The lead toxicity and pollution with this element in Poland

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Abstract

Background The aim of this review is to describe lead’s toxic effects on the human body from conception through adulthood.

Results One toxic heavy metal is lead. Pb is very dangerous when it is absorbed and accumulates in the main organs of the body where it can cause a range of symptoms that vary from person to person, the time of exposure and dose. Lead in adults can cause an increase in blood pressure, slow nerve conduction, fatigue, mood swings, drowsiness, impaired concentration, fertility disorders, decreased sex drive, headaches, constipation and in severe cases encephalopathy or death.

Conclusions Toxic exposure to lead in Poland remains an important public health problem. This review will cover the range of lead exposures, from mild to heavy. Public health interventions and policies also are needed to reduce occupational and environmental exposure to this heavy metal.

Background

Lead (Pb) is a toxic heavy metal that when absorbed by the body accumulates in blood and bones as well as organs such as the liver, kidneys, brain and skin. Its negative health effects can be both acute and chronic, because the human body poorly excretes Pb. In humans, lead has been shown to affect the normal function of the reproductive, hepatic, endocrine, immune and gastrointestinal systems [1]. There is limited evidence of a carcinogenic effect of lead and its inorganic compounds on humans [2].

Human exposure to lead can occur in a variety of ways, all of which involve exposure to the heavy metal as an environmental pollutant. Lead enters the body
via ingestion and inhalation with lead sources being soil, food, lead dust, contact with lead in products of everyday use, and concentration in the workplace (Figure 1). Lead has had many different industrial applications in the past and is currently used for a range of purposes. Currently, the heavy metal is used in battery plates and equipment for the production of sulfuric acid, cable covers, the paint and ceramics industry, the chemical industry and construction, soldering materials, the production of bearings and printing fonts, shields in atomic reactors, production of aviation gasoline, aprons and containers for radioactive materials, etc. Until recently, lead-based house paint and tetraethyl lead in gasoline were major sources of environmental lead [2-4]. Toxic exposure to lead in Poland remains an important public health problem.

The aim of this review is to describe lead’s toxic effects on the human body from conception through adulthood. The second main aim is to describe sources and levels of lead contamination in Poland, where exposure to environmental lead varies by region.

Figure 1. Exposure to lead pollution and possible health effects in humans [2].

**Lead absorption, excretion and storage in body**

Absorption and the biological fate of lead is dependent on its chemical form.

Organic forms of lead are easily absorbed by the respiratory, digestive and skin systems [4] and in the liver (including those found in lead gasoline in the past). Lead absorption from the gastrointestinal tract in humans is strongly influenced by age, fed status, nutrition, solubility and particle size [5,6].

*Inhalation*

The respiratory system is the principal pathway by which the inorganic form of Pb is
absorbed by the body. Small particles of lead reach the alveoli where they are absorbed with about 95% efficiency. Larger particles that are deposited in the nasopharyngeal segment, trachea and bronchi are absorbed mainly via the digestive system where they end up due to expectoration and swallowing of secretions. In the work environment, the main route of absorption of Pb and its compounds is through the respiratory system, although lead is also absorbed via the digestive system (atsdr.cdc.gov) [3,4,7].

Ingestion

Ingestion of lead occurs by consumption of lead-contaminated food and water, and from lead expelled by the respiratory system and subsequently absorbed (as described above). Tetraethyl and tetramethyl lead are absorbed by the digestive system and transported to the blood, from which it is distributed to the various tissues within an hour [4,8].

