
**BASIC KNOWLEDGE OF THE PRESENCE OF LEAD AND CADMIUM IN FOOD,
THEIR TOXICITY, AND PROTECTION METHODS AMONG THE POPULATION
OF SKOPJE, NORTH MACEDONIA**

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Abstract: Heavy metals are present in the soil, where their concentration is constantly increasing due to modern lifestyles and industrialization. Through environmental pollution via soil, air, and water they enter the human food chain. Plants absorb heavy metals from the soil through their roots and accumulate them in various parts, such as roots, stems, leaves, and fruits. Different types of vegetables and fruits exhibit varying capacities for heavy metal accumulation. By consuming plants, fruits, and vegetables, heavy metals are transferred to animals and humans, accumulating in specific body parts where they can remain for several years, causing chronic toxicity. Certain heavy metals, such as copper (Cu), iron (Fe), nickel (Ni), and zinc (Zn), are required by living organisms in low concentrations, but become toxic at higher levels. In contrast, lead (Pb) and cadmium (Cd) pose a significant hazard to human health even at very low concentrations. They are carcinogenic and induce neurotoxicity, nephrotoxicity, anemia, hypertension, and other severe diseases, with cadmium being markedly more toxic than lead. Nevertheless, certain types of food can reduce their absorption. To determine the public awareness regarding the presence of lead and cadmium in food and their toxicity, a study was conducted using a 16-question survey. The survey was administered to 100 respondents comprising employees and patients at the "Bukurešt" Polyclinic in Skopje. The findings revealed that a large proportion of respondents are aware that these metals are toxic even at low concentrations; however, they are uncertain which of the two is more toxic. More than half (62–68%) know which types of food contain the highest concentrations, yet only 40–47% are aware of the organs in which they accumulate and their retention duration within the organism. While over half of the respondents correctly identified diseases not caused by lead and cadmium, only 46% know how to reduce their absorption. Participants demonstrated high awareness and concern for their health, with 96% stating a need for additional education on this topic. Ultimately, the survey indicates that individuals require greater education regarding the harmful effects of these metals, their presence in food, and protective measures. Therefore, educational initiatives are necessary both within formal education and externally through various lectures, courses, and guidance provided by qualified professionals such as nutritionists.

Keywords: cadmium, lead, food, survey, toxicity

1. INTRODUCTION

Heavy metals are metals and metalloids named for their high density ($> 4 \text{ g/cm}^3$), which is several times greater than that of water. The group of heavy metals includes lead (Pb), cadmium (Cd), nickel (Ni), cobalt (Co), iron

(Fe), zinc (Zn), chromium (Cr), mercury (Hg), arsenic (As), silver (Ag), and the platinum group elements (Nagajyoti et al., 2010).

Heavy metals occur naturally in the soil; however, the ongoing increase in their concentration due to modern lifestyles driven by industry, agrochemicals, and fossil fuel combustion presents a major concern. Pollution by heavy metals is exceptionally detrimental due to its toxicity to humans, animals, and plants. Heavy metals enter the food chain via natural contamination or anthropogenic activities. Human exposure to heavy metals most frequently originates from industrial sources, subsequently transferring through soil and air into water and the food supply consumed by populations (Keshav & Mohan, 2016; Li et al., 2023; Tongprung et al., 2024).

Trace amounts of copper (Cu), iron (Fe), nickel (Ni), and zinc (Zn) are essential for living organisms, yet excessive quantities of these metals can be highly hazardous (Balkhair & Ashraf, 2016; Sonone et al., 2021). In contrast, arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) are non-essential for normal human physiological functions and can induce severe toxicity (Manwani et al., 2022).

