Acta Montanistica Slovaca
ISSN 1335-1788
actamont.tuke.sk

Changes in the Number of Volatile Components in the Soil Under the Influence of Household Waste

***Tokhtasin ABDRAKHMANOV*[1], *Zafarjon JABBAROV*[1], *Gulkhayo ATOYEVA*[1*], *Sardor SAYITOV*[2], *Inna CABELKOVA*[3] and *Lubos SMUTKA*[3]**

Authors' affiliations and addresses:
[1] National University of Uzbekistan named after Mirzo Ulugbek, University str., 4, 100174 Tashkent, Uzbekistan
e-mail: soilecology@yandex.com, zafarjonjabbarov@gmail.com, gulhayoatoyeva@gmail.com,

[2] Institute of Mineral Recourses, Olimlar str, 64, 100164 Tashkent, Uzbekistan
e-mail: sardorsayitov@gmail.com

[3] Czech University of Life Sciences Prague, Kamycka 129, Praha, 16500, Czechia
e-mail: cabelkova@pef.czu.czu, smutka@pef.czu.cz

***Correspondence:**
Gulkhayo Atoyeva, National University of Uzbekistan named after Mirzo Ulugbek, University str., 4, 100174
tel.: +998935152326
e-mail: gulhayoatoyeva@gmail.com

Acknowledgement: This study was financially supported by the project No. 3 funded by the National university of Uzbekistan

How to cite this article:
Abdrakhmanov, T., Jabbarov, Z., Atoyeva, G., Sayitov, S., Cabelkova, I. and Smutka, L. (2023). Changes in the Number of Volatile Components in the Soil Under the Influence of Household Waste. *Acta Montanistica Slovaca*, Volume 28 (3), 535-542

DOI:
https://doi.org/10.46544/AMS.v28i3.01

Abstract

Today, almost all large cities have a landfill for municipal solid waste, where solid waste is dumped, stored and partially disposed. Storage and disposal of household waste (mainly by burning) can negatively impact the structure, productivity indicators, and the agroecological state of the soil cover common around the landfill. Such high levels of heavy metals and metalloids in household waste ash, in turn, lead to soil contamination around the landfill. The reason is that the process of incineration and open storage of waste has a very negative impact on the environment. It should be noted that the level of heavy metal contamination of the soil around the domestic landfill is low. However, failure to fully comply with the measures for storage and disposal of waste can lead to contamination of soils around the landfill with heavy metals since the content of heavy metals in ashes is very high. Soil pollution with household waste affects all processes occurring in it and has a detrimental effect on the activity of living organisms living in the soil. In particular, soil pollution with household waste changes the amount of organic volatile compounds in the organic part of the soil. Studies have shown that benzofuran organic volatile compounds not found in background soils can be found in soils around municipal waste when exposed to pollution. Some compounds, such as carbonic acid-10.99% and di-n-desylsulfone-0.47%, which are noted in the background soils, were not found in soil sample No. 1 taken at the landfill. These compounds are removed from the soil as a result of waste incineration and other processes.

Keywords

Domestic waste, soil, volatile components, soil properties, change.

Introduction

All over the world, scientific research is being carried out to prevent and identify sources of pollution that adversely affect soil fertility, eliminate the resulting consequences, and restore and increase soil fertility. In this regard, attention is paid to the study of the activity of soil enzymes, microbiological, agrophysical and agrochemical properties aimed at increasing soil fertility. As a result of the accumulation, processing and incineration of waste, agricultural fields and fertile soils become unusable. As a result of waste incineration, organic hydrocarbon compounds, such as naphthalene, tetraphene, chrysene, and fluorene, as well as low contents of pyrene and pyrimidine, were found in the soil of the enclosing territories of solid household waste landfills (Tsibart 2011; Tsibart et al., 2011). The average concentration of polycyclic aromatic hydrocarbons in peat soils in northeastern Europe is 150–3700 ng/g (Pastukhov et al., 2017). An increase in the content of polycyclic aromatic hydrocarbon compounds, such as benzanthracene, 3,4-benzo(a)pyrene, and 7,12-dimethylbenzanthracene contained in gases, causes dangerous tumours in the human body. These compounds accumulate not only in the air but also in soil and agricultural products and enter the human body, infecting it (Filatov et al., 2020; Denisova, 2009). Scientists believe that soils contaminated with volatile organic compounds can be cleaned up to 70.8% using the oxidizing agent Fe2+, activated with calcium oxide (CaO2) and persulfate oxalate acid (S2O82-) (Jian Wang et al., 2021). When the scientists studied the soil of the household landfill, it was found that the content of microelements, minerals (quartz and glauconite), humus substances, and calcium and gypsum substances in plant remains changed. Soil is the main source of nutrition for plants, it acts as a natural medium that affects the condition of ground and air - absorbs pollutants. Soil pollution with industrial and household waste is a factor that fundamentally changes the composition of the soil and the life activity of organisms living in it and reduces soil fertility, making it unsuitable for agricultural activities. Heavy metals and various organic and toxic substances contained in these sources of pollution enter the soil under the influence of natural factors and damage it (Suaad Hadi Hassan Al-Taai, 2021; Ryabchenko et al., 2017).