Diet and nutritional status are very important factors that can influence lead absorption. A diet rich in zinc, copper, iron or calcium can reduce absorption of lead by the digestive system. Unfortunately, diets rich in fat or protein can promote Pb absorption and improve overall vitamin D status, which in turn can increase lead uptake. Phosphorus in food can cause the conversion of lead to well-soluble phosphates, which can be absorbed to a limited extent. Intake of vitamin C with Pb may increase the absorption of lead. The metal is also capable of displacing essential microelements from metalloenzymes. It can also impede the biosynthesis of heme and cause disturbances in microelement (Fe, Cu, Zn Se and Ca) metabolism [2,9-12]. Calcium and phosphorus administered singly reduce Pb absorption from the gastrointestinal tract by 1.3 and 1.2 times, albeit less than when these nutrients were given jointly (a 6-fold reduction). Zinc also plays a protective role, reducing
ALAD inhibition by Pb. Lead displaces zinc readily in one of the alloenzymes of the protein. The relationship between δ-aminolevulinic acid dehydratase genotype and sensitivity to lead at different blood lead concentrations is at present unclear. It also causes an increase in zinc protoporphyrin, by a mechanism that is not fully established [2,11]. Pb absorption in people with iron deficiency may be 2-3 times higher than in people without iron deficit [9,13,14].

**Lead in the Human Body**

Following absorption, Pb concentrations in the blood equilibrate approximately 3 months after exposure (atsdr.cdc.gov). Most lead is stored in the liver, and less in the kidneys, the rest is dispersed throughout the body (cerebral cortex, spinal cord, ovary, pancreas, spleen, prostate, adrenals, brain, fat tissue, testes, heart and skeletal muscles) [15].

In adults, Pb is found in bones and increases with age by up to ten times, especially in tibias. After the end of lead exposure, its elimination has a two-phase character. The first phase (elimination from blood and soft tissues) takes about 20-30 days. The second, slow elimination phase of lead from the blood reflects excretion from the bones. The biological half-life of lead in trabecular bone is estimated to be one year, and in the cortical bone as 10-20 years [16].

Most inorganic lead is removed via the urine (approximately 2/3s), while another 1/3 is expelled in bile into the intestine and then removed from the body in faeces. Small amounts of lead (Figure 2) can be secreted by sweat, milk, saliva, or accumulate in hair and nails (atsdr.cdc.gov) [4,8]. After discontinuation of exposure, the lead elimination half-life from blood and the soft tissues is about 30 days, and from bone 5-10 years; as a result, lead can remain in the body for decades [14,17,18].
Lead's effects

Metabolic and Genetic Effects

Lead impairs multiple biochemical processes that leads to its toxic effects, including its ability to inhibit calcium and react with proteins. On entering the body, Pb takes the place of calcium and then interacts with biological molecules, interfering with their normal function. Lead reduces the activity of various enzymes, causing changes in their structure, and inhibits their activity by competing with the necessary cations for binding sites. Oxidative stress caused by lead is the main mechanism responsible for its toxicity, causing changes in the composition of fatty acids in membranes (affects processes such as exocytosis and endocytosis and signal transduction processes). Pb can also cause gene expression alterations. Protein protamines are involved in Pb toxicity because of gene expression alterations and then lead interact with zinc binding sites on protamines. Some research has investigated the effect of Pb on the activity of glucose-6-phosphate dehydrogenase (G6PD), by causing anemia, it may interfere with the integrity of the RBC membrane, making it more fragile. Pb can also inhibit the enzyme ferrochelatase, reducing iron (Fe) incorporation into heme. The heavy metal inhibits δ-aminolevulinic acid dehydratase (δ-ALAD) enzyme thusly adding to increased blood levels of δ-aminolevulinic acid (δ-ALA). Pb induced oxidative damage is the result of disturbance in the balance of glutathione (GSH) to glutathione disulfide (GSSG). The
presence of lead in the body can cause rapid depletion of antioxidants in the body and can increase the production of reactive oxygen, as well as reactive forms of nitrogen. Thus, increased oxidative stress causes a reduction in the levels of glutathione reductase, leading to a reduction in the concentration of the antioxidant glutathione [11,19].

Location of Lead in the Body

Most lead is stored in the bones [16,20]. Lead in bones is not uniformly distributed. It tends to accumulate in bone regions undergoing the most active calcification at the time of exposure. The rate of development and accumulation of lead in bone in childhood and adulthood suggests that its accumulation will occur mainly in the trabecular bone during childhood, and in adulthood in the cortical bone. Bone-to-blood lead mobilization increases during advanced age, broken bones, chronic disease, hyperthyroidism, kidney disease, pregnancy and lactation, menopause, and physiologic stress. Calcium deficiency exacerbates, or worsens, bone-to-blood lead mobilization in all of the above instances [1,3].

