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Examining Heavy Metal Transfer from Soil to Bread

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ABSTRACT

For Turkish society, bread has been an indispensable part of the kitchen and daily life throughout history. Due to its high consumption in Turkish society, it plays an important role in terms of both health and nutritional habits. Contamination from the soil where wheat is planted to the bread making process is of great importance for health. In this study, the amounts of heavy metals such as aluminum, copper, nickel, chromium, manganese, iron, lead and cadmium in the soil of an agricultural land, in flour obtained from wheat grown there and in bread made from this flour were investigated using ICP-MS. The average levels of Al, Cr, Cu, Mn, Ni, Cd, Fe, Pb and As in soil samples were 120.46, 12.23, 44.9, 93.46, 10.83, 2.06, 196.87, 1.96 and 0.21 mg/kg, respectively. In flour samples, these levels were 17.20, 2.03, 28.93, 26.3, 3.37, 0.09, 30.93, 1.37 and 0.03 mg/kg, respectively. In bread samples, 11.27, 0.77, 8.27, 18.63, 0.4, 0.02, 12.76, 0.04 and 0.001 mg/kg, respectively. The results obtained show that high metal levels in the soil are also found in bread. This indicates that heavy metal levels in bread may pose health risks in long-term consumption. Especially levels of aluminum, nickel, chromium and cadmium metals can cause serious health problems. Therefore, it is important to reduce heavy metal contamination in agriculture and production processes and to conduct regular inspections. Compliance with maximum limits set by health authorities and regulatory agencies is also critical for public health.

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Introduction

Bread is a food item that has an important place in our daily diet and is consumed most frequently by consumers. It has an indispensable importance in terms of nutrition as it contains basic nutrients such as carbohydrates, proteins, vitamins and minerals. In Turkey, an average of 65% of an individual's daily energy intake is obtained from grains, and 55% of this is obtained from bread. Approximately 50% of the daily protein intake is obtained from bread consumption (Zioła- Lebbos et al. 2019; Frankowska et al. 2021; Yurt and Bayraklı 2022; Basaran 2022). This rate is 90% in poor countries and 40% in developed countries. The fact that people with limited income meet their nutritional needs from cheap grain group foods, especially bread, causes this rate to increase. Bread is not only a source of calories, but also provides important nutrients for human nutrition, such as essential amino acids, minerals, vitamins, beneficial phytochemicals and dietary fiber (NDND 2014; Shewry & Hey 2015; Onur & Ceylan, 2023). The bread industry is shaped by the contributions of various businesses consisting of local and national businesses of different sizes. In recent years, the variety of bread produced by the food industry has increased as a result of the development of consumer awareness and increasing population rates (Sundkvist et al. 2001; Dewettinck et al. 2008). There is therefore currently more than one bread brand operating in the market (Li et al. 2019). The bread production process involves a series of complex operations, from the cultivation and storage of grains to their production and sales and marketing, which can lead to increased food-borne health risks (Hembrom et al. 2020).

