HEAVY METAL ACCUMULATION IN WHEAT PLANTS IRRIGATED BY WASTE WATER

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Heavy metals, known as a highly polluting group with toxic and carcinogen effects, tend to accumulate in living organisms. As the farmers of Konya began to use the wastewater of the discharge channels for agricultural irrigation, the productive soils have been polluted for a long time period, and the plants growing in the vicinity of the discharge channel were negatively affected. The study investigates heavy metals accumulation in 60 wheat samples collected from wastewater-irrigated fields around discharge channels, during the growth period of plants. Results of this study showed that sewage channel water application for field watering increased the heavy metals (Cu, Cr, Mn, Ni, Pb and Zn) content in the root, body and seed parts of wheat plant, the increases recorded being higher for Mn and Zn.

Keywords: sewage, heavy metal, wheat, accumulation, toxic effect

INTRODUCTION

Heavy metal accumulation in plant and soil from natural and artificial sources and their effects represent important environmental pollution problems. Most of the heavy metals accumulate in the biological environment in different ways, via the nutrient chain. Increasing heavy metal accumulation at critical levels in living organisms from contaminated environment may have morbidity and mortality effects. Some of the most toxic trace elements for living organisms – all belonging to the heavy metal group – are As, Be, Cd, Cr, Pb, Mn, Hg, Ni, Se and V.

Sometimes, agricultural activities, including vegetal and animal production and utilization of natural water sources are incorrectly and unconsciously performed, although they can be equally constructive and destructive. In the same way, high quality soils, running water, lakes, and rivers are also polluted with heavy metals from the solid and liquid discharges of the industrial facilities.

In many developing countries, domestic and industrial – polluted – sewage water is usually used for irrigating agricultural lands, in the absence of any treatment, which negatively affects lands fertility and the quality of the plants. Besides, the increase of heavy metals concentration up to highly toxic levels may also affect animals and human body through the food chain to which they have thus access.

Some investigations showed that the level of heavy metals in the soil may raise the level of lead in plants. However, a close connection between the concentration of heavy metals in plants and the soil is quite difficult to establish, as the metal bioavailability of the soil depends on several factors, such as plant growth and metal distribution in different parts of the plants. Pollution of the biosphere with heavy metals, induced by industrial, agricultural, and domestic activities poses serious problems in the safe use of agricultural lands.
The main sources of trace elements to plants are represented by their growing media from which trace elements are taken up by either root or foliage. Certain trace elements are essential in plant nutrition, however, plants growing in a polluted environment can accumulate metals at high concentrations, causing serious risks to human health, when plant-based foodstuffs are consumed. Heavy metal uptake by the plants grown in polluted soils (mostly from anthropogenic activities such as sewage sludge application) has been extensively studied. Interactions between metals occurring on root surface and within the plant may affect the uptake, as well as translocation and toxicity. In the present investigation, the heavy metal concentration of the plants grown around the wastewater discharge canal of Konya city (Turkey), following cereals irrigation with wastewater, was studied.

**MATERIALS AND METHOD**

**Study area**

The city of Konya, in the middle of Anatolia and surrounded by mountains, is situated between the south border of the Toros Mountain and the north border of the neighbouring region of Konya (between 36.5-39.5 north latitude and 31.5-34.5 east longitude). In Konya there were 993 industrial establishments, producing brick, paper, oil, cement. Air pollution in the region was mostly caused by rural heating. For this reason, investigations were developed in the winter months. As, in the last 10 years, the city witnessed considerable development (at both industrial level and as to the population of Konya), environmental pollution has correspondingly increased.

The area taken into study is in the east part of the city. Konya Main Discharge Channel, reaching the Tuz Lake at a distance of about 150 km, affects an area of almost 300 km². Konya is approximately 1,100 meters above the sea level and has a semi-arid climate, hot and dry in summer and cold and snowy in winter.

There are three wastewater inputs to the lake of Tuz, namely the cities of Konya (the most important), Aksaray and Şereflıkoçhisar, the area appearing as a closed basin in which summer evaporation is the only water loss of the lake. Precipitations and polluted waters come from the residential and industrial area of Konya by the sewage system, connected to the Keçeli stream. The sewage system also brings the overflowing waters of the region. There are three promotion stations on the Konya Main Discharge system. The first station, in which the water is elevated 5 m at each pomp station, is about 15 km away from the city centre. The channel (about 350 km long) can also take the overflows of the Beyşehir Lake during the winter. The average flow rate of the discharge channel was about 25 m³ s⁻¹.

