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The Effect of Fertilizers on the Extraction of Heavy Metals and Arsenic in Soil by Plant Biomass

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ABSTRACT

According to the data given in the article, the soil around the Samarkand chemical plant is strongly contaminated with heavy metals. The greatest pollution is noted within a radius of 1500–2000 meters from a chemical plant in the western and northern directions. In areas subject to the influence of heavy metals and arsenic, the use of mineral and organic fertilizers reduced the content of mobile forms of these elements in the soil and improved the growth and development of plants. As a result, crop yields increase, and the transfer of heavy metals into plants is reduced. The use of mineral and organic fertilizers in soils contaminated with these elements, along with increasing the yield of cotton, reduced the amount of element removed by the crop by 25–80% compared to the control variant. That is, in the variant where mineral and organic fertilizers were applied together ($N_{250}P_{175}K_{125}$+ cattle manure, 30 t/ha), the largest reduction in the removal of these elements by the cotton crop was found in the cobalt (80%) and the lowest in the copper (25%).

Keywords: soil, heavy metals, arsenic, pollution, chemical plant.

INTRODUCTION

As a result of the rapid development of the chemical industry worldwide, the amount of various wastes released into the environment is increasing (Cribb, 2021). As a result, the movement of harmful chemicals in the air–water–soil–vegetation system leads to biocenosis pollution. In this system, the soil is one of the most important links, and together with the plant, it forms an important ecosystem. This ecosystem is important for ensuring food security, which is the most important thing for humanity. In addition, the plants grown in the soil provide the animal kingdom with food products. Plants are also a source of valuable raw materials for industries. Under the influence of human activities, soils is polluted with harmful chemicals to varying degrees. These chemicals include heavy metals and arsenic. Heavy metals accumulate more in the soil than in other parts of the biosphere and have a negative effect on the ecosystem in the soil-plant-animal-human system (Singh and Ajay, 2011). Therefore, studying the removal of heavy metals and arsenic from plant biomass and the effect of mineral and organic fertilizers on it is one of the urgent issues.

The prevention of heavy metal pollution in soil has been the subject of extensive scientific study in recent years. Particularly in the Saratov region of the Russian Federation's chernozems and kastanozems (zinc 28–45 mg/kg, copper 10.4–49 mg/kg, nickel 8.49–18 mg/kg, lead 7.14–14.7 mg/kg, arsenic 1.62–4.54 mg/kg, and cadmium 0.21–0.48 mg/kg). The overall amount of zinc in Nizhegorod region chernozems was 27.5 mg/kg, grey forest soils 24.4 mg/kg, and forest-podzolic soils 20.0 mg/kg (Shafronov and Polukhin, 2007; Derevyagin, 2009; Medvedev and Derevyagin, 2017). In the "Central Park" of the city of Vladimir, in the top 0–10 cm layer of soil, lead was found to be 67.2 mg/kg, zinc was 130.0 mg/kg, manganese was 1311 mg/kg, cobalt was 14.7 mg/kg, chromium was 94.2 mg/kg, and nickel was found to be up to 43.1 mg/kg. It is noted that they can fall mainly from the atmosphere in the form of aerosols and also fall into the soil as a result of rain and snow (Zabelina, 2014). It was also noted that the total zinc content of the soils around the cement factory in Ulyanov ranges from 20.8 to 35.2 mg/kg (Kazakova, 2014). In most of the studied sites, the zinc concentration was higher than or equal to its background value (24.2 mg/kg). The influence of the use of mineral fertilizers on the elements manganese (Mn), zinc (Zn), copper (Cu), lead (Pb), nickel (Ni), and cadmium (Cd) in the agrocenosis of corn under conditions of leached chernozems was studied. In this case, Mn in the tillage and sub-tillage layers of the soil is 615–656 mg/kg (Maximum Allowable Concentration (MAC) = 1500 mg/kg); Zn: 63.6–69.1 mg/kg (MAC = 150 mg/kg); Cu: 17.6–22.7 mg/kg (MAC = 100 mg/kg); Pb: 14.5–20.6 mg/kg (MAC = 100 mg/kg); Ni: 22.9–39.2 mg/kg (MAC =100 mg/kg); Cd: 0.18–0.31 mg/kg (MAC = 1 mg/kg) (Gorbunova and Stulin, 2016). Application of mineral fertilizers and cultivation of corn had no significant effect on the total content of the studied elements in the soil.