One of these threat factors is heavy metals, which attract the attention of both consumers, manufacturers and scientists. Therefore, the processes from bread production to consumption need to be carefully managed and supervised to reduce potential health risks, especially heavy metals (Pirsaheb et al. 2021; Basaran 2022). Heavy metal pollution resulting from population growth, natural events and industrial activities mixes with air, water and soil in various ways and contaminates food (Belhaj et al. 2016; Chaza et al. 2018; Garg et al. 2019; Affourtit et al. 2020). Published tests on the toxicity of metals in soil to microorganisms, plants and animals date back approximately 30-40 years. Most older studies are of limited use in defining allowable metal concentrations in soil because they lack a wide enough range to define a complete dose-response, examine only one or a few soils, do not use standard methods, or do not report important properties of the soils examined (Rooney et al. 2006; Criel et al. 2008; Li et al. 2019). Solid waste disposal, wastewater irrigation, sludge applications and industrial activities are the major sources of soil heavy metal pollution, and increased metal uptake of food products grown in such contaminated soils is quite high (Chaza et al. 2018; Affourtit et al. 2020). Environmental pollution caused by heavy metals causes great negativities on ecosystems. These negativities can be easily carried from one ecosystem to another, directly or indirectly. Heavy metals reaching the atmosphere, rain, snow and hail can pollute surface water resources such as lakes, streams and rivers, and also cause pollution of underground water resources by leaking from the soil. Heavy metals can be transported from the soil to the human body through food, to animals through plants that serve as feed sources, and to humans through the meat and milk of animals. When water with high amounts of heavy metals is used in agricultural areas, it causes many negative effects on plants, animals and humans (Yerli et al 2020). Heavy metal accumulation in the soil can be reduced thanks to the buffering capacity of the soil and the organic matter, clay, iron and aluminum oxides found in the soil. In addition, many factors such as soil texture, organic carbon, soil water content, soil temperature, phosphorus, clay type, carbonates and bicarbonates can affect the movement of heavy metals in the soil. The most abundant heavy metals in soil are arsenic, mercury, zinc, cadmium, chromium, lead and nickel (Wuana & Okieimen 2011). Heavy metals can easily pass from soil to seeds in agricultural lands, from seeds to bread or baked goods, and then to the human body. Excessive accumulation of heavy metals in agricultural soils not only causes soil contamination but can also lead to increased uptake of heavy metals by crops, threatening food quality and safety (Muchuweti et al. 2006). Between 2018 and 2019, samples were collected from Shenzhen city and region to investigate heavy metal pollution in rice, flour and products in Shenzhen. Flour and flour products have been tested for lead, cadmium, total mercury and total arsenic. The results show that the cadmium detection rate in flour and flour products is 98.13%, over 50% (Yang et al., 2020). In the study conducted by Mahdi and Omran (2021), the levels of toxic heavy metals such as Cd, Pb, Cr, Ni, Zn, Cu, Fe, Co, As were determined using X-Ray fluorescence in flour made from wheat samples collected randomly and seasonally from three silos in Baghdad and kept for a long time. The results obtained showed that the levels of Cd, Pb and Cr exceeded the permissible safe limits according to FAO/WHO. Although it is thought that storage conditions, as well as heavy metal pollution from the soil, affect this situation.

Effects of Heavy Metals on Human Health

Heavy metals that can be easily transported between ecosystems can cause serious damage to the environment and human health (Yerli, Çakmakcı, Sahin, & Tüfenkçi, 2020). Arsenic causes liver enlargement, skin staining and different skin diseases, respiratory cancer and bone disorders. High exposure to mercury metal causes kidney damage, damage to the nervous system and miscarriage during pregnancy (Çağlarırmak, & Hepçimen, 2010). While copper is one of the heavy metals necessary for the body, high amounts of copper intake cause brain damage and regression in body development (Özbolat, & Tuli, 2006). Boron causes bone damage. Boron poisoning causes nausea, headache, diarrhea, muscle spasms, skin lesions, irregularities in the digestive mechanism and glands (Velioğlu & Şimşek, 2003; Turkez, Geyikoglu, Tatar, Keles, & Kaplan, 2012). Mercury poisoning causes psychological disorders (Bakar & Baba, 2009). Iron plays an important role in maintaining various metabolic processes in the body. In case of deficiency, symptoms such as shortness of breath, weakness, fatigue and anemia may occur. However, excessive iron accumulation can lead to health problems such as liver failure, dizziness, and stomach disorders (Finkelman, Skinner, Plumlee, & Bunnell, 2001; Atıcı, Gültekin, Şen, & Elp, 2016). Zinc causes ulcers, pulmonary edema, irritation of mucous membranes and respiratory tract (Vural, 1993). Although lead is one of the first metals used since ancient times, it is known as an important heavy metal that causes serious toxic effects on human metabolism (Kara, Pırlak, & Özdilek, 2004; Asri & Sönmez, 2006).

