Volume 4, Issue 3, March - 2026
ISSN (E): 2938-3781

ASSESSMENT OF THE CURRENT SOIL-ECOLOGICAL STATE OF UZBEKISTAN'S SOILS

Mirkhaydarova Gulmira Sultanovna
Associate Professor of the Department of Agrochemistry and Soil Science
Tashkent State Agrarian University, Tashkent Region, Uzbekistan,
Authors email: sultonxonim_19@mail.ru
Orcid ID: 0000-0002-8621-1508

Ruzmetov Maksud Ismailovich
Professor, Institute of Soil Science and
Agrochemical Research Tashkent City, Uzbekistan.
Authors email: maksudruzmetov2022@gmail.com
Orcid ID: 0009-0009-4199-5757

Abstract

The increase in production volume leads to environmental pollution with residues and waste, the accumulation of various chemical compounds in large quantities in the soil, and negatively affects the ecological state of the soil cover. Priority tasks for providing the population with environmentally friendly products include soil remediation, as well as increasing the yield and quality of agricultural crops.

The research results presented in this article are in accordance with Article 6 of the Law of the Republic of Uzbekistan No. 903, which aims to protect, improve, and restore the fertility of contaminated, disturbed, or otherwise degraded soils.

Until now, soils of Uzbekistan have been evaluated only by their properties, without taking pollution processes into account. This article examines the soils of the Tashkent region of the Republic of Uzbekistan based on the results of their soil-ecological assessment. Some soil properties, such as mechanical composition, agrochemical properties, degree of salinity, as well as the amount of metals detected in the soils, were analyzed.

The methods used to determine soil properties are described in the following works: E.V. Arinushkina's "Agrochemical Methods of Soil Research" and "Manual on Chemical Analysis of Soils," N.A. Kachinsky's "Soil Physics," and L. Tursunov's "Soil Physics."

Based on the results of soil properties and the permissible norms of metal content, the Soil Quality Index (SQI) was calculated and the degree of soil health was determined.

Using geoinformation system technologies and based on the SQI indicators of the studied areas, the following were developed: an assessment map of soil condition, an assessment map of soil ecological state, and digital maps with a comprehensive soil-ecological assessment.

Keywords: Soil, mechanical composition, humus, soil pollution, heavy metals, SQI assessments, environmental score, assessment.

Introduction

Heavy metal pollution is one of the significant environmental problems facing the modern world. Human activities, such as mining, agriculture, and industrial operations, can facilitate the release of heavy metals into the environment.

The impact of heavy metals on soil biological activity has been reported in numerous studies. For instance, in our research conducted in the Tashkent region, the activity of the catalase enzyme in soils surrounding the Almalyk Mining and Metallurgical Complex was determined under laboratory conditions by Z. Jabborov, using the method developed by R.S. Kasneltsova and V.V. Yershova. According to the results, the catalase enzyme activity in soils 2000 meters from the complex was more active than in soils at 4400 meters. However, starting from soils at 7300 meters, the catalase enzyme activity began to increase again, with enzymatic activity stabilizing at 11900 meters. The sharp decrease in catalase enzyme activity in soils at 4400 meters indicates that the lead (Pb) content in the soil exceeded the established norm [15].

Heavy metals contaminating the soil can harm crops, disrupt the food chain, and pose a threat to human health. Therefore, the primary goal for both humans and the environment should be to prevent soil contamination with heavy metals. Heavy metals persistently present in the soil can be absorbed by plant tissues, enter the biosphere, and accumulate at various trophic levels of the food [1].

Soil pollution has a negative impact on humans and the environment, especially concerning widespread and non-biodegradable heavy metals. Negative effects persist for several decades and even longer. Therefore, it is important to obtain information on the concentration of heavy metals in food products and their consumption. Increasing attention is being paid to soil contamination with heavy metals and its impact on food security [12].

For soils contaminated with heavy metals, the physical and chemical form of the pollutant in the soil strongly influences the choice of suitable remediation method. The US Environmental Protection Agency (USEPA, 2010) classified contaminated soil treatment technologies as follows: 1) pollution source control and 2) pollution containment measures. There is another classification of soil remediation technologies for heavy metal contamination: isolation, immobilization, toxicity reduction, physical separation, and extraction [12].

The removal of heavy metals from contaminated soil can be achieved through various physical, synthetic, and natural remediation methods (both in situ and ex situ). Among these, phytoremediation is considered the most controlled (accessible and environmentally friendly) method [1].

