc Protoporphyrin

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The authors declare no conflict of interest.

Data Availability

The data supporting this review are from previously reported studies and datasets, which have been cited. The processed data are available from the corresponding authors upon request.

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