In this study, the amounts of heavy metals in the soil of an agricultural land, in the flour obtained from wheat grown there, and in the bread made from that flour were examined. For the purpose of this study, the changes in Cr, Al, Cd, Mn, Pb, As, Fe, Cu and Ni grades in soil, flour, and bread were examined as shown schematically in Figure 1.

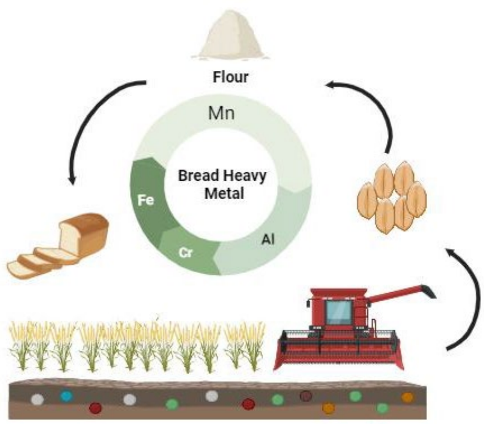

Figure 1. Schematic illustration of farm to table

Experimental

Material and Methods

All chemicals belonged to the category of analytical reagents. %65 HNO_3 and %48 HF, %30 H_2O_2 were purchased from Sigma-Aldrich and Merck, respectively. Multi-element standard solutions were obtained from Agilent (Santa Clara, USA) and were based on Merck standard mixture solutions. Ultrapure deionized water was used for the preparation of standard and sample solutions. Heavy metal analyses were performed using an ICP-MS 7900/ASX 500 instrument (Agilent Technologies, Japan). In addition, the Microwave Digestion System (CEM Mars5, USA), wheat grinder Perten Instrument (LM-3100, Sweden), an ultra-distilled water device (Millipore, USA) were used.

Three soil samples were taken from different parts of the cultivated field. It was taken from the flour coming out of the wheat mill and samples were taken from the bread whose making is given in detail below using this flour. The samples were first dried in an oven at 70 °C for 3 h. Later, a method that could address all sample types and ensure complete dissolution was created in the CEM Mars 5 Microwave Disintegration System. 0.5 g of each samples was weighed and 12 mL of HNO_3 and 3 mL H_2O_2 were added on it, and a closed system was created. The segments were pulled out at the end of the 30 min. method (Temperature: 240 ˚C, Gradient temperature-time: 30 min, Holding time: 15 min) in the device. An extra 3 mL of HF was added to soil samples only to dissolve silicon. After cooling to room temperature, the samples were passed through a filter with a pore size of 0.45 µm and then analyzed by ICP-MS. The analyses were performed in three replicates and three parallel runs.

Bread Making

The wheat obtained from the Bolu region was cleaned and ground in a wheat grinder to obtain flour. After the necessary resting process of the flour is done, it is ready for use. In the laboratory selected for bread making, 1 kg of flour obtained from ground wheat was kneaded with 700 ml of water in a spiral mixer with a capacity of 5 L for 2 min. at a slow speed and 3 min. at a fast speed. Afterwards, 25 g of salt and 40 g of yeast were added and the kneading process was continued for another 2 min.. In order for the yeast to become active in the dough, the internal temperature of the dough must be 21-27 °C. After the internal temperature of the dough reached +22°C, the dough was placed in a lightly oiled storage container and pre-fermented for 30 min.. At the end of the pre-fermentation, the dough was divided into two 500 gr pieces and shaped into bread. Then, for the final fermentation, the bread was placed in the baking container and kept in the fermentation cabinet at 30 °C and 80% humidity for 60 min.. At the end of the fermentation period, the breads were baked in the oven at 220 °C for 40 min.. At the end of the baking time, the breads were removed from the oven and allowed to cool. Cooled breads were analysed without waiting.