In the conditions of our republic, a number of studies have been conducted to study the amount of heavy metals in the soil. For example, in the arable layer of the old irrigated typical serozems of Pastdargom and Payariq districts of the Samarkand region, the amount of total manganese fluctuates from 497.7 to 656.3 mg/kg, depending on the rocks that form the soil, the granulometric composition of the soil, the pH, and the amount of humus (Rozikova et al., 2020). Chromium, nickel, and cadmium mobile forms in the meadow serozem soils of Guzor district of the Kashkadarya region are accumulated in the lower layers of the soil profile in excess of the permissible norm for these elements. For example, in the 0–30 cm layers of 1-variant 1.16 times more than the allowed norm of elements was recorded, and in 50–80 cm, their amount was up to 34.5 mg/kg. Along the soil profile, their amount decreased to the permissible limit, and in some variants, it was observed to decrease even more (Karimov et al., 2021). A number of heavy metals were studied around the areas where solid household waste is collected in Tashkent according to the data Zn (1610 g/t), Pb (26.7 g/t), Cu (306 g/t), Cr (91.0 g/t), and Se (9.08 g/t) were found (Zhabbarov et al., 2021). According to the results of the research conducted by Kholikulov et al. (2021) on the study of the effect of the waste of the complex on the amount of heavy metals in the light serozem soils around the Shurtangazkimyo complex, copper-42 mg/kg in 1 kg of soil 100 m from the chemical complex in the north direction; zinc-72 mg/kg; lead-151 mg/kg; if nickel-184 mg/kg was determined, the amount of these elements in the western direction is 44 mg/kg, respectively; 73 mg/kg, 168 mg/kg, 197 mg/kg, 44 mg/kg in the south direction; 68 mg/kg; 160 mg/kg; 197 mg/kg; 43 mg/kg; respectively; in the east direction, 67 mg/kg, 148 mg/kg, 178 mg/kg. The highest amount of mobile lead, 55.2 mg/kg of soil, was recorded at a distance of 850 m in the south direction of the complex (Kholikulov and Yakubov, 2021).

In agreement with the studies conducted on the amount of heavy metals in the soil, their removal by plants, and the effect of mineral and organic fertilizers on the conditions of irrigated soils in our republic, these have not been sufficiently studied. Therefore, we want to study the effect of mineral and organic fertilizers on the removal of heavy metals and arsenic by cotton biomass in typical serozem soils around the Samarkand chemical plant.

RESEARCH OBJECTS AND METHODS

Natural conditions of the research area

The research was carried out in the conditions of irrigated typical serozem soils around the Samarkand chemical plant located in the Zarafshan oasis. According to the data from the Samarkand zonal hydrometeorological station, the average annual temperature of the researched area is +13.1°C, and the maximal temperature of +42.3°C was recorded in July. The average annual precipitation is 250–300 mm, most of which falls in the winter and spring seasons. The average temperature in the area from April to October is above +14°C. The peculiarity of the local relief affects the formation of winds. Wind is of great importance in the distribution of factory waste to the environment.The wind direction and annual mean recurrence of the area were shown in Figure 1. The wind balance is mostly calm. The wind speed at rest is very low (less than 2 m/s). During this period, according to the laws of distribution of atmospheric waste, the waste from the chemical plant falls directly into places close to the plant.

Description of soil and plant cover

The soil of the research area corresponds to the region of typical serozem soils that have been irrigated since ancient times (Soil Atlas of the Republic of Uzbekistan, 2010). Soil-forming rocks are loess and loess, as well as various irrigated deposits. In addition to these rocks, there are various alluvial and diluvial-proluvial deposits that formed in the quaternary period. The plant cover is extremely diverse: *Matricaria chamomilla* L., *Papaver pavoninum* C.A. Meyer, *Cousinia resinosa* Juz, *Artemisia absinthium* L., *Glycyrrhiza glabra* L., *Mentha longifolia* L., and various other plants grow. Also, cotton (*Gossypium hirsutum* L), wheat (*Triticum aestivum* L), corn (*Zea mays* L), and other crops are cultivated in the investigated area. There are also gardens and vineyards.

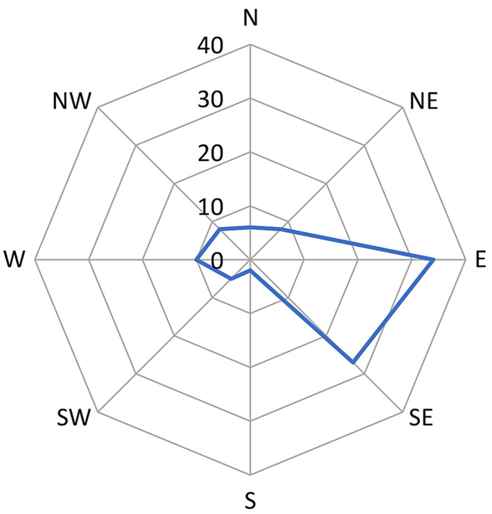

Figure 1. "Wind rose"diagram of the area

Description of the Samarkand chemical plant

The Samarkand chemical plant is one of the sources of soil pollution with heavy metals in this region (Figure 2).The chemical plant was established in 1954 under the name of the Samarkand Superphosphate Plant, and until 1975, it produced about 320000 tons of superphosphate and 120000 tons of sulfuric acid, as well as 1250–1800 tons of sodium-silicon fluoride and selenium concentrate. 220000 tons of black phosphorite and several thousand tons of apatite concentrate, as well as 100–120000 tons of iron pyrites, were used for the production of these products. About 250000 tons of pyrite powder, which is the main solid waste of the plant, were collected and released to the environment along with the dust of cleaning facilities by rail to cement plants and by road transport.In 1975, after the radical reconstruction of the superphosphate plant, it produced ammophosphate and