Household waste affected the activities of soil enzymes (phosphatase, urease, protease, deaminase and sulfatase). A decrease in the activity of microorganisms showed a decrease in the amount of mobile nitrogen, phosphorus and potassium minerals in the soil (Suleymanov et al., 2007), and as a result of a change in the activity of enzymes, a decrease in the amount of S and N in the soil is observed. The number of parasitic organisms such as Ascaris sp., Toxocara sp., T. leonina, N. vitulorum, Metastrongylus sp., Parascaris equorum, Nematoda belonging to the group Nematoda increases (Romanova et al., 2017). Open storage and disposal of household waste without separation and processing (Nidhi Kundariya et al., 2021; Holotová et al., 2020) causes an increase in antibiotic-resistant bacteria in the waste. As a result, the number of bacteria increases and gets added to the subsoil and wastewater, which has a negative effect on agricultural products and human health (Uttpal Anand et al., 2021; Ginevičius, 2022).

Household waste contains a large amount of plastic products, which pollute the soil for many years after they fall into the soil. These plastic products have a dangerous effect not only on the soil but also on plant, animal and human organisms (Harmita Golwala et al., 2021). As a result of soil pollution with household waste, not only chemical trends but also the amount of organic matter in the soil increase (Claudia Moeckel et al., 2020). Volatile organic compounds produced in household waste are released into the air and slow down the formation of the ozone layer (Pakkattil et al., 2021). As a result of scientists' research, it was determined that the amount of diphenyl ether in the soil of the household landfill increased from 6.81 to 33.67 mg/g dw (Sonam Paliya et al., 2022). Soils contaminated with volatile organic compounds can be treated with calcium oxide (CaO2) and persulfate (S2O82-) oxalic acid-activated Fe2+ oxidizer with 70.8 % accuracy (Jian Wang et all 2021). Domestic waste is created as a result of human activity, and as a result of human activity, it spreads and pollutes the environment. The generation of these wastes puts pressure on natural resources and seriously affects their sustainable development. At the same time, it leads to deterioration of various properties of soils. The best way to prevent damage to soils and natural resources is to use and control waste effectively (Shiv Shankar et al., 2021). Nowadays, soil contamination with lead is widespread and considered one of the most ecologically dangerous types of pollution (Xin Sun et al., 2023). The increase of lead in the soil over 80 mg/kg had a negative effect on the activity of microorganisms, reducing their activity, and the activity of actinomycetes decreased by 20% (Yuanxin Liu et al., 2021). Lead heavy metal is absorbed into the body of young children five times faster and easier than that of adults (Elvira Dzhumelia et al., 2021). Deterioration of the agrochemical properties of the soil affects the changes in biological processes in the soil, the quality, composition and productivity of agricultural products (Sipos et al., 2007; Smutka et al., 2015; Naglova et al., 2017; Hornowski et al., 2020), and ultimately has a harmful effect on the health of humans and living organisms (Ram Swaroop Meena et al., 2020).