Results and discussion

Within the scope of the study, soil samples taken from the field where wheat was planted, flour obtained from the wheat grown and harvested after planting, and finally samples from the bread made from this flour were taken to determine the levels of 9 different heavy metals. Findings regarding heavy metal levels are given in table 1. Additionally, heavy metal distribution in each of the soil, flour and bread samples is shown in Figures 3-5. The change in heavy metal content in the process from soil to bread making has not been examined in the literature. Each of the sample types mentioned in the literature was examined and evaluated separately. An attempt was made to compare and examine the distribution of heavy metals in bread, which is among the most basic food sources that pose a risk to health. When the studies in the literature are examined, it has been seen that the heavy metal content in the soil is in accordance with the standards and even insufficient in terms of metals that will be beneficial for the plant depending on the type of product to be grown. The average Al, Cr, Cu, Mn, Ni, Cd, Fe, Pb and As heavy metal levels obtained in the soil samples were found to be 120.46 ± 2.7 mg/kg, 12.23 ±0.7 mg/kg, 44.9 ± 4.6 mg/kg, 93.46 ± 2.3 mg/kg, 10.83 ± 2.8 mg/kg, 2.06 ± 0.06 mg/kg, 196.87 ± 7.8 mg/kg, 1.96 ± 0.11 mg/kg and 0.21 ± 0.04 mg/kg, respectively.

Average Al levels in flour and bread samples were found to be 17.2 ± 1.6 and 11.7 ± 1.5 mg/kg, respectively. It is seen that the Al level is very high, especially in soil samples. This situation was also seen in the amount of Fe. Fe levels were found to be 196.8 ± 7.9, 30.9 ± 3.0 and 12.8 ± 1.5 mg/kg, respectively. It has been observed that these two elements pass into wheat from the soil at high levels. It has been shown that the amount of iron in food products is beneficial for health and is found at high levels, starting from the soil and ending with bread.

Figure 2. Demonstration of bread making.

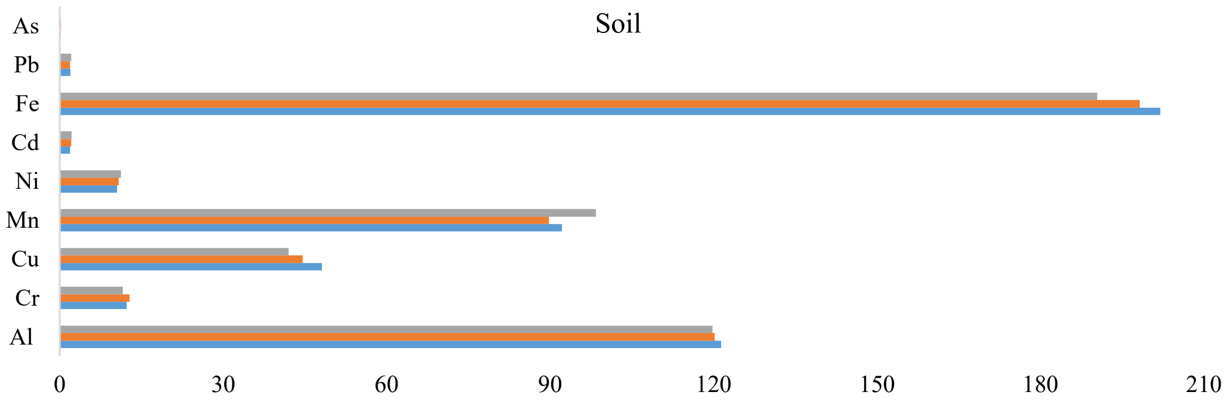

Figure 3. Illustration of heavy metal contents of soil samples.