Heavy metals carry serious implications for human health. They can enter the organism through direct ingestion, dermal contact, inhalation, and absorption (Sodhi et al., 2022). Lead and cadmium are highly toxic heavy metals introduced into the human body via air, water, and food. The highest concentrations of lead and cadmium are found in offal (variety meats), seafood, and bivalves. Substantial amounts of lead are also present in cereals, fruits, and vegetables. Nevertheless, the primary daily dietary intake of lead stems from cereals, fruits, and vegetables, whereas cadmium intake is predominantly derived from vegetables and nuts, followed by cereals, offal (liver, kidneys, heart), fish, and meat (Klapec, 2010; Sarkanj, 2010). Leafy vegetables (such as lettuce, spinach, and parsley) contain elevated concentrations of lead and cadmium (Eissa & Negim, 2018; Edraki et al., 2024), in contrast to fruits (such as apricots, peaches, pears, and raspberries), where heavy metal concentrations are considerably lower (Pavlovska et al., 2016; Rusin et al., 2021).

Lead and cadmium are highly toxic metals that, once ingested, can persist within the organism for several years. Following ingestion, dietary lead first enters the bloodstream, remains in the kidneys and liver for a certain period, and ultimately accumulates in the bones. Cadmium accumulates in the kidneys and liver, where it can persist for over 30 years (Sarkanj, 2010; WHO, 2006).

Lead causes neurotoxicity, anemia, hypertension, cardiovascular diseases, nephrotoxicity, immunosuppression, reproductive toxicity, and carcinogenicity. The most vulnerable populations include young children, fetuses, pregnant women, nursing mothers, the elderly, and individuals with a deficient intake of Ca, Fe, and Zn. Children absorb approximately 50% of the ingested lead into their bodies, whereas adults absorb 10–20%. Fasting or starvation can significantly increase the intestinal absorption of lead from food (Sarkanj, 2010). Cadmium is markedly more toxic than lead and, according to the World Health Organization (WHO) and the International Agency for Research on Cancer (IARC), it is classified as a Group 1B carcinogenic compound, meaning it is carcinogenic to humans (WHO, 2006).

Dietary patterns can greatly reduce the absorption and adverse effects of lead within the organism. Adequate nutrition and foods rich in zinc, iron, and calcium minimize lead absorption. Proper dietary habits can similarly mitigate the harmful impacts of cadmium. Frequent consumption of animal liver and kidneys should be avoided. Foods rich in zinc, copper, selenium, iron, and antioxidants reduce the toxicity of cadmium (Sarkanj, 2010). Furthermore, vegetable processing and preparation techniques such as boiling, blanching, and fermentation can effectively decrease the concentration of lead and cadmium (Temelkowska Ristevska et al., 2026).

Due to the significant adverse effects and escalating intake of these heavy metals, the public needs to understand how and in what ways these metals are ingested. The aim of this study is to determine the extent to which the population is familiar with the harmful effects of these metals, their presence in food, and methods of protection against them.

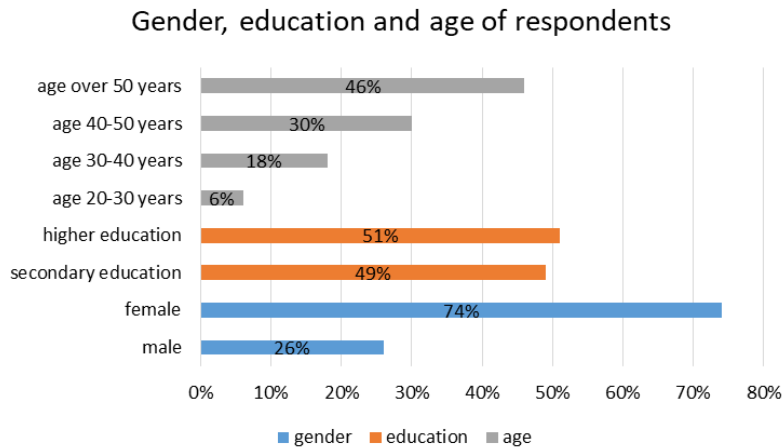
2. MATERIALS AND METHODS

As a method of data collection for this research, a questionnaire was designed. The survey was conducted through the completion of the questionnaire by the respondents. The sample consisted of 100 respondents of both genders, varying in age and educational background. The respondents comprised employees and patients at the "Bukurešt" Polyclinic in Skopje.