**Method of analysis**

Sixty wheat samples were collected from the 2nd and 3rd elevation pomp of the Konya main discharge channel. The wheat samples, collected from the plantations irrigated with sewage channel water, during harvesting, were divided into four parts as root, body, leaves and seed, and were investigated separately. They were dried in a ventilated oven at 70 °C until stable weight. One gram of each dried sample was separately put into the liners, for microwave burning. 10 mL of pure nitric acid (HNO₃) were added to each sample and left until the end of the gas release. Further on, the samples were put in a microwave burning cabinet (CEM – Mars x 5 model), burning being performed at 200 °C, 170 PSI, for 40 min., after which the samples were transferred to a 20 mL glass flask, the volume being completed with 25 mL distilled water, and finally analysed on a VISTA AX CCD Simultaneous ICP – AES system after filtration on fine filter paper.

**RESULTS**

60 wheat samples collected from the 2nd and 3rd elevation pumps on the Konya main discharge channel (divided into 4 parts as root, body, leaves and seed) were investigated. The heavy metal content in the wheat sample parts is plotted in the following figures.

![Figure 1: Heavy metal contents of wheat roots when changing the sampling period from April to June](image)
with 4.21 mg kg\(^{-1}\) at the 2nd pump and 3.58 mg kg\(^{-1}\), respectively, at the 3rd pump. In the stem, the copper content was similar in the same sampling period, increasing with 2.93 mg kg\(^{-1}\) and 2.88 mg kg\(^{-1}\), respectively, for the 2nd and 3rd pump.

The maximum copper content in the leaves was recorded with the 2nd pump (4.23 mg kg\(^{-1}\)). The copper content in the seeds collected in June was maximum at the second pump (4.21 mg kg\(^{-1}\)).

When sampling in June, the maximum level for the chromium content in four parts of the wheat plant was attained. In the root, the chromium content for the samples of the 2nd pump was of 3.65 mg kg\(^{-1}\), and of 3.85 mg kg\(^{-1}\) at the 3rd pump while in the wheat body, it was the highest at the 2nd pump (i.e., of 0.70 mg kg\(^{-1}\)). Chromium content in leaves was also the highest at the 2nd pump (0.91 mg kg\(^{-1}\)).

The chromium content of the seeds increased from April to June, the highest value being registered in June, at the 2nd pump (5.47 mg kg\(^{-1}\)).

The content of manganese in leaves and seeds was four times higher than in the roots and body parts of the plants. In June, it was also more than 4 times higher than in April, the highest values occurring in the roots, at the 2nd and 3rd pumps – 42.98 and 33.20 mg kg\(^{-1}\), respectively.

The maximum manganese content in the root was of 42.98 mg kg\(^{-1}\) for the 2nd pump, and of 33.20 mg kg\(^{-1}\) for the 3rd pump, respectively, while, in the plant body, it was lower than in the roots, the highest values being of 8.41 and 7.51 mg kg\(^{-1}\), respectively, for the 3rd and 2nd pump stations. In the leaves, the content of manganese was similar to that of the plant body and lower than that of the roots, its concentration attaining maximum values, of 10.46 and 9.69 mg kg\(^{-1}\), respectively, for the 2nd and 3rd pump stations. The wheat seeds contained high amounts of manganese, similarly to the root – 38.42 mg kg\(^{-1}\), at the 2nd pump station.

The nickel content in the root of the wheat increased in summer, reaching its maximum levels in June (5.55 and 11.23 mg kg\(^{-1}\), at the 2nd and 3rd pump stations, respectively). Similarly, the nickel content of the other parts of the wheat plant was the highest in June. The highest nickel levels in plants body and seeds were recorded for the 2nd pump station (0.76 and 9.92 mg kg\(^{-1}\) respectively) while, in the leaves, it was recorded for the 3rd pump (0.75 mg kg\(^{-1}\)).

The levels of lead in all parts of the wheat plant were generally higher in the samples of the 3rd pump station as compared to the 2nd pump. Higher lead levels in the root, body and leaves were of 1.70, 0.20 and 0.2 mg kg\(^{-1}\), respectively. In the seeds, the lead level was
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higher with 1.63 mg kg\textsuperscript{-1} in the 2\textsuperscript{nd} pump sample, where it also recorded its highest concentration.