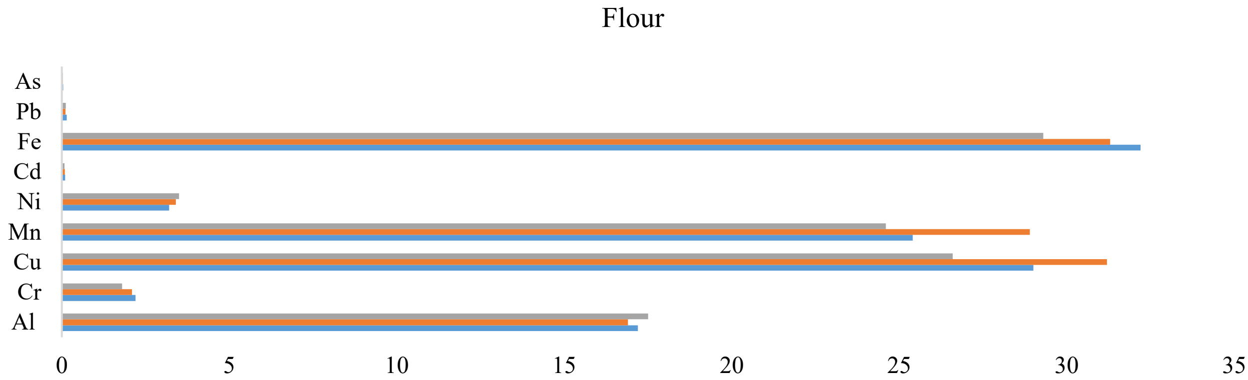

Figure 4. Illustration of heavy metal contents of flour samples.

Table 1. Mean heavy metal levels of samples(mg/kg)

Samples	n	Al	Cr	Cu	Mn	Ni	Cd	Fe	Pb	As
Soil 1	3	121.4±2.3	12.3±0.6	48.1±3.5	92.2±4.2	10.5±1.2	1.9±0.4	202±8.8	1.92±0.5	0.2±0.02
Soil 2	3	120.2 ±2.4	12.8±1.1	44.6±4.2	89.8±4.3	10.8±0.8	2.1±0.2	198.2±5.6	1.86±0.4	0.24±0.07
Soil 3	3	119.8±3.5	11.6±0.4	42±6.3	98.4±6.3	11.2±1.5	2.2±0.3	190.4±9.2	2.1±0.8	0.18±0.04
Flour 1	3	17.2±1.3	2.2±0.5	29±2.4	25.4±2.4	3.2±0.6	0.1±0.008	32.2±4.6	0.15±0.06	0.04±0.003
Flour 2	3	16.9±1.8	2.1±0.3	31.2±2.1	28.9±5.2	3.4±0.9	0.088±0.004	31.3±2.4	0.11±0.004	0.03±0.006
Flour 3	3	17.5±1.9	1.8±0.2	26.6±4.3	24.6±2.1	3.5±0.8	0.08±0.002	29.3±2.1	0.12±0.002	0.03±0.002
Bread 1	3	11.8±2.1	0.7±0.08	9.2±2.2	18.8±1.4	0.36±0.03	0.025±0.012	13.2±0.9	0.046±0.006	0.0012±0.00008
Bread 2	3	11.1±1.6	0.8±0.06	8.9±2.1	19.6±1.2	0.44±0.08	0.024±0.01	12.4±2.5	0.042±0.009	0.0011±0.0002
Bread 3	3	10.9±0.8	0.8±0.08	6.7±2.6	17.5±3.2	0.38±0.04	0.012±0.002	12.7±1.2	0.032±0.003	0.0009±0.0001

n: Number of sample replicates

Therefore, it is seen that bread has higher levels than other heavy metals. In addition, when the average Al level in the literature was examined to determine the heavy metal contents in different types of bread, Arnich et al. (2012), Wang et al. (2020) and Zioła-Frankowska et al. found it to be 2.6 mg/kg, 4.79 mg/kg, 3.62 mg/kg, respectively. It seems that the average Al value obtained in this study is higher. It is seen that the amounts of Cd, As and Pb in all soil, flour and bread samples are in trace amounts, as seen in Table 1. It is seen that the average values of Cr amounts in all flour and bread samples, are 2.0 ± 0.3 and 0.76 ± 0.07 mg/kg, respectively. It is seen that the average values of Ni amounts in all flour and bread samples, are 3.37 ± 0.37 and 0.39 ± 0.076 mg/kg, respectively (Table 1).