Children

WHO experts stress the importance of Pb control in this age group because research consistently shows lead adversely affects the central nervous system and development of children [21]. Pb is especially harmful to children under the age of six, most likely because of rapid brain growth and development with associated periods of heightened vulnerability, and because of high demand for nutrients [2, 9, 21]. Children are particularly vulnerable to the effects of lead. The heavy metal can interfere with the ability to learn, impair memory, lower IQ, and interfere with growth and development. Pb has documented effects on speech, hearing, hyperactivity, nerve conduction, intestinal discomfort, constipation, vomiting,
weight loss, muscle aches. At high blood concentrations (Table 1), lead poisoning can lead to anemia, nephropathy, paralysis, convulsions or death [4,11].

Table 1. Symptoms of poisoning according to the degree of exposure in children and adults [English translated from original paper: 4].

Lead’s damage to the child can begin as early as pregnancy. Maternal lead can be passed through the placenta to the developing fetus [11,22]. The Pb content in the placenta is the result of many complex biochemical reactions and various factors related to the mother’s body. The concentration of Pb in umbilical cord blood can be up to 85% of the Pb concentration in the mother's blood. When a woman becomes pregnant, the lead stored in her bones can be released and transferred through the blood to the fetus, especially if the mother’s calcium intake is low. Therefore, fetal development can be influenced by both current and past maternal exposure to Pb via the heavy metal’s storage in the mother’s bones [23,24].

Research has found that even slight Pb exposure is associated with increased the risk of miscarriage, stillbirth, low birth weight and underdeveloped children. It is still not known what Pb levels can cause mutations and congenital abnormalities in the fetus, as well as the exact mechanisms of these changes. Based on current evidence, the WHO has targeted a blood Pb concentration of 5 μg/dl or less for children. Damage from lead exposure can occur at levels below this value [2,9,21,23,24].

Severe lead poisoning in children can cause dementia, irritability, headaches, muscle twitches, hallucinations, memory disorders, learning or behavioral problems, concentration and attention issues, reductions in IQ, hearing loss, restlessness or hyperactivity. Acute poisoning can lead to convulsions, paralysis and coma. In fatal cases, brain damage can occur due to edema and changes in the blood vessels...
Children are exposed to environmental lead via inhalation and ingestion. Inhalation contributes to higher blood levels in children than in adults. Dirt, dust and food are the largest contributors of Pb in children, while ingestion from water is generally a less significant source (Figure 3). Young children’s exposure to lead is substantially enhanced by the common infant and toddler behaviors of tasting objects, putting hands into the mouth immediately after play, etc. [2,11]. When young children live in environments with Pb contamination, ingestion of the heavy metal is likely. Increased risk of lead poisoning occurs in families where one parent works in a high-level lead environment. Parents who are exposed to lead in workplaces too often bring leaded dust to the home with clothes or on the skin, thereby increasing the chances of their children being exposed to the heavy metal. Monitoring of Pb concentrations in children's blood is recommended (atsdr.cdc.gov) because of their vulnerability to the heavy metal [2,9].

Figure 3. Possible sources of lead poisoning among children in the environment home [2].

Adults

The effects of lead exposure in adults are underappreciated. High lead concentrations can result in serious morphological and functional changes in some organs [2,24]. Lead in adults can cause changes in the nervous system (affecting slow nerve conduction, fatigue, mood swings, drowsiness, concentration disorders, headaches, coma), the circulatory system (increase in blood pressure, in severe cases encephalopathy), the gastrointestinal effects (colic/pain, nausea, vomiting, diarrhea, and constipation), hormonal (fertility disorders, decreased libido), other symptoms include astringency of the mouth, metallic taste in the mouth, and thirst
or death [2]. In particular, Pb can seriously affect the cardiovascular system. People exposed to very high doses of Pb (blood lead concentrations between 500-870 μg/L blood) can experience sinus node dysfunction, atrioventricular conduction disturbances and atrioventricular block [18]. Pb exposure can also lead to morphological changes in the heart, including the heart muscle. Visible changes in the electrocardiographic picture, impaired systolic and diastolic function of the heart and changes in repolarization dispersion, increases blood pressure [18,25].