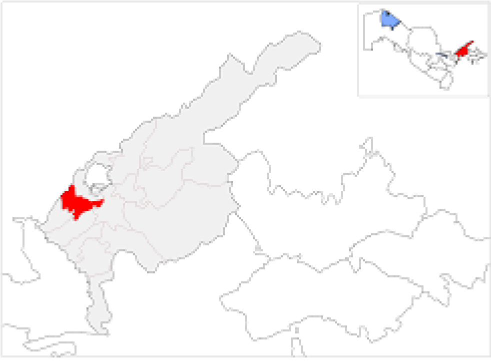
Inorganic pollutants occur as natural components of the Earth's crust or atmosphere, and human activity contributes to their release into the environment, leading to pollution. Inorganic pollutants cannot be degraded; however, phytoremediation can purify the environment of these pollutants by stabilizing or isolating them in plant tissues. Phytoremediation can be successfully applied to remove a range of inorganic pollutants, including plant macronutrients (nitrates, phosphates), micronutrients (such as Cr, Cu, Fe, Mn, Mo, Zn), elements non-essential for plants (Cd, Co, F, Hg, Se, Pb, V, W), and radioactive isotopes (U238, Cs137, and Sr90). The phytoremediation method of removing pollutants from natural environments through their accumulation in plants is an alternative to existing methods for restoring a favorable environment.

Scientists from the University of Washington, Oregon State University, and Purdue University

(Indiana), working under the guidance of Dr. Sharon Doty, claim that the genetically modified poplars they created absorb up to 91% of trichloroethylene - the most common groundwater contaminant in the USA - under laboratory conditions. Ordinary plants absorb no more than 3% of the compound. Moreover, experimental poplars growing in test tubes, which are only a few inches tall, break down trichloroethylene into safe compounds 100 times faster than the control group plants [14].

Currently in Uzbekistan, the issue of cleaning soil and wastewater contaminated with heavy metals, organic and inorganic pollutants remains unresolved. However, before addressing these problems, it is necessary to create soil-ecological maps of Uzbekistan's soils, indicating their health status based on Soil Quality Indices (SQI).

1. Materials and Methods.



Research was conducted in areas of the Republic of Uzbekistan with contaminated soils. One such area is the Tashkent region, where the Almalyk Mining and Metallurgical Combine serves as the primary source of soil pollution. The study focused on the land areas of Yangiyul and Pskent districts in the Tashkent region, which are located in close proximity to the pollution source. This article presents the research findings obtained from the soil analysis of the Yangiyul district land areas.

The Yangiyul district of Tashkent region borders Kazakhstan's South Kazakhstan region to the west and northwest, the Zangiata district of Tashkent region to the north and northeast, the Lower Chirchiq district to the southeast, and the Chinoz district to the southwest. The area covers 0.42 thousand square kilometers. The territory of the district is predominantly flat, with some areas of foothills.

The comprehensive study aimed at assessing the levels of chemical elements in the soils of Tashkent region in Uzbekistan was meticulously conducted employing a range of established methods in soil science to ensure accuracy and reliability of results. To provide a holistic understanding of soil contamination across these diverse geographic areas, the research incorporated a multi-faceted approach that included genetic-geographical analysis to understand the influence of gene flow and geographical distribution on soil composition, and lithological-geomorphological examination to assess how variations in rock types and landforms influence soil mineral content. The study utilized comparative-chemical-analytical methods to directly measure the concentration of various pollutants in the soil samples, thereby offering concrete data on the levels of contamination. The profiling method allowed for a detailed examination of soil layers, contributing to a deeper understanding of how pollutants distribute vertically within the soil column, which is critical for assessing the mobility and bioavailability of contaminants. The determination of pollutant levels in the soil adhered to stringent standards, as outlined in several GOST protocols including GOST 17,4,3,01-83 and GOST 17,4,4,02-84 for the assessment of environmental pollutants, GOST 28168-89 for the analysis of soil composition, and GOST 17.4.3.06-86 (ST SEV 5301-85), which provides a framework for soil classification based on the impact of chemical pollutants. These standards are essential for ensuring that the research methods are consistent, reliable, and comparable with other studies, facilitating a unified approach to understanding and addressing soil contamination. Additionally, the study followed the "Guidelines for conducting field and laboratory studies when monitoring environmental pollution with metals," a comprehensive manual that outlines best practices for collecting, analyzing, and interpreting soil samples for metal contamination. This ensured that the research was conducted with precision and adherence to international standards, providing a solid basis for evaluating the environmental and health risks posed by soil contamination in these regions. By integrating these diverse methodologies and standards, the research offers a robust and detailed picture of soil contamination by chemical elements in Uzbekistan, laying the groundwork for targeted interventions to mitigate pollution and protect environmental health [13].