Average Cu levels in soil, flour and bread samples were found to be 44.9 ± 4.7, 28.9 ± 2.9 and 4.7 ± 2.3 mg/kg, respectively. The fact that the amount of copper in wheat is high compared to the amount of copper in the soil suggests that wheat receives external copper supplements. External copper supplementation is generally applied to wheat during its development period. In addition, the average Cu level in flour was found to be higher than the studies conducted in the literature and was found to be 28.93 ± 2.9 mg/kg. In the study conducted by Lei et al. (2015), it was observed that the amount of Cu in the soil of a roadside field was 28.1 mg/kg, while the amount of Cu in the flour obtained from there was 2.66 mg/kg. It is seen that the Cu level is very high, especially in flour samples. In copper deficiency, wheat ears do not form well, the stem bends and there is a tendency to lean sideways. Resistance to diseases decreases. In this study, the average Mn level in bread was found to be 18.63 mg/kg; however, it corresponds to a higher value than the literature in general. Shokunbi et al. (2019) stated that the average Mn levels in bread were 7.32 mg/kg (5.08–9.57 mg/kg); Zioła-Frankowska et al. (2021) stated that the average level in different types of bread is 7.28 mg/kg.

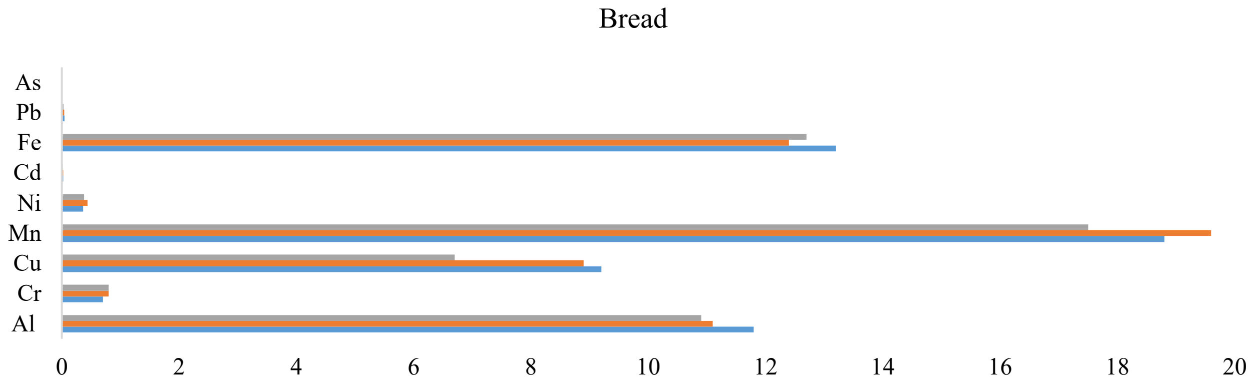

Figure 5. Illustration of heavy metal contents of bread samples.

When all the results were examined, it was seen that the amount of Al and Fe was at high levels in the samples collected during the process from soil to bread, and the levels of Mn and Cu were also at high levels. It has been observed that toxic metal levels other than this do not pose any threat to health. It is known that the reason why these values are at these levels is not only due to the metal content of the soil but also to the conscious use of pesticides and water use. Studies show that the accumulation of heavy metals in the soil will increase day by day due to factors such as unconscious tillage, incorrect irrigation, pesticide application and fertilization, and as a result, it will become increasingly difficult to obtain healthy products.

Aluminum (Al): High intake of aluminum is associated with neurotoxic effects and Alzheimer's disease (Odukoya, et al, 2022). The presence of 11.27 mg/kg Al level in bread poses health risks in the long term.

Bakır (Cu): Although copper is an essential trace element, excessive intake can be toxic and cause gastrointestinal disorders (Zhao, et al, 2020). The 0.77 mg/kg Cu level in bread appears to be within acceptable limits.