The concentration of zinc was the highest in all the samples taken over in June. The maximum Zn content in the samples was detected in the 3\textsuperscript{rd} pump station. The highest values, of 40.12, 21.65, 21.45 and 22.31 mg kg\textsuperscript{-1}, respectively, were recorded in the root, plant body, leaves and seeds.

DISCUSSION

The study, performed on 60 plant samples, determined the heavy metal accumulation in wheat plant samples collected during their growing period, in soils irrigated with water from the Konya Main Discharge Channel. The effect of sewage application on cereals production and the content of Pb, Cd, Ni, Fe, Cu for two growing periods were investigated by Vigerust et al.\textsuperscript{11} The results showed that the Zn content increased in soils heavily irrigated with sewage water, while the heavy metal content of clay sandy soils in the 0-10 and 0-40 cm parts increased by the application of sewage waste. Such increases were also dependent on plant type.

When adding lime to the local sewage, the level of chromium, copper, lead, mercury, nickel, and zinc contents increased, while the heavy metal content remained at normal levels in plants structure.\textsuperscript{12} Experiments of Sanders et al.,\textsuperscript{13} performed on four different soils, showed that the effect of heavy metals on the agricultural production may be directly related to both soil structure and heavy metals accumulation into it.

After investigating the heavy metal accumulation in the soil and the fibres of tobacco plant following sewage discharge application, it was evidenced\textsuperscript{14} that the content of Zn, Cu, Mn, Ni, and Cd increased significantly, while the Fe level decreased with the increase of sewage application.

A study of Truby et al.\textsuperscript{15} on heavy metal uptake by garden plants irrigated with Freiburg city waste water evidenced a higher heavy metal content in the soil, alongwith higher Zn, Pb and Cd accumulations in the garbage, lettuce, spinach, carrot, potatoes, onion, cucumber, tomatoes and bean, etc. A linear relation was thus established between increasing irrigation with sewerage and petroleum refineries wastewater and the accumulation of Cd, Cu, Fe, Cr, Mn, Ni, Pb and Zn in Trifolii plants.\textsuperscript{16} The investigations carried out on the effects of soil pollution on heavy metal accumulation in the maize irrigated with sewage water and on the production obtained showed that the Cd, Cu, Pb, and Zn contents of the plants increased, which was more evident in cadmium and zinc, versus copper and lead.\textsuperscript{17} On the other hand, heavy metals concentration in the plants grown on unpolluted or less polluted soils remained within normal levels.\textsuperscript{18}

Seasonal modifications in the content of heavy metal of the rice field water, plants and soil around a Korean Pb-Zn mine showed that Cd, Pb, Cu and Zn concentrations in the irrigation water, soil and rice plant grown around the mine, irrigated with discharge water, are higher than the normal values.\textsuperscript{19} The heavy metal content in the body, leaves and seed of the plants grown near the mining area was also higher.

Wenzel et al.\textsuperscript{5} investigated the heavy metal content in plants grown on the Austrian Alpines mineral soils and the behaviour of Alpines terrestrial plants, in which both heavy metal (Cd, Cu, Ni, Pb and Zn) accumulations in the new plant shoots and the heavy metal content in the root were lower. Fytianos et al.\textsuperscript{4} compared the heavy metal (Pb, Cd, Ni, Cu, Mn and Zn) contents of the plants grown in industrialised and rural areas, on 60 soil and vegetable samples. No differences were recorded in the heavy metal content of the vegetables grown in green houses and in urban areas, yet significant differences were noticed as to the heavy metal content of plants grown in industrialised and, respectively, rural area.

Differences were also observed between plants grown in industrial and rural areas\textsuperscript{4} as to heavy metals deposition. Thus, Cu was found in carrots and celery, Cd in spinach and Pb in chicory. In addition, there were important differences in the soils of industrial and rural areas as to lead and zinc. According to other researches, heavy metals concentrations increased in the seeds, leaves, root and body of wheat irrigated with wastewater from the Konya Main Discharge Channel studied in this paper. The Cu, Cr, Mn, Ni, Pb and Zn in all parts of the plant increased, as due to the watering sewage system, the increases being
highest for Mn and Zn. Heavy metal accumulation was lower in the plants at the beginning of the irrigation period, heavy metal increases being recorded after irrigation. This increase is especially important when the plant and seeds enter the food chain of animals and humans.

Heavy metal concentrations in the wastewater would linearly increase with the rise of the population and industrialisation in Konya. For this reason, wastewater treatment plants should be opened as soon as possible.

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REFERENCES