In the studies, the humus content of the soils was determined using the Tyurin method, while the mechanical composition was analyzed using A.A. Kachinsky's pipette method. The amounts of mobile phosphorus and exchangeable potassium in the soil were determined using the Machigin-Protasov methods (with the aid of 1% $(NH_4)_2CO_3$).

Methods employed to determine other properties and characteristics of soils are described in the following works: E.V. Arinushkina's "Agrochemical Methods of Soil Research" and "Guide to Chemical Analysis of Soils," N.A. Kachinsky's "Soil Physics," and L. Tursunov's "Soil Physics."

Based on the study of advanced practices in foreign countries for assessing and mapping soil health levels, indices and methodological guidelines for evaluating soil health levels have been developed.

Digital maps based on SQI indicators of the studied areas were created using geoinformation system technologies: a soil condition assessment map, a soil ecological condition assessment map, and a general soil-ecological assessment map. Interpolation methods of geoinformation system technologies were utilized in the development of these maps.

2. Results and Discussion

General characteristics of the soils in the "Khalqobod" and "Navoiy" massifs of the Yangiyo'l district, Tashkent region.

Soil granulometric composition. Analyses of the mechanical composition of the soils of the "Khalkabad" and Navoi massifs of the Yangiyul district of the Tashkent region are presented in Table 1 on the example of section 28 and in Table 2 on the example of section 33. From the table data, it can be seen that the soils of this section have a medium loamy mechanical composition, and the content of physical clay particles (<0.01 mm) is 31.4-37.8% and 36.9-40.9%. These sections retain a medium loamy mechanical composition up to 150 cm.

Humus and nutrients. The humus content in the plowed layer of the soil in the "Khalqobod" and "Navoiy" massifs of the Yangiyul district, Tashkent region, is 1.102% and 1.319% respectively, falling into the low humus content (0.5-1.0%) category. The humus content further decreases in the lower layers, and based on the level of humus provision, these layers belong to the low and medium-supplied groups.

The arable layer of soils in the "Khalkobod" and "Navoi" massifs of the Yangiyul district, Tashkent region, is characterized by very low mobile phosphorus content. The amount of mobile phosphorus in the arable layer of these soils is 8.64 mg/kg. In the subsequent layers, the amount of mobile phosphorus decreases, ranging from 5.44 to 5.76 mg/kg. These layers are classified as very poorly supplied with mobile phosphorus. In contrast, the arable horizon of the soils in the "Navoi" massif forms a group with a very high content of mobile phosphorus. The amount of mobile phosphorus in the arable layer of these soils is 72 mg/kg. In the subsequent layers, the amount of mobile phosphorus decreases, ranging from 17.92 to 6.4 mg/kg. These layers are classified as moderately, poorly, and very poorly supplied with mobile phosphorus.

The soils of the "Khalkobod" massif are classified into groups with very low (0-100 mg/kg) and low (100-200 mg/kg) plant-available potassium content. The soils of the "Navoiy" massif are categorized into groups with very low (0-100 mg/kg), low (100-200 mg/kg), and medium (200-300 mg/kg) plant-available potassium content. In these soils, the amount of exchangeable potassium in the arable layer is 309 mg/kg and decreases in the subsequent layers. The amount of exchangeable potassium in the lowest layer is 84 mg/kg.

Soil salinization. Analysis results of the soils in the "Khalqobod" and "Navoiy" areas of Yangiyul district, Tashkent region, revealed that the soils are slightly saline and the type of salinity is predominantly chloride-sulfate.

The level of chemical element contamination in the soils of Tashkent region.

Pollution of agricultural soils with heavy metals (HM) is a global problem. In addition to certain geogenic and climatic factors, the main causes of environmental pollution with heavy metals at present appear to be specific circumstances such as rapid urbanization and the growth of industrial, municipal, agricultural, domestic, medical, and technological applications. However, this problem is more pronounced in many developing countries, partly due to the aforementioned reasons, and partly, perhaps, due to the lack of proper awareness about the toxic effects of these elements not only on human health but also on the health of agricultural crops. [8].