3. RESULTS AND DISCUSSIONS

The questionnaire consisted of 16 questions divided into two sections. The first section aimed to collect general demographic data regarding the respondents, such as gender, age, and educational level. The results obtained from these questions are presented in Figure 1. The majority of the respondents were female (74%), possessed higher education (51%), and were over 50 years of age (46%).

Figure 1. Gender, education, and age of the respondents



Source: Authors' research

The second section of the questionnaire evaluated the respondents' knowledge regarding the toxicity of lead and cadmium, their presence in food, bioaccumulation, prevention, and related aspects.

Figure 2. Low concentrations of lead and cadmium in the human body: desirable or harmful

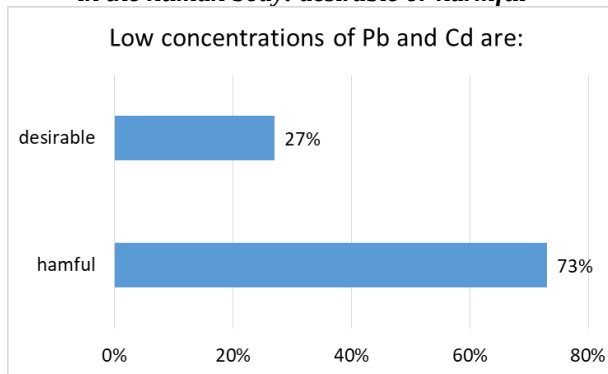
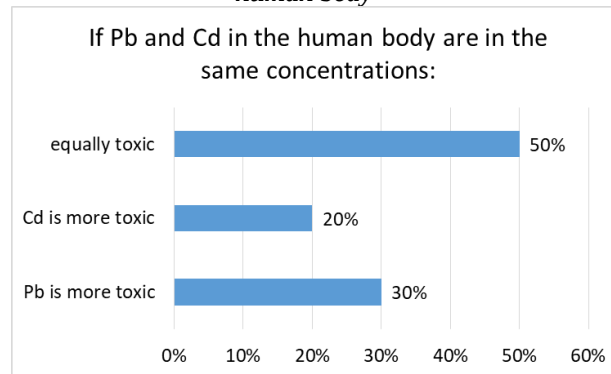


Figure 3. Toxicity of lead and cadmium in the human body



Source: Authors' research

The responses obtained to the first question of this group are presented in Figure 2. The majority of the respondents (73%) provided the correct answer that low concentrations of lead and cadmium have a harmful effect, whereas only 25% of the respondents considered these elements to be desirable in low concentrations. The subsequent question addressed which of the two metals is more toxic lead or cadmium when present in identical concentrations (Figure 3). The lowest percentage of respondents provided the correct answer to this question (20%). Half of the respondents (50%) considered that these metals have equal toxicity, and as many as 30% believed that lead is more toxic.

Figure 4. Presence of lead and cadmium in food

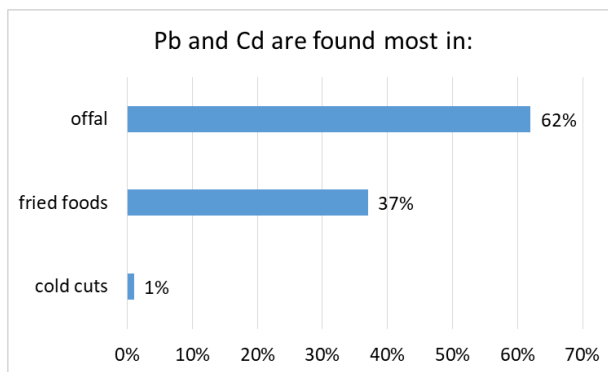
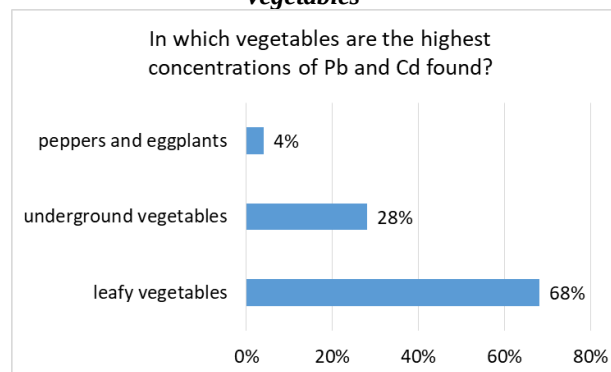