It is well known that soil pollution with domestic waste also leads to pollution with a certain amount of heavy metals. The amount of soil contamination with heavy metals varies depending on the location and distance from the source. Heavy metals are abundant near the polluting source, and the amount of pollution decreases further away (Vitalii Ishchenko et al., 2021). Due to the fact that soil pollution with household waste is increasing year by year, the problem of cleaning and restoring the properties of contaminated soil is a problem that worries people all over the world. Currently, the use of methods such as anaerobic digestion, composting, hydrothermal carbonization, and pyrolysis with the participation of anaerobic microorganisms (Renju Babu et al., 2021) has been launched.

Material and Methods

Soil sampling and storage for studying the organic properties of soils contaminated with household waste was carried out in accordance with the Interstate Standard (GOST: 17.4.4.02-84). The first sample was taken from a household waste landfill in the Akhangaran district of the Tashkent region, and the second sample was taken at a distance of 9 km (background) from the landfill from a depth of 0-20 cm. The total amount of organic matter in the samples was determined according to GOST-26213-91 using a spectrophotocalorimeter, and the amount of volatile compounds in soil organic matter using gas chromatography (Agilent 8890 GC da SIM, SCAN va Electron Impact (EI), ionization mode method (Agilent 5977B Series GC/MSDc).

The Agilent 8890 GC is a state-of-the-art gas chromatograph that provides superior performance for all applications. Key to its performance is the use of advanced electronic pneumatic control (EPC) modules and high-performance GC oven temperature control, which lead to extremely precise retention time reproducibility, the basis for all chromatographic measurements. The 8890 7-inch capacitive touchscreen interface provides real-time access to instrument status, configuration, and flow path information. A signal plot confirms that analyses are running as intended. Additional tabs provide quick access to key functions such as editing method parameters, diagnostics, maintenance, logs, and help screens. The Browser Interface is the most extensive interface to the 8890 GC's intelligence and mobile access features. Optimized for a 10-inch tablet, the Browser Interface can be used on tablets or a PC. Now, one can view setup information, troubleshoot problems, check for leaks (autonomous hands-free), backflush columns, pause and start sample runs, and manage method development. GC performance can be monitored by automatically evaluating blanks using advanced onboard analytical techniques.

Analysis through emotional maps.

Tashkent region is geographically located in the northeastern part of our republic, between the Syr Darya and the Western Tianshan mountains. The northwestern part corresponds to the borders of Qorjontov and Ugom between Kazakhstan and Uzbekistan. The border with Kyrgyzstan in the eastern part passes through Talas Olatov Piskom and Chatkal mountains. The Kurama ridge separates it from the Fergana valley. The southwestern border includes the Syr Darya River, part of the Western Tianshan Mountains and the Chirchik and Ohangaron valleys, as well as the Dalvarzin desert. The solid waste landfill of Tashkent is located in the Akhangaran district of the Tashkent region. The study area is represented by foothills, plains, hills and river valleys. The region's continental climate is characterized by dry and hot summers and cold winters. The average annual temperature is +15.0°C, with average temperatures of -3.0°C in January and +26.0 °C in July. Absolute minimum -28°C, maximum +50 °C. 220–280 mm is the average amount of precipitation per year, most of which falls in autumn and spring. The growing season lasts 180 days. Typical irrigated grey soils are spread around the landfill of solid waste of Tashkent and used in agriculture for growing vegetables. This landfill has been operating since 1968. In 2012, another 30 hectares were added to the landfill in accordance with the Cabinet of Ministers of the Republic of Uzbekistan's decision.

Fig. 1. Space image of the investigated area.

Soil samples for research were selected according to the following coordinates (Fig. 1): (41°05'32.5"N / 69°28'48.8"E, 41°05'31.9"N / 69°28'48.0"E, 41°05'26.7"N / 69°28'45.8"E, 41°05'20.7"N / 69°28'45.4"E, 41°05'19.0"N / 69°28'31.8"E, 41°05'32,5"N / 69°28'48,8"E, 41°05'32,5"N / 69°28'48,8"E, 41°08'15.0"N / 69°26'35.0"E, 41°10'13.6"N /69°24'49.0"E.).

In the territory of Tashkent region, the following major geomorphological regions are distinguished: high mountains, medium mountains and low mountains, mountain and sub-mountain plains, and lower and upper terraces of rivers. The diverse structure of the Earth's surface has led to significant changes in climate, affecting plant species and genetic types of soils. The hydrogeological conditions of the area result from geomorphological-lithological and relief conditions. Groundwater is mainly formed as a result of underground transit water flowing in mountain and sub-mountain plains; it is non-saline, fresh and less mineralized.