The content of chemical elements Be, V, Cr, Mn, Co, B, Mo, Sb, Pb, Cd, Ni, Zn, Cu, Se, As, and Sn in the soils of the Yangiyul district was studied in field soils where various crops are cultivated. In the arable layer of the Khalkabad and Navoi residential areas of the Yangiyul district, the **chromium** content was 58.8-65.5 mg/kg, while the **cobalt** content was 13.4-12.7 mg/kg. It was determined that the levels of chromium and cobalt in the soils exceeded the permissible limits, with soil samples taken from areas planted with certain crops (orchards, vineyards, and wheat fields) showing concentrations more than 2 times higher than the allowed amounts.

The boron content in the plow layer of Khalkabad massif soils was 25.8 mg/kg, while in Navoi massif soils it was 26.7 mg/kg. In these massifs, boron levels exceeding the permissible amount were detected in some soil samples (from gardens, medicinal plants, cotton, grapes, legumes, and vegetables).

In the arable layer of soils in the Khalkabad and Navoi massifs, the **molybdenum** content was 22.6-20.8 mg/kg, while the **lead** content was 21.2-20.1 mg/kg. It was determined that the molybdenum levels in the soils of these massifs exceeded the permissible amount by 3-5 times in all soil samples, and the lead content was up to 2 times higher than the allowed limit.

The **cadmium** content in the arable layer of soils in the Khalkabad and Navoi massifs ranged from 0.384 to 0.672 mg/kg, while the **nickel** content was between 50.3 and 45.4 mg/kg. Analysis of soil samples from the main profile selected in the Yangiyul district massif revealed that the cadmium levels exceeded the permissible limit, and the nickel content in all soil samples was 2 to 2.5 times higher than the allowed amount.

The **copper** content in the arable layer of the soils of the Khalkabad and Navoi massifs was 65.3-55.9 mg/kg. In the soils of the Khalkabad massif, the copper content in the sample taken from the area sown with corn was found to be higher than the permissible amount (120 mg/kg).

The **selenium** content in the arable layer of soils in the Khalkabad and Navoi massifs ranged from 0.50 to 17.4 mg/kg. It was determined that the amount of selenium in the sample taken from the main part of the soils in the Navoi massif exceeded the permissible level.

The arsenic content in the plow layer of the Khalkabad massif soils was 21.0 mg/kg, while in the Navoi massif soils it was 11.2 mg/kg. High levels of arsenic, up to 12 times the permissible amount, were detected in all soil samples collected from these massifs.

In conclusion, It was determined that the concentrations of **beryllium**, **antimony** and **tin** in the arable layer of soils from the Khalkabad and Navoi massifs did not exceed the permissible levels in soil samples collected from these areas, regarding the level of contamination with chemical elements in the soils **B**, **Mn**, and **Cu** exceeded the permissible amounts. The elements **V**, **Cr**, and **Ni** exceeded the permissible amounts by two times, **Co** by 3 times, **Mo** by 3-5 times, **Zn** by 6 times, **Pb** by 6-7 times, **Cd** by 10 times, and **As** by up to 14 times higher than the permissible levels.

Heavy metals and metalloids (HM) are environmental pollutants. They are also contaminants of agricultural soils, as HM can negatively affect the health and productivity of agricultural crops when present in the soil at elevated concentrations [3].

HM are resistant to degradation, and if they are not absorbed by plants or removed through leaching, they can accumulate in the soil and persist for long periods [4]. Elements that frequently contaminate agricultural soils and have toxic effects on plants at elevated concentrations include Cd, Pb, Cr, As, Hg, Ni, Cu, and Zn [7].

Among these, Cd, Pb, As, Hg, and Cr are highly toxic and harmful to plant health at virtually all levels of contamination [2].