The relationship between lead concentrations in blood and blood pressure has been widely studied. The effect of lead on blood pressure is dependent on the size of the exposure dose and the time of exposure [2]. Even low lead exposure can adversely influence cardiovascular disease [26]. Many researchers have observed a positive relationship between lead and blood pressure, while others have not. However, exposure to even low lead levels is associated with oxidative stress and deficiency of the enzyme catalase and may contribute to hypertension. Increasing the level of lead in the body causes greater cardiovascular responses to acute stressors. Thus, increased cardiovascular reactivity predicts higher baseline blood pressure, increased left ventricle mass and atherosclerosis in adults. Consequently, increased blood pressure reactions to acute stressors are one of the possible mechanisms by which lead can affect resting blood pressure. Also lead levels in the blood may affect cardiac output or total resistance of peripheral vessels, and thus increase the response to blood pressure to acute stressors [3,15,27]. The main problem of lead is the effect on myocytes of the muscular layer of blood vessels. Many researchers point to vasoconstrictor effects in chronic lead intoxication, but it is not this fact is sufficiently confirmed [18]. Some experimental and epidemiological data suggest
that prolonged exposure to lead may result in an increase in blood pressure. There is a need to confirm and further verify the above assumptions and to determine the place that lead occupies among other factors playing a role in the pathogenesis of hypertension [25].

Lead compounds can adversely affect blood and the metabolism of blood cells. This red blood cell effect is manifested by a disorder of cell metabolism of the red blood cell line in the bone marrow or mature erythrocytes. Pb impairs the integrity of the permeability of the membrane, to which RBC's are more susceptible. Heme synthesis is disturbed by Pb exposure [11].

As in children, lead exposure can have adverse effects on the nervous system. The blood Pb concentration threshold for asymptomatic CNS function disturbances has been set at 400-600 μg/L (atsdr.cdc.gov) [16]. Adverse effects include impaired visual intelligence and eye-hand coordination, decreased learning ability, impairment of the ability to praise, memory, potential visual and auditory disturbances.

In men who have been exposed to Pb, there can be reduction in sperm count, quality of semen, and their motility, morphological disorders, longer time to pregnancy in pairs, sterility / impotency and endocrine disorders. In men, the number of spermatozoa is reduced and sperm volume changes (> 40 μg/dl). And in women, toxic lead levels can lead to miscarriages, low birth weight, prematurity, or developmental problems in children. Lead present in the mother's blood passes to the fetus through the placenta and through breast milk [2]. The symptoms of poisoning according to the degree of exposure in children and adults shows Table 1 [4].

Lead colic is a frequent result of short-term exposure to large doses. At the
beginning, the person is hungry, and has indigestion and constipation. Following this is extensive paroxysmal abdominal pain, pale skin and bradycardia. Acute coronary encephalopathy is rare in adults. When this has occurred, the blood lead concentration in people with symptoms of encephalopathy was 800-1000 to 3000 μg/L (atsdr.cdc.gov) [16].

Lead exposure in Poland

_In the environment_

Poland is home to some of the richest zinc-lead ore deposits in Europe (the Silesian Uplands and Kraków-Częstochowa Uplands). Mining operations began as early as the 12th century and these regions were leading producers of Pb in the Middle Ages. In prior centuries, Pb was commonly used for covering roofs, window frames, pipes, tableware, jewelry, weights, making glass, shooting balls, printing fonts and for the toy industry for the production of lead soldiers [1,12,28].