I-section was taken by ash layers, which formed after burning waste inside the landfill. It contains a variety of refractory glass, slate, brick fragments, and various large and small stone fragments. The nearby lands of the area are used for farming purposes. In the 0-30 cm layer from which the cross-section was taken, ash particles and ash residues formed from the burning of waste can be found. Therefore, the physical properties of the soil have also changed, and the density, moisture level, and structural condition of the soil have changed due to very severe pollution.

X-section was taken from the southeastern part of the area, 10,000 meters away from the research object (for background). Typical grey soils with light, medium, and heavy sand are distributed in the lower part of the delta area of the mountainous region of Tashkent.

The research area is the flora

Found in the study area: Artemisia dracunculus, Urtica dioica, Ddracocephalum nutans, Chamerion angustifolium, Distamnus angustifolius, Rosa canina, Hippophea rhamnoides, Ziziphora pedicellat, Thalictrum minus, Heracleum lehmannianum, Rheum maximoviczii, Origanum tutthanthum, Nepeta cataria, Achillea millefolium, Peganum harmala, Prunella vulgaris, Tussilago farfara, Lamium album, Agrimonia asiatica, Hyupericum perforatum, **Capparis herbacea, Orthurus kokanicus, Helichrysum maracandicum, Rosa maracandica**, Korolkovia Severtzovii, Robinia pseudacacia, Alhogi pseudoalhagi, Salvia sclarea, Thermopsis alterniflora, Amugdalus spinosissima, Achillea filipendulina, Leanurus turkestanicus, Crataegus turkestanica, Rhodiola heterodonta, Betula tianschanica, Rumex tianchanicus, Inula macrophyla, Pyrola rotundifolia, Mediasia macrophylla, Dracocephalum integrifolium, Prangos pabularia, Lycopus europeus, Tanacetum psedoachillea, Juglans regia, Artemisia tenuisecta, Juniperus zeravchanicus, Lagochilus sevarchanicus, Hypericum elongatum, Glaucium fimbrilligerum plant species such as.

Results and Discussion

The fertility of the soil is directly related to its physicochemical properties, the humus cover, the organic and mineral substances contained in it, and especially the number of various beneficial microorganisms in it and their biological activity. In addition, a targeted selection of crops is required, depending on the location of agricultural areas in different geographic latitudes, the characteristics of development, and the creation of modern harmless biotechnologies. The impact of soil pollutants on nitrogen bacteria is very small, and an increase in their number leads to a decrease in soil contamination.

Another group of microorganisms in the soil is very sensitive to pollution from household waste, the function of which is to maintain and restore soil fertility. In addition, soil organic composition is also one of the important soil indicators. An increase and decrease in organic matter content also negatively affects plants and the activity of microorganisms living in the soil. When studying organic soil pollutants in the study area, it was found that soil waste contains alkane hydrocarbons, various essential substances and acids (Fig. 2).

The results of the analysis showed that the soils located around the territory of the municipal waste landfill contained o-xylene, oxalic acid, alkanes, oleamide, pyridine, carboxylic, carbonic acid, etc. The study showed that almost all organic compounds in the contaminated soils were higher than in the background soil sample (Tables 1 and 2).

As a result of the accumulation and incineration of household waste at the household waste landfill, the organic substances contained in them enter the soil, accumulate and pollute it. Oleamide and Di-n-Desylsulfone, the carbonate acid in the background sample, accumulate due to the release of these substances into the atmosphere during waste incineration. In addition, pentafluoropropionic acid 9.71% and benzofuran 14.1% were found in the composition of soil samples taken near the landfill, which are practically not present in the background soil sample.

Also, the analysis results showed the absence of other volatile organic compounds in the background soil sample, which were found in soil samples contaminated with household waste (Table 1 and Table 2).