Figure 5. Presence of lead and cadmium in vegetables



Source: Authors' research

The question in Figure 4 provides insight into the respondents' knowledge regarding the food categories containing the highest levels of these heavy metals. The majority of the respondents (62%) provided the correct answer that animal offal (variety meats) contains the highest concentrations, while a high percentage (37%) gave the entirely incorrect answer that lead and cadmium are most abundant in fried foods. Only 1% of the respondents considered lead and cadmium to be most prevalent in cured meat products.

Figure 5 presents the responses to the question regarding which types of vegetables contain the highest concentrations of lead and cadmium. The majority of the respondents (68%) provided the correct answer that leafy vegetables contain the highest levels, 28% believed that lead and cadmium are most abundant in root vegetables, and 4% indicated that these elements are most present in peppers and tomatoes.

Figure 6. Lead in plants from industrial and rural areas

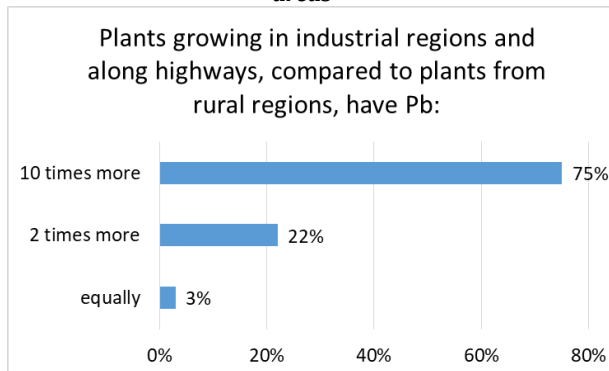
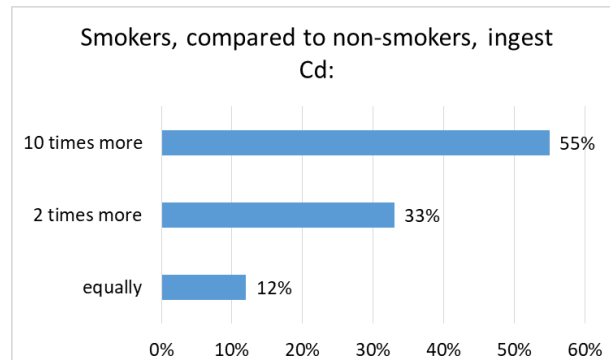


Figure 7. Cadmium intake through smoking



Source: Authors' research

The subsequent question provided insight into the respondents' knowledge regarding how many times higher the lead content is in plants from industrial regions compared to those from rural regions. As shown in Figure 6, as many as 75% of the respondents provided the correct answer, while only 3% of the respondents considered that the concentration of lead and cadmium in plants from industrial and rural areas is identical.

The responses to the next question were once again incorrect for a large percentage of the respondents. Specifically, 55% of the respondents believed that smokers ingest 10 times more cadmium through smoking than non-smokers, and 12% considered that smokers and non-smokers ingest the same amount of cadmium, which are incorrect answers. Only 33% of the respondents provided the correct answer (Figure 7).