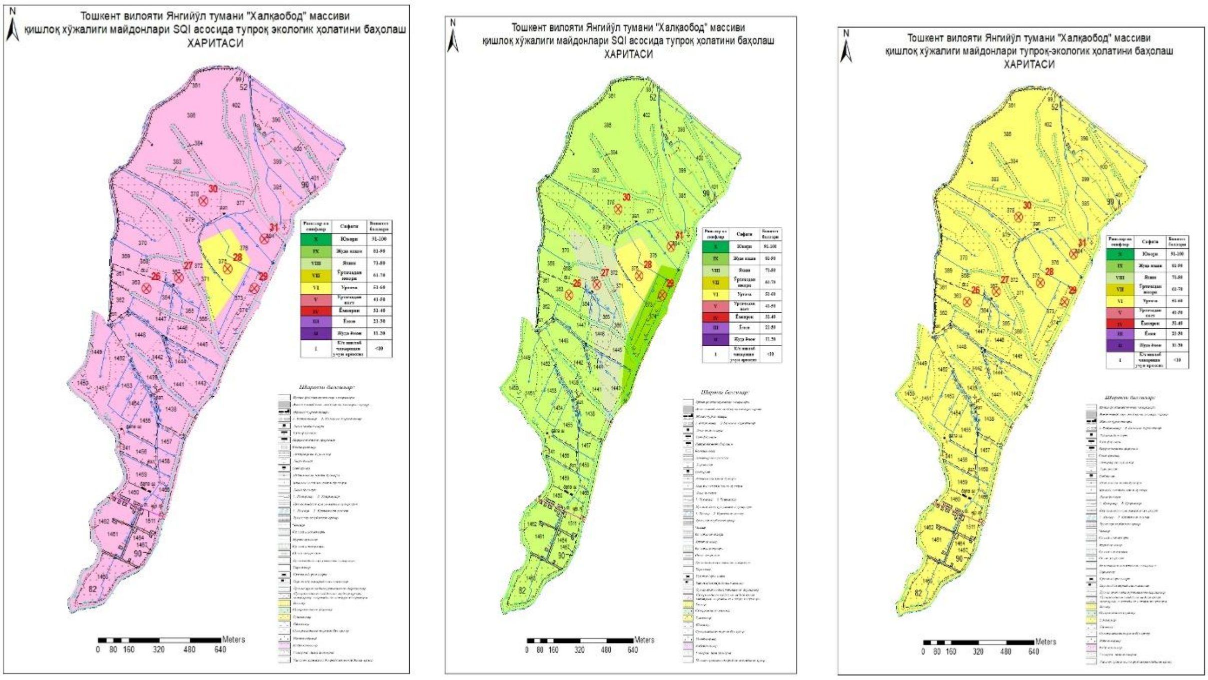
Assessment of Tashkent region soils based on soil quality indices (Soil Quality Index). Advanced practices from foreign countries for assessing soil health levels were studied.

After examining soil fertility indicators (agrochemical and physical-mechanical properties, degree and types of salinity, levels of humus and nutrient content in soils) and the state of heavy metal contamination, an evaluation was conducted based on the Soil Quality Indicator (SQI) system. Soil fertility indicators, the ecological condition of soils, and the soil-ecological state were assessed on a 100-point scale according to the SQI.

Based on the analysis of the main soil profiles obtained, the soils of this massif score between 89-59 points for soil properties, with an average of 74 points. The scores for ecological condition are somewhat lower, ranging from 51-41, with an average of 46. Regarding the total SQI scores, they range from 57-52 points, indicating that these soils are of average quality. The overall average score for these soils is 54 points, which corresponds to the average quality level.

Based on the analysis of the main soil profiles obtained, the soil properties of this massif range from 100 to 62 points, with an average of 81 points. The ecological condition scores are considerably lower, ranging from 49 to 43, with an average of 46. Regarding the overall SQI scores, they range from 58 to 50 points, indicating that these soils are of average quality. The total average score for these soils is 54 points, which corresponds to the average quality level.

The natural concentration of heavy metals in agricultural soils depends primarily on the geological composition of the parent rock. However, conventional farming methods can typically lead to the accumulation of heavy metals. In agricultural ecosystems where livestock farming and related agricultural practices are conducted intensively, heavy metals can also enter the soil due to the use of industrial fertilizers, sewage sludge, and pesticides, which usually contain a wide range of heavy metals as impurities



Map of ecological, soil state, and soil-ecological assessment of soils based on the SQI of agricultural lands of the "Khalkabad" massif of the Yangiyul district of the Tashkent region

Furthermore, in some areas, elevated levels may be caused by atmospheric precipitation resulting from proximity to industrial enterprises or the burning of fossil fuels [11]. In our research, the Almalyk Mining and Metallurgical Combine (AMMC), located in the city of Almalyk, is identified as the source of soil contamination in the Tashkent region.

1. Conclusions

In analyzing the ecological state of soils in the studied areas, the amounts of heavy metals were calculated. According to the analysis of ecological pollution levels based on the permissible norms of heavy metals (PNM) in soil, it was found that in most of the studied areas, the amounts of heavy metals were at or slightly above the PNM levels. In some areas, however, the amount of heavy metals was found to be several times higher than the PNM.