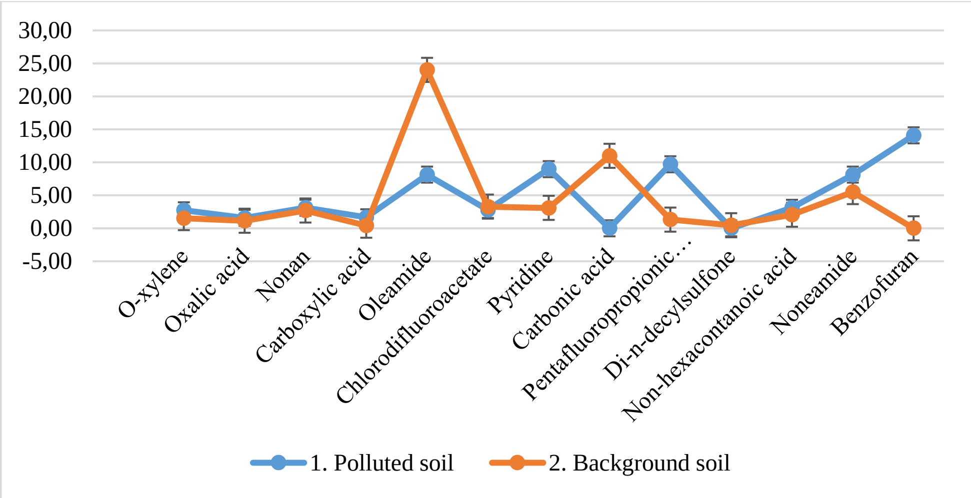

Fig. 2. The amount of volatile organic compounds in soils contaminated with household waste and background.

Tab. 1. The amount of volatile compounds of organic substances in contaminated soils with household waste (landfill soil).

№	Name of substances	%	Formula
1	1-cyclohexene	1,83%	C8H10
2	Dean	2,74%	C10H22
3	1-hexanol 5-methyl-2(1-methylethyl)	1,52%	C10H22O
4	Oxalate Acid	1,60%	C15P26O4
5	2-ethylhexine isoether of acid oxalate sining	3,10%	C16H30O4
6	Ionol (hydroxytoluene butyl acetate)	6,82%	C15H24O
7	2-ethyl hexanol	7,91%	C8H16O
8	Nonyl tetradesyl ether	3,16%	C23H42O
9	5,5-dimethyl-3-oxo-1-pyrroline, 1-9 oxide	1,67%	C12H15NO
10	Modified 2,3-epoxydan	2,54%	C10H20O
11	1,2-nonylpropyl ether of carbonate acid	2,00%	C14H25O3
12	Carbonate acid tridesyl ether	1,44%	C22H44O3
13	6-ethyl oct-3-li ethyl ether of oxalic acid	1,05%	C14H26O3
14	2H-pyran, 2-tetrahydro 3-ethylinoxy ether	0,52%	C9H14O2
15	Z,Z-6,28-Heptotriactontadiene-2,1	1,55%	C37H70O
16	3-heptene, 7-chloro	2,78%	C7H11Cl
17	4-cyclopentene-1,3-diol	1,79%	C5H8O2
18	8-oxabitcyclo 5-1-0 octane	9,79%	C7H12O
19	2-butylthio pyridine	0,90%	Synthetics

Tab. 2. Amount of volatile compounds of organic matter in the soils of the study area (background soil)

№	Name of substances	%	№	Name of substances	%
1	1,3-Cyclopentadiene, 5-(1-methylet hylidene)	0,88	16	trans-2,3-Epoxydecane	0,52
2	1-Hexanol, 5-methyl-2-(1-methylethyl)	0,20	17	N-Hexadecylpyridinium bromide	0,72
3	Bicyclo[3.2.1]oct-2-ene, 3-methyl-4-methylene-	0,78	18	Citronellol epoxide (R or S)	0,85
4	1,4-Cyclohexadiene, 3-ethenyl-1,2-dimethyl	1,19	19	2-Octyn-1-ol	0,16
5	Oxalic acid, 6-ethyloct-3-yl ethyl ester	1,16	20	2-Butyl-3-methylcyclopent-2-en-1-one	0,7
6	Decane, 3-methyl	1,18	21	3-Heptyne, 7-chloro-	0,49
7	Oxalic acid, cyclobutyl tetradecyl ester	2,15	22	Bicyclo[10.1.0]trideca-4,8-diene-1, 3-carboxamide, N-(4-fluorophenyl)	0,35
8	2,4,6,8-Tetramethyl-1-undecene	1,12	23	Aspidofractinine-3-methanol, pha.,3.beta.,5.alpha.)	8,89
9	4-Allyloxyimino-2-carene	4,37	24	7-Octenal, 3,7-dimethyl	14,26
10	Oxalic acid, allyl undecyl ester	1,81	25	Carbonic acid, but-3-yn-1-yl undecyl ester	2,4