Figure 8. Accumulation time of lead and cadmium in the human body

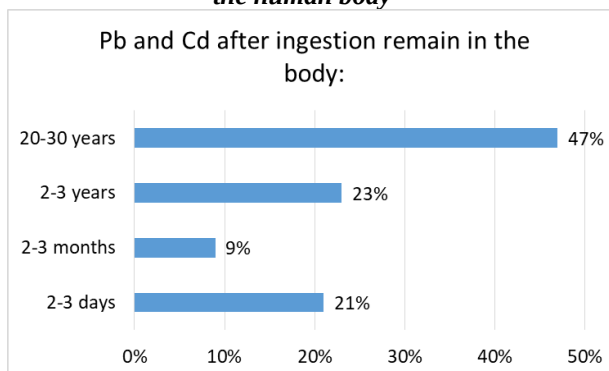
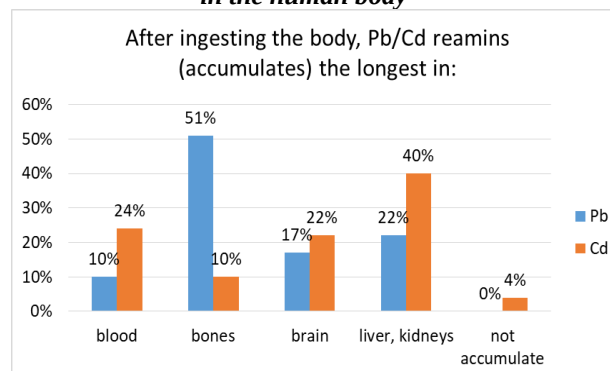


Figure 9. Accumulation sites of lead and cadmium in the human body



Source: Authors' research

The results regarding the question concerning the accumulation of lead and cadmium in the human body are presented in Figure 8. The majority of the respondents provided the correct answer that, upon ingestion, lead and cadmium remain in the body for 20 to 30 years. However, more than half of the respondents gave incorrect answers, and it is concerning that as many as 21% believed that these harmful metals remain in the body for only 2 to 3 days.

The body parts where lead and cadmium accumulate are addressed by the questions presented in Figure 9. Specifically, 51% of the respondents provided the correct answer that accumulation occurs in the bones. Furthermore, regarding the question of where cadmium accumulates and remains the longest, the majority of the

respondents correctly identified the liver and kidneys (40%), yet as many as 60% of the respondents gave incorrect answers.

Figure 10. Diseases not caused by cadmium

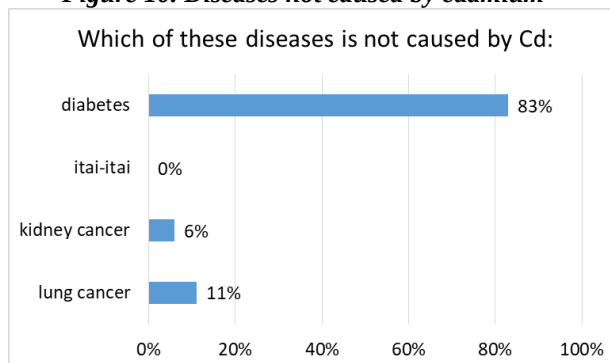
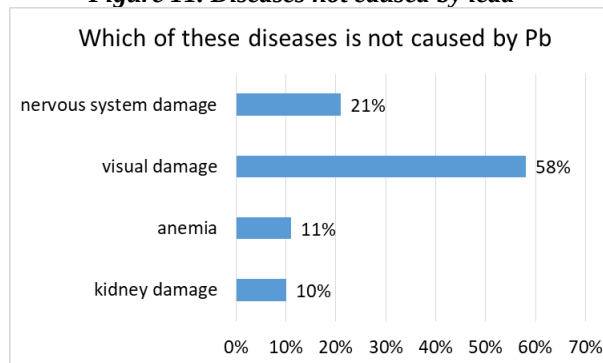


Figure 11. Diseases not caused by lead



Source: Authors' research

The next two questions referred to the diseases caused by lead and cadmium. Figure 10 presents the diseases not caused by cadmium, whereas Figure 11 illustrates those not caused by lead. As can be seen from Figure 10, as many as 83% of the respondents knew that among all the listed conditions, only diabetes was not caused by cadmium. Figure 11 shows that more than half of the respondents (58%) provided the correct answer that only vision impairment is not a consequence of lead presence.