In Poland, as in many other countries, lead in gasoline was a major pollutant for much of the 20th Century. Thanks to legislative changes in Poland in the 1990s and in the first decade of the 21st century, a significant drop in the concentration of Pb in atmospheric air occurred. This reduction was mainly due to the elimination of lead in car fuel [21]. However, since 2010 Pb emissions in Poland have been reduced by only 10% [29]. Studies of forest ecosystems in Polish national parks (concentrations of heavy metals in two layers of soil: Ojcowski – 2.32 mg/kg, Magurski – 1.25 mg/kg, and Gorczański National Parks – 0.92 mg/kg) located in the south-west regions of the country have been shown to be the most polluted, caused by higher industrial activity and the transboundary transport of air pollutants. The most polluted air occurs in the vicinity of mines and metalworks in the
Voivodeships: Śląskie, Opolskie and Małopolskie [30].

A special report prepared for Poland in 2016 assessed the total emission of heavy metals: arsenic, chromium, zinc, cadmium, copper, nickel, lead, and mercury. It has been shown that, depending on the types of industrial activity, Pb almost always ranks second in terms of environmental pollution when burning in energy production and processing (incineration); non-industrial combustion installations; combustion in industry; or production processes. This means it is dangerous for the environment and it has very serious consequences for us. However, it occupies first place in waste management and is in third place during emissions from road transport [29].

The work environment is a significant source of lead exposure for many, which in consequence leads to numerous disorders and absenteeism of the employees of the metallurgical industry [31]. Many professional groups, such as miners and steel workers, welders, plumbers and fitters, car mechanics, glass producers, construction workers, battery manufacturers and recyclers, shooting ranges and plastics manufacturers, are exposed to risk of contact with lead [2].

Currently, the biological limit value of Pb varies between 270 and 300 μg/L, but it depends on dose-effect and dose-response which was considered as a result of human population surveys exposed to lead in the work and living environments [16]. It is also associated with the formation of free radicals during lead intoxication [18].

One study has shown the average concentration of Pb (29.39 ± 17.05 μg/L) in the group of men working in the metal industry in Podlasie Voivodeship, which was below the biological limit in Poland [31]. Another study found a higher average Pb blood lead concentration (33 ± 9.6 μg/L) in a group of male employees mills in southern Poland (Śląskie Voivodeship). Other workers who were professionally
exposed to heavy metals in mills in Legnica and Głogów had a 10 times higher Pb concentrations [25] than a group of men working in the metal industry in Podlasie Voivodeship [31]. The results indicate that men who are occupationally exposed to heavy metals should be carefully monitored to preserve their health [31].

In paints

In Poland, Pb was present in paints manufactured before 1978. Unfortunately, lead paint can still be found on many painted surfaces in older homes, such as doors, windows and verandas. Lead dust and chips can come from paint lead that peels and falls off painted surfaces. Grinding and stripping of lead paint during repainting or renovation can create a serious problem with lead dust. And, old paint, which has fallen off the house, can also poison the soil with lead [1,11]. Currently, lead acetate is found only in some hair dyes [4,28]. Lead-rich inks are currently not used in Poland; however, lead remains in many locations because of lead’s low mobility in soil [9].

Lead in food

An estimated 97% of agricultural soils are characterized by natural or only slightly increased Pb content. However, in areas under the influence of the steel industry, lead content in soil can significantly exceed the standard by 10 times (OJ 2002, No. 165, item 1359). Public health professionals presume that food grown in soil near active landfills or shipyards may contain dangerous amounts of Pb. Concentrations may depend on the type of parent rock from which the soil was formed, and the pollutants emitted in a given area, e.g. through transport and industry. Lead’s absorption by plants depends on the properties of the soil, the characteristic features of the species or the physiological state of the plant (dicotyledons absorb metals much more easily than monocotyledons). Plant roots (including lettuce,
radishes, beets, spinach, parsley, carrots, beetroot, white cabbage, cauliflower and lettuce) can effectively absorb lead, mainly near industrial plants. Among food products, the highest Pb concentrations have been observed in vegetables, potatoes and milk [9].