11	1,2-dibromo-Dodecane	4,53	26	Tricyclo[6.3.3.0]tetradec-4-ene,10, 13-dioxo	0,94
12	Carbonic acid, but-3-yn-1-yl dodecyl ester	1,06	27	cis-9,10-Epoxyoctadecan-1-ol	1,04
13	8-Methyl-6-nonenoic acid	1,33	28	Oxirane, (7-octenyl)	1,05
14	Sulfurous acid, octadecyl 2-propyl ester	0,89	29	1H-3a,7-Methanoazulene, octahydro-1,4,9,9-tetramethyl	0,62
15	1-(Cyclopropyl-nitro-methyl)-cyclo pentanol	0,91			

Various organic compounds, polycyclic aromatic hydrocarbon compounds, and free hydrocarbon gases are found in large quantities in soils that are common around landfills and various industrial zones. In the soils of zones remote from industrial enterprises, these compounds decrease (Gennadiev et al., 2016; Agapkina et al., 2007). Accumulation of household waste on agricultural land and their incineration leads to the accumulation of various organic pollutants in the soil, resulting in agricultural land becoming unusable (Maksimova et al., 2013). n-tridecane, hexane and xylene have toxic properties, disrupt the soil's structure after entering it, and negatively affect its biological activity. Soil contamination with these substances leads to phytotoxic effects on plant growth and biomass; the application of ammonia fertilizers to the soil and the accumulation of waste also leads to more severe soil contamination with the above substances (Denisova 2009). Polycyclic aromatic hydrocarbons - these highly mobile organic compounds of the benzene series, capable of dispersing in the biosphere, are formed as a result of natural and technogenic pollution (Abakumov et al., 2015). A study of Moscow urban soils revealed a six times increase in the amount of benzo(a)pyrene, which in the background soils is 10-740 μg/kg. In the soils of Europe, this figure is 2-6 times higher (Belonskaya et al., 2015).

Household waste accumulated at landfills releases various volatile organic compounds into the atmosphere. When the activity of bacteria in soils contaminated with household waste is high, it reduces the emission of CO_2, CH_4, phenolic compounds, aromatic hydrocarbons, and alkanes emitted into the air by assimilating organic volatile compounds released from the waste (Randazzo 2020). Due to various organic volatile compounds and water waste generated during the decomposition of household waste, a favourable environment is created for the development of various harmful insects, rodents, vectors of infectious diseases and pathogens. This poses a serious threat to human health (Zomarev, 2010). Volatile organic compounds generated in landfills where household waste accumulates slow down the formation of the ozone layer as a result of their release into the air (Pakkattil et al., 2021). Polycyclic aromatic hydrocarbons in soils are closely related to agricultural, residential, transport, and industrial activities (Jomolca Parra et al., 2020).

Conclusions

It was concluded that these organic compounds are mainly composed of alkanes, esters, and polycyclic aromatic hydrocarbons, which have been formed as a result of the incineration of household waste for many years. In addition, the presence of various volatile organic compounds was found in the background soils: cyclohexane 1.82%, decane 2.74%, bulyt acetate 6.82%, various carboxylic acid esters 3.44%. The presence of these volatile organic compounds in the background soil sample is justified by their release into the atmosphere during the incineration of household waste.

In conclusion, we can say that the amount of volatile organic compounds in the soils located around the household waste landfill has increased as a result of the accumulation and incineration of waste over the years. In soil samples contaminated with household waste, increased contents of organic compounds, such as alkanes, ethers, various organic acids, benzene, amides and polyamides, dangerous to human life, are found, which are practically not present in the background soil sample taken at a distance from the landfill of household waste. The increase in the content of these organic compounds in the soil complicates the biological, chemical, physical and agrochemical processes occurring in the soil, which leads to a decrease in soil fertility.