Figure 12. How the absorption of lead and cadmium is reduced

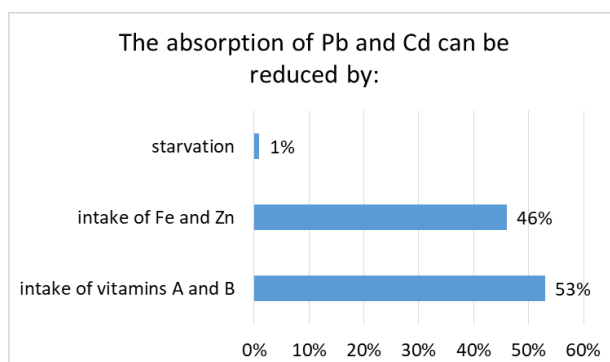
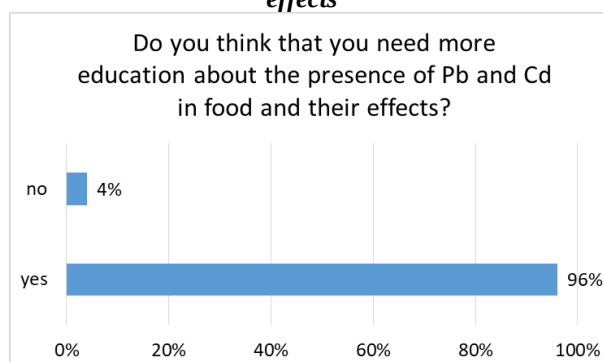


Figure 13. Need for further education regarding the presence of lead and cadmium in food and their effects



Source: Authors' research

The next question provided insight into what should be consumed, i.e., introduced into the body, to reduce the absorption of lead and cadmium. The highest percentage of respondents gave incorrect answers: 53% considered that vitamins A and B should be ingested, and 1% believed that fasting is necessary. The correct answer was provided by 46% of the respondents, who stated that the absorption of lead and cadmium is reduced by the intake of Fe and Zn (Figure 12).

The final question addressed whether the respondents felt they needed more education regarding the presence of lead and cadmium in food and their effects. The results of this question are presented in Figure 13, which shows that as many as 96% believed they needed further education on this topic.

4. CONCLUSIONS

A study was conducted among the population of Skopje to assess their knowledge regarding the presence of lead and cadmium in food and their harmful effects. For this purpose, a questionnaire consisting of 16 questions was designed. The survey was conducted among 100 respondents who were employees and patients at the "Bukurešt" Polyclinic. The questions were divided into two groups: the first group comprised general questions regarding the respondents' profile, while the second group focused on the presence of lead and cadmium in food, their accumulation, absorption, and toxic effects.

Nearly three-quarters of the respondents, specifically 74%, were female, aged over 50 years (46%) and between 40 and 50 years (30%), with nearly half of them holding higher education (49%) and the other half (51%) having secondary education.

A large proportion of the respondents (73%) knew that lead and cadmium are very harmful even at low concentrations, but only a small fraction (20%) knew that cadmium is much more toxic than lead when present in identical concentrations.

The research showed that respondents were generally aware of where these metals are present: 68% knew that these metals are most abundant in leafy vegetables, and 62% knew that animal offal (variety meats) is the food of animal origin containing the highest levels. As many as 75% of them knew that plants growing in industrial regions and along roadsides contain 10 times more lead than plants in rural areas, yet only 33% of them knew that smokers ingest twice as much cadmium through smoking as non-smokers.

Regarding the question of how long lead and cadmium remain in the body, only 47% of the respondents provided the correct answer that they remain for 20 to 30 years, and it is a concerning finding that as many as 21% of them believed these elements remain in the body for only 2 to 3 days. Furthermore, 49% of them did not know that lead accumulates in the bones, and as many as 60% were unaware that cadmium accumulates in the liver and kidneys.

The research demonstrated that the respondents possessed partial knowledge regarding these hazardous elements, and as many as 96% of them considered that they needed further education on this issue. Therefore, greater attention should be devoted to additional education concerning the hazards originating from food.

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