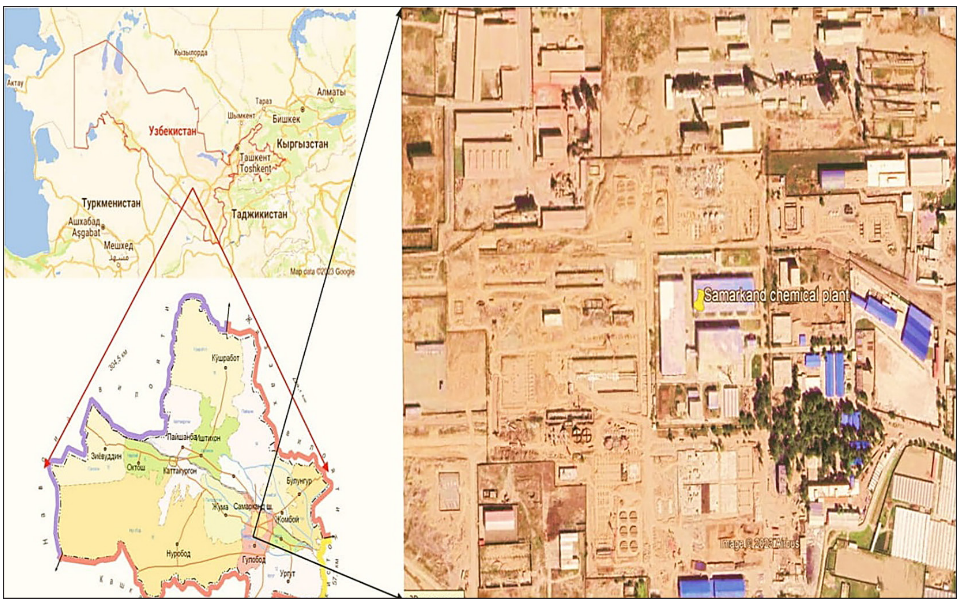

Figure 2. Location of Samarkand chemical plant

was called a chemical plant. After the production capacity increased (600,000 tons of ammophosphate in per year), the release of sulfur IV-oxide (5000 tons per year) and fluorine compounds (85 tons per year) increased. Even after the reconstruction of the plant, piles of pyrite powder remained the main source of heavy metal pollution. Several times, the exhaust pipe burst, which led to additional pollution of the environment. Therefore, during the period when the chemical plant produced superphosphate and ammophos, its raw materials and waste heavily polluted the environment with heavy metals.

Research methods – soil samples

In order to study the amount of heavy metals and arsenic in the soil, samples were taken every 50 meters from the Samarkand chemical plant on the sides of the road up to 1 km, every 100 meters from 1 km to 2 km, every 200 meters up to 3 km, and every 500 meters up to 10 km. Soil samples were taken at 500 meters and 20 km as background. When taking samples, individual samples were taken and mixed by the envelope method, and the average sample was taken. The average weight of each sample was 1000 grams (Kovalsky and Gololobov, 1969; Guidelines for the determination of heavy metals in agricultural soils and crop production, 1992).

Plant sampling

Plant (cotton fiber, seed, stem, and leaf) samples were taken in the autumn to study the amount of heavy metals and arsenic in plants around the plant. These samples were immediately washed, first in tap water and then in distilled water. It was cleaned of all kinds of foreign matter, then dried at room temperature and burned. The burning was carried out in two stages. First, all plant samples were burned in a porcelain mortar on an electric plate and then in a muffle furnace at a temperature of 450°C for 2 hours. Ash content was measured, and elements were quantified from each sample using a spectrophotometer.

Method for determination of total and mobile forms of heavy metals and arsenic

Total and mobile forms of copper, zinc, lead, cobalt, and arsenic elements from heavy metals were studied. To determined the total amount of these elements, the soil in air-dry condition was determined by "wet" burning in a mixture of perchlorate ($HClO_4$) and sulfuric acids (H_2SO_4). After filtration, the extract is dried, and the precipitate is transferred to a decinormal solution of hydrochloric acid (0.1 n HCl). Then, the total amount of elements is determined in the DFS-8 spectrograph by evaporation on the lower electrode in the method of emission spectral analysis. When determining the amount of mobile forms of heavy metals and arsenic in the soil, the soil is crushed and air-dried. Acetate buffer is then poured over the soil sample and shaken in the equipment for 8 hours, and the sample is filtered. The amount of heavy metals in the extract is determined using the atomic-absorption method using the "Saturn-2" spectrophotometer (Vorobiev et al., 1980).

Methodology of the field experiment

A field experiment was conducted in an area polluted with heavy metals, 1500 meters northwest of the chemical plant, to study the effect of mineral and organic fertilizers on the content of heavy metals in irrigated typical serozem soils and cotton crops. The field experiment was conducted in the following variants:

1. Control (without fertilizer),
2. $N_{250}P_{175}K_{125}$,
3. Cattle manure (30 t/ha) (N -0.48%, P_2O_5 -0.25%, K_2O -0.56%),
4. Cattle manure (10 t/ha) as mulch,
5. Biohumus: 7 t/ha (N-1.8%, P_2O_5-1.32%, K_2O-1.2%),
6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha),
7. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha) as mulch,
8. $N_{250}P_{175}K_{125}$+ biohumus (7 t/ha),
9. Cattle manure (10 t/ha),
10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha),
11. $N_{350}P_{175}K_{125}$.