When assessing soil quality based on the Soil Quality Indicators (SQI) system, soil evaluation scores were first determined according to fertility indicators. Then, assessment scores for their ecological condition were determined. Subsequently, based on both assessment criteria, overall soil-ecological condition scores for these soils were established. According to the results of these analyses, all area soils had relatively high scores in terms of soil condition, while their scores for ecological condition were observed to be low.

Using geoinformation system technologies, the following digital maps were developed based on the SQI indicators of the studied areas: a soil condition assessment map, a soil ecological condition assessment map, and an overall soil-ecological assessment map.

The obtained results serve as a scientific basis for implementing measures aimed at improving the ecological state of soils, preventing the negative effects of pollutants on agricultural crops, restoring soil fertility, as well as properly selecting and placing agricultural crops based on the ecological condition of soils, determining crop yields, and allocating land for non-agricultural purposes.

The application of remote sensing technologies in monitoring agricultural crops will form the foundation for measures aimed at digitizing the agricultural sector, effectively managing agricultural land areas, and combating crop losses.

References

1. Priya A. K. et al. (2023) Clean-up of heavy metals from contaminated soil by phytoremediation: A multidisciplinary and eco-friendly approach.Toxics. T. 11. №. 5. C. 422. DOI:10.3390/toxics11050422
2. Rashid A. et al. (2023) Heavy metal contamination in agricultural soil: environmental pollutants affecting crop health. Agronomy. T. 13. №. 6. C. 1521. DOI:10.20944/preprints202305.0398.v1
3. Shahid M. et al. (2015) Heavy metal stress and crop productivity. Crop production and global environmental issues. Cham : Springer International Publishing, C. 1-25.
4. Wuana R. A., Okieimen F. E. (2011) Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. International Scholarly Research Notices. T. №. 1. C. 402647. https://doi.org/10.5402/2011/402647
5. Ghori N. H. et al. (2019) Heavy metal stress and responses in plants. International journal of environmental science and technology. T. 16. №. 3. C. 1807-1828.
6. Ali N. Khan E., and Ilahi I. (2019). “Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental Persistence, Toxicity, and Bioaccumulation”, J. of Chemistry. T. 4. C. 1-14. DOI:10.1155/2019/6730305
7. Tóth G. et al. (2016) Heavy metals in agricultural soils of the European Union with implications for food safety. Environment international. T. 88. C. 299-309. https://doi.org/10.1016/j.envint.2015.12.017
8. Kumar D. et al. (2016) Heavy metal and their regulation in plant system: an overview. Plant responses to xenobiotics. C. 19-38. DOI:10.1007/978-981-10-2860-1_2
9. Hasnine M. T. et al. (2017) Heavy metal contamination in agricultural soil at DEPZA, Bangladesh. Environment and ecology research. T. 5. №. 7. C. 510-516. DOI:10.13189/eer.2017.050707
10. Ahmed M. et al. (2019) Heavy metal contamination of irrigation water, soil, and vegetables and the difference between dry and wet seasons near a multi-industry zone in Bangladesh. Water. T. 11. №. 3. C. 583. DOI:10.3390/w11030583
11. Cai L. et al. (2012) Source identification of eight hazardous heavy metals in agricultural soils of Huizhou, Guangdong Province, China. Ecotoxicology and environmental safety. T. 78. C. 2-8. DOI:10.1016/j.ecoenv.2011.07.004
12. Hu Z. et al. (2019) Soil contamination with heavy metals and its impact on food security in

China. Journal of Geoscience and Environment Protection. Т. 7. №. 05. С. 168. DOI:10.4236/gep.2019.75015

13. Mirkhaydarova G., Ruzmetov M., Turdaliev J. (2024) Factors and problems of chemical pollution of soils in Uzbekistan. E3S Web of Conferences. EDP Sciences, Т. 563. С. 03032. DOI:10.1051/e3sconf/202456303032
14. https://ecoportal.su/public/industry/view/1175.html
15. Jabbarov Z., Sultonova N. (2022) Тупроқларнинг техноген ифлосланиши ва бузилиш тенденциялари/https://www.researchgate.net/publication/362732369_TUPROKLARNING_TEHNOGEN_IFLOSLANISI_VA_BUZILIS_TENDENCIALARI