Nikel (Ni): Nickel can cause allergic reactions and chronic exposure can increase the risk of cancer. The presence of a Ni level of 7.39 mg/kg in bread may pose a potential health risk.

Demir (Fe): Iron is an essential mineral for the body, but excessive intake can be toxic and cause liver damage (Odukoya, et al, 2022). The 12.76 mg/kg Fe level in bread seems to be within acceptable limits.

Kurşun (Pb): Lead is toxic and can cause developmental problems in children and various health problems in adults (Román-Ochoa, et al, 2023). Although the level of 0.04 mg/kg Pb in bread is low, caution should be exercised as there is no safe level of lead exposure.

Kadmiyum (Cd): Cadmium can cause kidney damage, osteoporosis, and cancer (Özden, & Erkan, 2016). The presence of a Cd level of 0.02 mg/kg in bread is noteworthy and may pose health risks in long-term consumption.

Arsenik (As): Arsenic is toxic and classified as a carcinogen (Sarwar, et al, 2021). The level of 0.001 mg/kg As in bread is low, but it may cause health problems with long-term intake.

Conclusions

In this study, the stages of the production process of bread, one of the basic foods of our daily life; The changes in heavy metal amounts in the soil in the cultivated field, the flour obtained from the wheat grown there, and the bread made from this flour were examined. The results obtained show that the variable parameters in the production process of the raw materials used, rather than the bread consumed, change the levels of heavy metals and that they are found at a certain level in the final consumer product, bread. While it is necessary to constantly check whether these levels are harmful to human health, it is known that these controls are not carried out in the world. With this study, authorities need to develop a strategy by creating awareness about following this process. It is important to be compatible and follow not only with bread but also with all the basic food products in our daily lives. As a result of the data obtained, the presence of heavy metal levels in bread poses various health risks and some risks in long-term consumption. In particular, levels of metals such as aluminum, nickel, chromium and cadmium cause significant health problems with long-term consumption.

It has also been determined that exposure to high doses of Cu can cause irritation in the nose, mouth and eyes and cause headaches (Lei et al. 2015). Cd causes both acute and chronic toxicity in the human body and in some parts of the human body (such as the kidneys, lungs and bones) (Oteef et al., 2015). High concentrations of Ni are said to cause cancer, fatigue, headache and dizziness, skin rash, heart and respiratory diseases (Khan et al., 2013). One of the most important ways of exposure to environmental pollutants is through the consumption of contaminated foods. Especially in Turkey, wheat and its products are important nutrients because they constitute a significant part of the daily diet. Therefore, consumers have a high potential for exposure to environmental pollutants due to contaminated wheat products.

Therefore, it is important to use appropriate agricultural and production methods to minimize heavy metal contamination in the bread production process, as well as to carry out regular inspections. Compliance with the maximum limits set by health authorities and regulatory bodies is also critical for public health.

Organic Farming and Green Fertilization Methods: Organic farming protects soil health by replacing chemical fertilizers and synthetic pesticides with natural animal or plant fertilizers such as compost. These methods can reduce the accumulation of heavy metals in the soil.

Phosphorus and pH Management: Balancing phosphorus and pH levels can affect the mobility of heavy metals in soil. Phosphorus deficiency can lead to greater absorption of heavy metals by plants, so a balanced phosphorus management is important.

Phytoremediation: Plant species that absorb heavy metals from the soil can absorb and store heavy metals from the soil and reduce heavy metal pollution. However, the use of these methods requires careful selection of plants and careful determination of growing conditions.

Education: In addition to these practices, another important factor to reduce heavy metal pollution in soil is to ensure the development of conscious farmers. Conscious farmers contribute to healthy and safe food production.

Soil Analyses and Management Plans: Regular analysis of samples taken from fields is very important for the health of the practices. These analyses show which areas are at risk of heavy metal contamination and management plans can be created accordingly. At the same time, these analyses ensure the safety of products reaching human consumption along the food chain.

Declarations

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Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations/Conflict of Interest

I have no conflict of interest to declare.

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