Ammonium nitrate (N-34.6%), ammophosphate (N-11%, P_2O_5-46%), and potassium chloride (K_2O-60%) were used in the experiment. Fertilizer application methods and periods were carried out based on the recommendations of the Scientific Research Institute of Cotton (Methods of field experiments with cotton, 1981). In the experiment, manure was applied at a dose of 30 t/ha under the plow and 10 t/ha as mulch. Biohumus was applied at a dose of 7 t/ha only during the vegetation season. The field experiment was conducted in four replicates and two tiers. The number of variants is 11, and the number of patches is 44. 1 study site is 50 m long, 4,8 m wide, and has an area of 240 m^2. There were 8 rows in one study site, the outer two rows served as protection rows, and the middle four rows served as calculation rows. Soil samples were taken between the rows to be counted. Experimental observation methods, phenological observations, and biometric measurements were carried out according to the recommendations of UzPITI (Methods of field experiments with cotton,1981). The statistical analysis of the results of the experiment was carried out according to the method of Dospekhov's EXEL (Dospekhov,1985).

RESULTS AND DISCUSSION

According to the studies conducted, the soils scattered around the Samarkand chemical plant are highly contaminated with heavy metals and arsenic. The strongest pollution was observed in the radius of 1500–2000 meters from the combine and in the fields on the west and north–west sides along the wind direction. The highest total amount of elements studied, copper (1240 mg/kg (250 meters west of the plant), zinc (1450 mg/kg (700 meters west), lead (526 mg/kg), arsenic (410 mg/kg (250 meters west in the western direction), cobalt (550 mg/kg (750 meters north–west), were determined in the 0–30 cm layer of the soil. Soils less contaminated with heavy metals and arsenic were recorded in the fields in the east, south, and southeast directions of the chemical plant. Heavy metals and arsenic accumulate mainly in the upper layer of the soil and decrease over the deeper layers (Bobobekov, 2006; Kholikulov, 2018; Kholikulov and Bobobekov, 2019).

Soils around the plant are also contaminated with mobile forms of the studied heavy metals and arsenic. The largest amounts of copper, zinc, and cobalt elements in mobile form were observed in the western direction, 250 meters away from the plant. At this distance, the amount of mobile copper in the soil was 32 mg/kg, zinc was 42 mg/kg, and cobalt was 40 mg/kg. The highest amounts of mobile forms of lead and arsenic elements were also recorded at a distance of 500 meters in this direction and were 46 mg/kg and 19 mg/kg, respectively. The highest concentration of elements contamination is found mainly at a distance of 1500–2000 meters from the plant. It is known that enrichment of soils with organic matter, the use of mineral fertilizers, including phosphorus fertilizers, and liming also reduce the mobility of heavy metals in the soil. The toxicity of heavy metals depends on many factors. Such factors include the amount of humus in the soil, its environmental response, its mechanical composition, carbonation, the climatic conditions of the place, and the characteristics of the plants growing in the soil. The negative effects of heavy metals are observed more in light and humus–poor soils. Heavy metals are more adsorbed by clay particles in heavy, humus–rich, and highly absorbent soils. That is why they pose relatively little danger in such soil (Dobrovolsky and Grishina, 1985; Alekseev, 1987; Salama et al., 1993; Salama, 1993, Kirillov and Asonov, 2010; Kholikulov et al., 2010; Karimov and Riskiyeva, 2014; Karimov, 2014).

In an experiment conducted on irrigated typical serozem soil around the Samarkand chemical plant, the application of mineral and organic fertilizers affected the amount of heavy metals and arsenic in mobile form (Figure 3). In the experiment, it was observed that the amount of heavy metal and arsenic in the soil increased until June. This situation may have happened as a result of the cold spring weather and precipitation, the accumulation of dust, fumes, and waste from the combine, as well as the rising temperature and the increase in the activity of microbiological processes in the soil. The decrease in the amount of heavy metals starting in June can be explained by their greater absorption by the plant or by their transition to a water-insoluble form under the influence of applied mineral and organic fertilizers. The obtained data show that the application of mineral fertilizers reduced the amount of heavy metals and arsenic in their mobile form in the soil. For example, in the control variant, at the beginning of the growing season (April 20), in the soil, Cu was 1.5 mg/kg; Zn was 14.5 mg/kg; Pb was 10.0 mg/kg; Co was 11.5 mg/kg; and As was 6.5 mg/kg (Figure 3). The end of the growing season (September 20), respectively, it was 1.0, 10.5; 8.7; 8.8; and 4.5 mg/kg. On September 20, in the variant $N_{250}P_{175}K_{125}$, these elements were respectively 0.85: 9.7; 8.4; 8.6; and 4.2 mg/kg. Compared to the control variants, Cu-44%, Zn-33%, Pb-16%, Co-25%, and As-36% decreased. This situation can be explained by the fact that cations of heavy metals in the soil bind with anions of mineral fertilizers, especially phosphates, forming complex compounds that are insoluble in water. The decrease in the amount of heavy metals and arsenic

