Impact of Anthropogenic Activities on Environmental Hazards Caused by Heavy Metal Pollution in Agricultural Ecosystems

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1. Introduction

Environmental pollution is one of the most contributing factors to the degradation of the biosphere quality and its components. Among these, heavy metals play an important role in human health. Metals can be divided into two categories in terms of plant nutrition. The first category includes some metals such as copper (Cu), nickel (Ni), selenium (Se) and zinc (Zn) that are essential in low concentrations for the health, growth, and production of microorganisms, plants, animals, and humans. Other groups of metals such as lead (Pb), arsenic (As), cadmium (Cd), and mercury (Hg) are not essential metals and may cause toxicity in plants and animals even in low concentrations. Soil contamination with heavy metals has become a global concern due to its threats to ecosystems including soil, water, plants, animals, and human life. Soil contamination by excess metals occur primary as a result of industrial activities such as metallurgical processes, mining, and sewage sludge application to agricultural land. In Iran, as the result of development of urbanization and industrialization, there is considerable concern about soil contamination by heavy metals.

Zanjan province is one of the most industrialized cities in Iran due to having many heavy metal mines. One such heavy metal contaminated area is in the vicinities of the mining site of Zanjan Zinc Industrial Complex, Zanjan, Iran, where significant metal contamination of agricultural soils has been identified. Mining waste generated by mines and smelting units in this area is spread by wind or runoff to other areas and thus pollutes the soil, plants, surfaces, and groundwater. Crops grown in polluted areas are contaminated directly through the roots and indirectly through atmospheric subsidence. It has also been reported that agricultural products in Zanjan province are heavily contaminated with heavy metals in some areas and these metals can enter the food chain and thus affect human and animal health. The potential health risk from consumption of crops is assessed by hazard quotient (HQ). The safe range of HQ is values less than one. When the quotient is <1, this means no potential health effects are expected from exposure, but when it is >1, it signifies that there are potential health risks due to

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exposure. Despite the existence of many mines in Zanjan province, a comprehensive study on the potential health risks of consumption of grain crops has not been done, so the aim of this study was to investigate the changes in the concentrations of lead (Pb), cadmium (Cd), copper (Cu) and zinc (Zn) in wheat grains and soils at selected distances from a heavy metal pollution source (the mining site of Zanjan Zinc Industrial Complex, Zanjan, Iran) as well as the potential hazard quotient (HQ) related to these metals through the consumption of the product.

2. Materials and Methods

This descriptive cross-sectional study was performed on soil and wheat randomly selected samples located around the zinc mines in Zanjan; so that the samples could indicate the distribution of Pb, Cd, Cu and Zn in the area. Ten samples of wheat plants were harvested randomly from a radius of 10 to 40 km (10 (S1), 20 (S2), 30 (S3) and 40 (S4) km) from the mine during the harvest season. After separating the plant grain from other parts, the samples were placed in the oven for 24 hours at 100 ° C. Then plant extracts were extracted using digestion with 65% nitric acid and the concentrations of Pb, Cd, Cu and Zn were analyzed using atomic absorption spectrometry (AAS). Also, in order to study the changes in the concentrations of the soil metals at the selected distances from the mine, 3 soil samples were taken from a depth of 0-20 cm at any specified distance from the mine (S1, S2, S3 and S4). After air drying and sieving the soil samples, Pb, Cu, Zn and Cd available and total concentrations in the studied samples were extracted by DTPA-TEA and 4M nitric acid method, respectively, and then analyzed by AAS.

3. Results and Discussion

The results showed that distancing from the mine, the total and available concentrations of all four metals significantly decreased. The highest total concentrations of Pb (168.9 mg kg^{-1}), Cd (5.6 mg kg^{-1}), Zn (434.5 mg kg^{-1}) and Cu (97.6 mg kg^{-1}) were obtained from the S1 soil. The lowest total concentrations of these metals were recorded in S4 soil and equal to 59.1, 1.1, 88.5 and 28.9 mg kg^{-1}, respectively. The available concentrations of all four metals were also decreased with increasing distance from the mine so that the highest concentrations of available Pb (45.6 mg kg^{-1}), Cd (1.7 mg kg^{-1}), Zn (52.4 mg kg^{-1}) and Cu (24.8 mg kg^{-1}) were obtained from the S1 soil. The lowest available concentrations of these metals were recorded in S4 soil and equal to 9.6, 0.2, 14.3 and 1.9 mg kg^{-1}, respectively. However, no significant difference was observed between the available Pb concentration of soils taken from S3 soil and S4 soil. The comparison results of the mean Pb, Cd, Cu and Zn concentrations in wheat grains harvested from the soils around the mine showed that Pb, Cd, Zn and Cu concentrations in grain decreased with increasing distance from the mine. The highest concentrations of Pb (59.3 mg kg^{-1}), Cd (1.3 mg kg^{-1}), Zn (79.7 mg kg^{-1}) and Cu (48.8 mg kg^{-1}) were obtained from the grain samples harvested from S1 soil, followed by grains harvested from S2, S3 and S4 soils. Also, unlike Zn, Cu and Cd, no significant difference was observed in the Pb concentrations of grain samples harvested from S3 and S4 soils, which can be due to the non-significant reduction of the available concentration of Pb in

the soil of S4 compared to S3 soil. Comparison results of hazard quotients (HQ) revealed that the HQ amounts of all four metals were significantly decreased with increasing distance from the mine. The HQ levels of each metals at all distances from the mine are below one (with the exception of Pb), which indicates that the possibility of exposure to non-cancerous diseases caused by that metals will not be present for the consumer throughout life. If the HQ value of metal is greater than one, the toxicity of that metal may adversely affect the health of the consumer. Therefore, Pb has such a property and the HQ values of this metals in the distances of 10 (6.17), 20 (5.35), 30 (3.48) and 40 (3.31) km from the mine are high and dangerous.

4. Conclusion

It is concluded that the consumers of these products will not be in the safe range in terms of the adverse effects of non-cancerous diseases caused by high concentrations of Pb. Moreover, despite the low HQ amounts of Zn, Cu and Cd, it is likely that the amounts of HQ increase in the coming years, especially for Cd and Cu. Therefore, much attention should be paid to consumption and cultivation around industrial areas.

Keywords: Hazard Quotient, Heavy Metal, Environmental Hazard, Agricultural Ecosystem

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