An important source of contamination of food products can be technological processes. The source of lead can be devices used in food production and can come from various types of dishes, packaging, kitchen appliances, canning, soldering cans, ceramic products, such as glassware or porcelain parts (most often decoration). To reduce this amount, it is necessary to properly prepare the product before consumption, wash thoroughly, and cook or blanch for a long time [9,13,14].

In 2009, a study assessed Pb concentrations in wheat, rye/wheat flours, rye flours, rye breads, wheat breads and noodles in Lublin province. The average ranges of Pb content were: wheat (0.057-0.067 mg/kg), rye flours (0.060 mg/kg), breads (0.032 mg/kg), noodles (0.040-0.090 mg/kg) and potatoes (0.027 mg/kg) [32]. In 2011, a second study assessed the Pb content in cereal products (flour, groats, bakery products, pasta, flakes and rice) from Podlaskie Voivodeship. Their analysis revealed a significantly higher Pb content in buckwheat groats (0.144 mg/kg), bran (0.130 mg/kg) and crunchy bread (0.124 mg/kg) as compared to other cereal products. In 10% of the examined buckwheat groats samples Pb content was 0.375 mg/kg [33]. Other research has found no concentrations of Pb that exceeded standards in tested milk, herbs and spices samples, water irrespective of the place of origin.

Research carried out in 2011 showed concentrations of Pb in bovine meat tissue of 0.110 mg/kg, while in other samples taken from pigs and poultry were lower (0.066
mg/kg and 0.034 mg/kg). The livers of the tested animals were characterized by a slightly higher content of Pb in comparison to meat. Pb accumulation in fish meat was at a lower level (0.010 mg/kg) compared to canned fish (0.036 mg/kg). It was found that milk and eggs were characterized by the smallest Pb level. Research found that food products purchased in the commercial network in the Podkarpackie voivodship they did not exceed admissible limits of Pb [34].

The literature suggests relatively safe levels of lead in the Polish food supply, but Pb content should be constantly monitored in food products [9,35-37].

Prevention and monitoring of lead poisoning

There is no threshold below which there are no adverse effects of lead, no level of lead exposure is acceptable. Therefore, programs and policies are needed to prevent exposure to the heavy metal. Primary prevention of lead exposure requires programs and policies that ensure that all homes, workplaces, and the external environment are safe and do not contribute to lead exposure by both children and adults. Every effort should be made to increase awareness of the risks of lead and to promote lead-focused nutritional interventions because these are key elements of an effective prevention policy [23].

In view of the high risk to the fetus, specific guidelines for prenatal healthcare providers and women of childbearing age are needed as there are currently no national recommendations or guidelines from maternity, family, pediatric or nursing groups that include lead risk assessment and management of pregnancy and lactation [23].

To prevent exposure of children to lead, children's hands should be washed frequently, and their intakes of calcium and iron optimized, which will reduce the
absorption of lead by the body. Children should be discouraged from touching the mouth frequently. Also, public health professionals recommend that homes be keep free of PB by cleaning only cold water) and to eliminate items that may contain lead such as blinds and jewelry. Old home water pipes should be replaced as potential sources of lead. Public health professionals assume that hot water contains a higher level of lead than cold water; therefore, it is recommended that in the household, especially when cooking and cleaning cold water is mainly used [2]. Monitoring of lead exposure is needed to assess the magnitude and nature of lead exposure, and to ensure that timely and effect treatment for lead poisoning occurs. International guidelines recommend interventions beginning with a blood lead concentration of ≥ 5 μg/dl in pregnant women. The susceptibility of the developing fetus to lead’s adverse effects and the potential for preventing additional postnatal lead exposure justify intervention for pregnant women showing signs of exposure to lead [22]. When mothers blood lead concentrations are high, they should be encouraged to pump and eject milk until the level of lead in the blood drops below 40 μg/dl [23]. In adults, the most critical systems are kidneys and hematopoietic systems, peripheral, nervous and circulatory. And in children the critical system is the central system nervous, however, in children, its central effect the nervous system is fretless [16]. But WHO recommend a blood Pb concentration of 5 μg/dl or less for children because damage from lead exposure can occur at levels below this value [21].