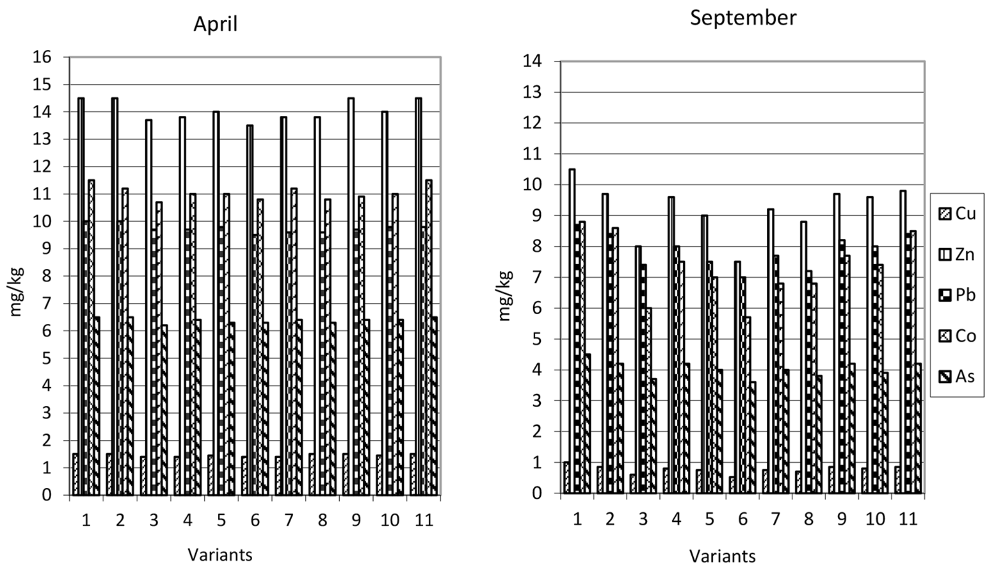

Figure 3. Effect of mineral and organic fertilizers on the amount of mobile heavy metals and arsenic, mg/kg (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

in mobile form in soils where organic fertilizers are applied every year is due to their adsorption and retention in the absorbed state. Furthermore, the use of organic fertilizers increases the amount of humus in the soil. Organic fertilizers can also retain heavy metals in their absorbed state and reduce their mobility. Application of organic fertilizers at a dose of 30 t/ha per hectare and application of manure at the same dose with NPK significantly reduced the amount of heavy metals and arsenic. For example, in the control variant, Cu was 1.0; Zn was 10.5; Pb was 8.7; Co was 8.8; and As was 3.7 mg/kg. In the variants of applying 30 t/ha of cattle manure, Cu was 0.6; Zn was 8.0; Pb was 7.4; Co was 6.0; and As was 3.7 mg/kg. The greatest reduction of heavy metals and arsenic was observed in the variant where $N_{250}P_{175}K_{125}$+30 t/ha cattle manure was used. In these variants, their amounts were respectively 0.52, 7.5, 7.0, 5.7, and 3.6 mg/kg. That is, in this variant, compared to the control, Cu-65%, Zn-48%, Pb-30%, Co-51%, and As-45% decreased (Figure 3). The application of mineral and organic fertilizers in the conditions of irrigated typical serozem soils contaminated with heavy metals and arsenic around the chemical plant had a positive effect on the growth and development of the cotton plant and significantly increased the yield. For example, in the $N_{350}P_{175}K_{125}$ variant, where mineral fertilizers were used separately, the average three-year yield was 33.5 tons/ha, and in the $N_{250}P_{175}K_{125}$ variant, it was 32.3 tons/ha. The yield increased even more when mineral fertilizers were used together with organic fertilizers. That is, the $N_{250}P_{175}K_{125}$+30 t/ha cattle manure variant was -35.7 t/ha. The application of organic and mineral fertilizers not only improved the growth, development, and yield of cotton but also affected the amount of heavy metals in the crop. As a result of the use of mineral and organic fertilizers, the amount of heavy metal and arsenic in the cotton stem decreased. For example, in the control variant, the stem contains copper elements of 3.5 mg/kg, zinc 10.0 mg/kg, lead 0.90 mg/kg, cobalt 0.4 mg/kg, and arsenic 0.3 mg/kg. If there were, in the variants that used mineral fertilizers in the ratio of $N_{250}P_{175}K_{125}$, the copper element was 3.3 mg/kg, zinc 7.3 mg/kg, lead 0.60 mg/kg, cobalt 0.24 mg/kg, and arsenic 0.25 mg/kg.

The application of organic fertilizers at different rates also had a significant effect on the content of these elements in cotton stems. That is, in the variants of applying 30 t/ha of cattle manure, it was found that copper was 3.1 mg/kg, zinc was 5.4 mg/kg, lead was 0.44 mg/kg, cobalt was 0.07 mg/kg, and arsenic was 0.11 mg/kg. Also, the amount of heavy metals and arsenic in the cotton stem decreased in comparison to the control variant in variants where 7 tons of biohumus, 10 tons of cattle manure, and the same amount of cattle manure were used as mulch (Figure 4–5). The amount of heavy metals and arsenic in the cotton stem was also lower in the variants where mineral and organic fertilizers were used together compared to the control variant. Among the variants studied, the greatest reduction of heavy metals and arsenic in the stem of cotton was recorded in this variant ($N_{250}P_{175}K_{125}$+ Cattle manure, 30 t/ha). The amount of these elements in this variant was as follows: copper, 3.0 mg/kg; zinc, 5.2 mg/kg; lead, 0.50 mg/kg; cobalt, 0.06 mg/kg; and arsenic, 0.08 mg/kg (Figure 4–5). According to the results of the experiment, applied mineral and organic fertilizers had a significant effect on the removal of heavy metals from cotton leaves (Figure 6–7).That is, in the control variant, the leaf contains copper at 1.5 mg/kg, zinc at 6.0 mg/kg, lead at 0.50 mg/kg, cobalt at 0.1 mg/kg, and arsenic at 0.1 mg/kg. However, applied fertilizers reduced the content of heavy metals in cotton leaves. In this case, their greatest reduction was observed in the $N_{250}P_{175}K_{125}$+ cattle manure 30 t/ha variant with copper at 1.0 mg/kg, zinc at 2.2 mg/kg, lead at 0.2 mg/kg, cobalt at 0.02 mg/kg, and arsenic at 0.02 mg/kg (Figure 6–7).

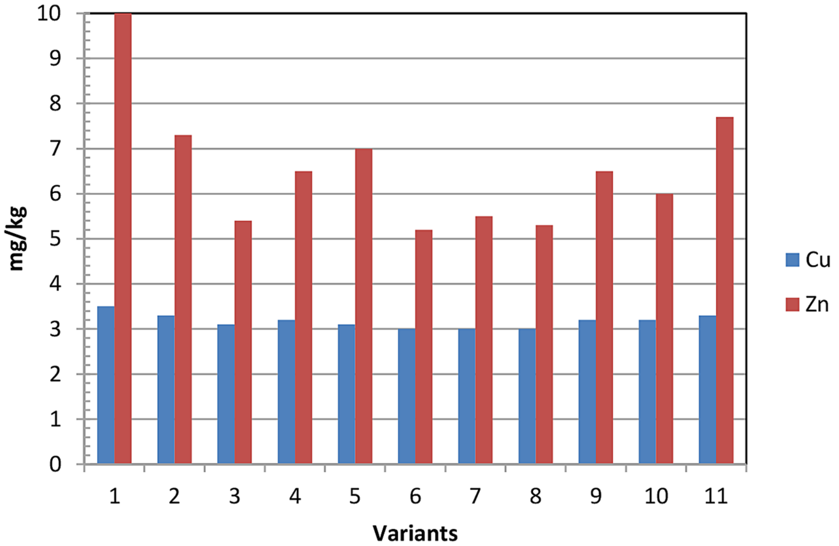

Figure 4. The amount of copper and zinc in cotton stems, mg/kg**.** (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

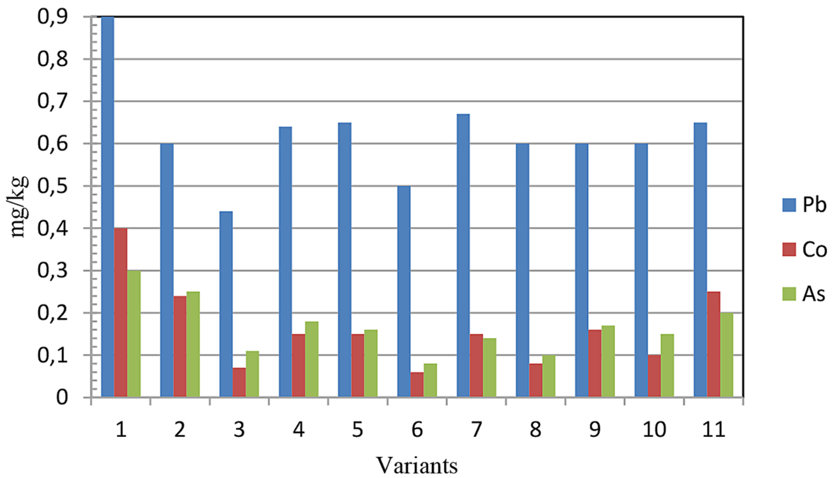

Figure 5. The amount of lead, cobalt and arsenic in cotton stems, mg/kg**.** (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

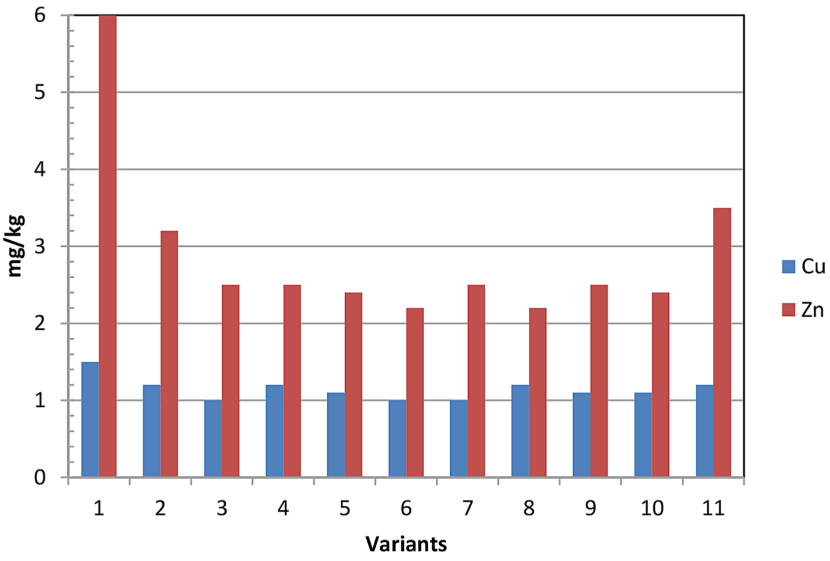

Figure 6. The amount of copper and zinc in cotton leaves, mg/kg. (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