According to the WHO, 98% of adults affected by Pb live in low- and middle-income countries. Workers with blood lead concentrations above 400 μg/L should receive medical care. Exposure to lead should be carefully monitored because the effects of its accumulation in the body are not necessarily visible immediately, and can
manifest themselves years later, posing a serious challenge to medicine and public health [17,38].

In most industrialized countries, levels of blood Pb in are steadily falling along due to the discontinuation of lead fuels. However, some populations are still exposed to high levels of lead: mainly from deteriorating dwellings with residual lead paint [17,38].

Conclusions

IARC found lead to be a proven factor carcinogenic effects. Any exposure to Pb causes a wide range mostly of toxic physiological effects, biochemical and behavioral functions. The most dangerous negative effects can be seen on the central and peripheral nervous system, hematopoietic system, cardiovascular system and some organs such as liver and kidneys. A review of the literature suggest that some regions of Poland are more contaminated with lead, both in soil and in the air than other areas. Public policy should have as its goal the minimization of exposure to lead in the workplace, home, and larger human environment. Therefore, the levels of this heavy metal should be monitored in all groups, not only in women planning pregnancy, but also in young children, adults and the elderly. A nation-wide lead monitoring program is indicated. Social and professional education should promote lead awareness, increase health knowledge and provide the skills necessary to prevent lead poisoning. The Polish food supply appears to be safe. An comprehensive regulatory plan and health intervention program should be developed and implemented in Poland to reduce lead exposure and health risks, including major lead-borne diseases, cardiovascular disease, reproduction, kidneys, central nervous system.
List of Abbreviations

Pb - lead

ALAD - aromatic l-amino acid decarboxylase

G6PD - glucose-6-phosphate dehydrogenase

δ-ALAD - δ-aminolevulinic acid dehydratase

δ-ALA - δ-aminolevulinic acid

GSH - glutathione

GSSG - glutathione disulfide

WHO - World Health Organization

IARC - International Agency for Research on Cancer

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Ethics approval and consent to participate

Not applicable

Consent for publication

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Table

Table 1. Symptoms of poisoning according to the degree of exposure in children and adults [English translated from original paper: 4].
| Blood lead level (µg/L) | The degrees of lead poisoning | Adults | Symptoms | Children |
|-------------------------|-------------------------------|--------|----------|----------|
| < 10                    | asymptomatic                  |        | passing through the placenta into the fetal bloodstream | IQ reduction, learning and memory abilities, hearing, speech and language disorders, hyperactivity, decreased IQ, decreased learning and memory abilities, decreased hearing, speech and language skills | |
| 10 – 40                 | gentle                        |        | elevated blood pressure, slowing down nerve conduction | sporadic intestinal discomfort, hearing, speech and language disorders, hyperactivity, decreased IQ, decreased learning and memory abilities, decreased hearing, speech and language skills | |
| 40 – 70                 | moderate                      |        | drowsiness, fatigue, mood swings, reduced mental abilities, impaired fertility, chronic hypertension, impaired hemoglobin synthesis | drowsiness, fatigue, mood swings, reduced mental abilities, impaired fertility, chronic hypertension, impaired hemoglobin synthesis | |
| 70 – 100                | serious                       |        | metallic taste in the mouth, constipation, headaches, abdominal pain, muscles and joints, insomnia, memory loss, decreased sex drive, nephropathy | metallic taste in the mouth, constipation, headaches, abdominal pain, muscles and joints, insomnia, memory loss, decreased sex drive, nephropathy | |
| > 100                   | acute poisoning                |        | encephalopathy, anemia, death (> 150 µg/L) | encephalopathy, anemia, death (> 150 µg/L) | |

**Figures**
Figure 1

Exposure to lead pollution and possible health effects in humans [2].
Figure 2

Absorption, Distribution and Excretion of Pb from the body (thin arrows - absorpti
Figure 3

Possible sources of lead poisoning among children in the environment home [2].