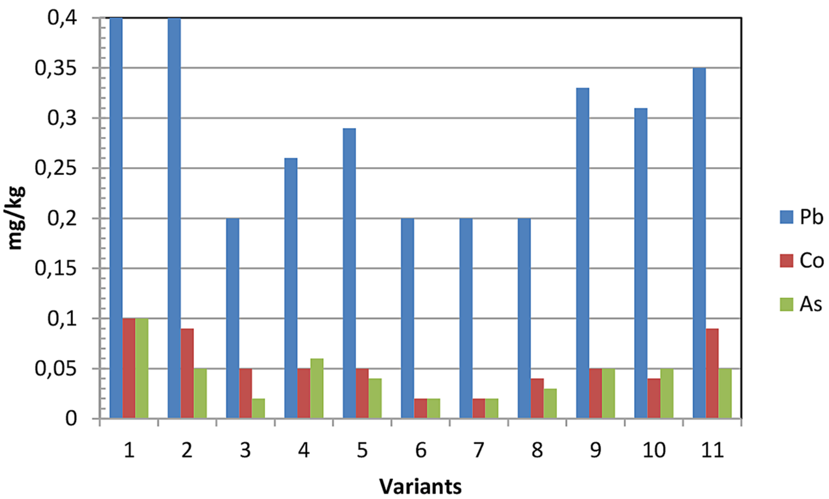

Figure 7. The amount of lead, cobalt and arsenic in cotton leaves, mg/kg. (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

Cotton fiber and seed had greater levels of heavy metals and arsenic. It was found that the fiber and seeds in the control variant had 5.0 mg/kg of copper, 10.0 mg/kg of zinc, 1.4 mg/kg of lead, 0.5 mg/kg of cobalt, and 0.3 mg/kg of arsenic. The application of mineral and organic fertilizers also significantly affected the amount of heavy metals in fiber and seed (Figure 8-9). Due to the application of fertilizers, the amount of these elements in this part of the cotton crop has been significantly reduced. The lowest amount of heavy metals was recorded in $N_{250}P_{175}K_{125}$+ manure (30 t/ha) variants: copper at 3.5 mg/kg, zinc at 7.8 mg/kg, lead at 0.8 mg/kg, cobalt at 0.12 mg/kg, and arsenic at 0.1 mg/kg (Figure 7 and 8). In the research conducted, the highest amount of heavy metals and arsenic in the whole crop element of the cotton plant was observed in the control variant. In this variant, cotton organs contained a total of 10.0 mg/kg of copper, 26.0 mg/kg of zinc, 2.4 mg/kg of lead, 1.0 mg/kg of cobalt, and 0.7 mg/kg of arsenic. elements, respectively, in the cotton stalk: 3.5; 10.0; 0.9; 0.4; 0.3; and 1.5 mg/kg; in the leaf: 6.0; 0.5; 0.1; 5.0; 0.1 mg/kg; and in the fiber+seed: 5,0; 10,0; 1,4; 0,5; and 0,3 mg/kg (Figures 3–8).

The applied fertilizers reduced the amount of heavy metals and arsenic in the cotton organs. In this case, there was no significant difference between the two variants where mineral fertilizers were used. Application of organic fertilizers under the plow and in the form of mulch combination with mineral fertilizers, also reduced the amount of heavy metals and arsenic in the plant. In the variant where mineral fertilizers $N_{250}P_{175}K_{125}$ were used together with 30 t of manure, the content of heavy metals in cotton was the lowest, at Cu–7.5, Zn–15.2, Pb–1.5, Co–0.2, and As–0.2 mg/kg. According to studies, the transfer of heavy metals to plant composition is reduced by 25–80% when fertilizers are used compared to the control variants. More of these elements were absorbed when 30 t/ha manure variants were applied separately, and more heavy metals were assimilated when $N_{250}P_{175}K_{125}$+ biohumus (7 t/ha) variants, $N_{250}P_{175}K_{125}$+ 10 t/ha manure, 7 t/ha biohumus,

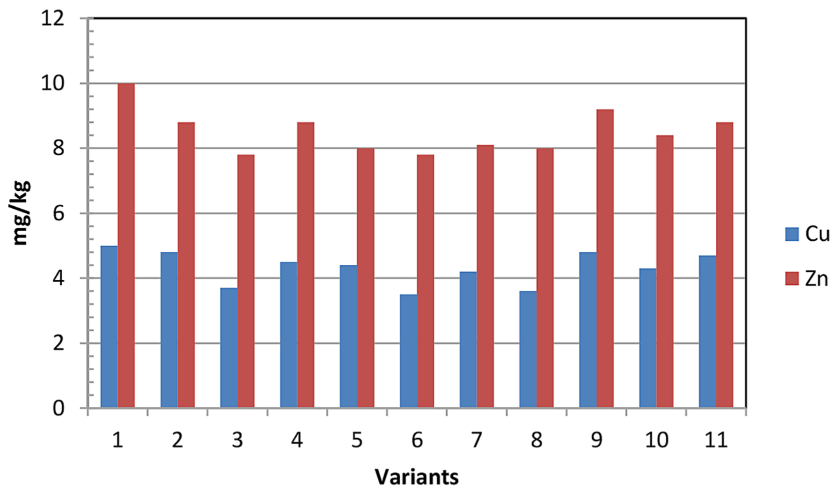

Figure 8. The amount of copper and zinc in cotton crop (fiber-seed), mg/kg. (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

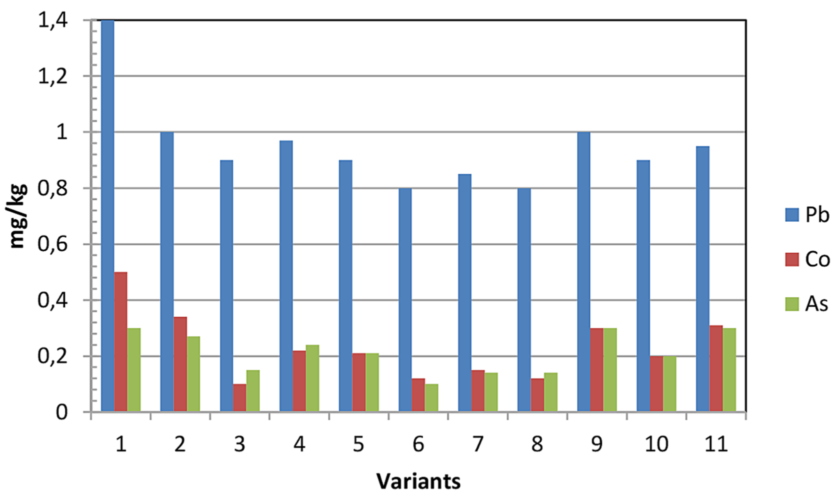

Figure 9. The amount of lead, cobalt and arsenic in cotton crop (fiber-seed), mg/kg. (Variants: 1. Control (without fertilizer). 2. $N_{250}P_{175}K_{125}$. 3. Cattle manure (30 t/ha). 4. Cattle manure (10 t/ha) as mulch. 5. Biohumus (7 t/ha). 6. $N_{250}P_{175}K_{125}$+ Cattle manure (30 t/ha). 7. $N_{250}P_{175}K_{125}$ + Cattle manure (10 t/ha) as mulch. 8. $N_{250}P_{175}K_{125}$ + biohumus (7 t/ha). 9. Cattle manure (10 t/ha). 10. $N_{250}P_{175}K_{125}$+ Cattle manure (10 t/ha). 11. $N_{350}P_{175}K_{125}$)

10 t/ha manure+mulch, and 10 t/ha manure under plow was applied. The reduction of the amount of heavy metals and arsenic in the plant organs, especially in the fiber and seeds, leads to the improvement of the quality of cotton; that is, the yield of fiber increases, and its quality—fiber length, hardness, relative breaking length, and other parameters—improves. The level of these elements was discovered to be substantially lower in this kind of cotton that was not impacted by heavy metals, that is, planted in areas 20 kilometers distant from the chemical plant. Cotton fiber and seed have greater levels of arsenic and heavy metals. Fiber and seeds were found to have 5.0 mg/kg of copper, 10.0 mg/kg of zinc, 1.4 mg/kg of lead, 0.5 mg/kg of cobalt, and 0.3 mg/kg of arsenic in the control variant. In the cotton leaf grown in this area, copper is 0.9 mg/kg, zinc is 1.5 mg/kg, lead is 0.2 mg/kg, and arsenic is 0.03 mg/kg. Cotton from this region had a cobalt content of less than 0.01 mg/kg and was unaffected by heavy metals.

CONCLUSION

Around the Samarkand chemical plant, irrigated typical serozem soils are severely polluted with heavy metals and arsenic. The fields and combine were most polluted within a radius of 1500–2000 meters to the west and north–west, perpendicular to the direction of the wind. The amount of heavy metals and arsenic in mobile form in the soil was decreased by applying mineral and organic fertilizers to the region impacted by heavy metals. The greatest reduction of these elements was observed in the variant where $N_{250}P_{175}K_{125}$ + 30 t/ha fertilizer was used. That is, compared to the control, Cu-65%, Zn-48%, Pb-30%, Co-51%, and As-45% decreased in this variant.

In addition to the reduction of mobile heavy metals and arsenic in the soil under the influence of fertilizers, the nutrition and growth of the cotton plant improved, and the yield increased. Fertilizers have increased the yield of cotton as well as reduced the amount of heavy metals in the crop. In the variant where mineral fertilizers $N_{250}P_{175}K_{125}$ were used together with 30 t/ha of cattle manure, the content of these elements in cotton was the lowest: Cu 7.5, Zn 15.2, Pb 1.5, Co 0.2, and As 0.2 mg/kg. The most reduction of heavy metals in the content of cotton crop was found in cobalt (80%), and the least in copper (25%).

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