References

Abakumov E.V., Parnikoza I.Yu., Lupachev A.V., Lodygin E.D., Gabov D.N., Kunakh V.A. (2015). The content of polycyclic aromatic hydrocarbons in the soils of the vicinity of the Antarctic stations. *Hygiene and Sanitation*, vol.7 with. 20-25;

Agapkina G.I., Chikov P.A., Shelepchikov A.A., Brodsky E.S., Feshin D.B., Bukhanko N.G., Balashova SP. (2007). Polycyclic aromatic hydrocarbons in Moscow soils. *Bulletin of Moscow University*. Vol.17: Soil Science, p. 38-47;

Belinskaya E.A., Zykova G.V., Semenov S.Yu., Finakov G.G. (2015). Polycyclic aromatic hydrocarbons in the soils of Moscow. *Soil Science*. Moscow, p. 668;

Claudia Moeckel., Knut Breivika., Therese Haugdahl Nosta, Alhaji Sankoh, Kevin C. Jones, Andrew Sweetman. (2020). Soil pollution at a major West African E-waste recycling site: Contamination pathways and implications for potential mitigation strategies. *Environment International*. 137-105563, www.elsevier.com/locate/envint.

Denisova A.P. (2009). The role of natural materials and mineral fertilizers in the binding and biodegradation of fuel hydrocarbons in soils. *Abstract*, *Kazan*, p. 23;

Egamberdieva, D., Jabbarov, Z., Arora, N.K. (2021). Biochar mitigates effects of pesticides on soil biological activities. *Environmental Sustainability*. https://doi.org/10.1007/s42398-021-00190-w.;

Elvira Dzhumelia., Volodymyr Pohrebennyk.(2021). Methods of Soils Pollution Spread Analysis: Case Study of Mining and Chemical Enterprise in Lviv Region (Ukraine). *Ecological engineering & environmental technology*, 22(4), 39–44.

Filatov V.V., Kairgaliev D.V., Vasiliev D.V., Melnikov I.N., Pichkhidze S.Ya. (2020). Possibilities of liquid chromatography in the determination of polycyclic aromatic hydrocarbons. *Federal State Treasury Institution of Higher Professional Education Modern Problems of Science and Education*, Moscow, p. 852;

Gennadiev A.N., Zhidkin A.P., Pikovskiy Yu. I., Kovach R.G., Koshovskiy T.S., Khlynina N.I. (2016). Hydrocarbon state of soils in conditions of atmospheric pollution by a localized industrial source. *Soil science*, no. 9, p. 1-11

Ginevičius, R. (2022). The efficiency of municipal waste management systems in the environmental context in the countries of the European Union. *Journal of International Studies*, 15(4), 63-79. doi:10.14254/2071-8330.2022/15-4/4

Harmita Golwala, Xueyao Zhang, Syeed Md Iskander, Adam L. Smith. (2021). Solid Waste: An Overlooked Source of Microplastics to the Environment. *Science of The Total Environment*, Vol. 769.

Holotová, M., Nagyová, Ľ., Holota, T. (2020). The impact of environmental responsibility on changing consumer behaviour – sustainable market in Slovakia. *Economics and Sociology*, 13(3), 84-96. doi:10.14254/2071-789X.2020/13-3/6

Hornowski, A., Parzonko, A., Kotyza, P., Kondraszuk, T., Bórawski, P., & Smutka, L. (2020). Factors determining the development of small farms in central and eastern Poland. *Sustainability (Switzerland)*, Vol. 12, No. 12. https://doi:10.3390/su12125095

Jabbarov Z.A., Atoeva G.R. (2021). Soil contamination with heavy metals during the impact of the landfill of solid domestic waste. *International Scientific and Practical Conference* "Soil and ecological problems of agrocennoses and ways to solve them" June 3-4, 2021 Baku.

Jabborov Z.A., Atoeva G.R. (2020). Changes in the agrochemical properties of soils contaminated with household waste. *Scientific Review*. Vol 4, p. 22-26;

Jabborova, D. Choudhary, R. Karunakaran, R.; Ercisli, S.Ahlawat, J., Sulaymanov, K., Azimov, A., Jabbarov, Z. (2021). The Chemical Element Composition of Turmeric Grown in Soil-Climate Conditions of Tashkent Region, Uzbekistan. *Plants.* Vol., 10, 1426. https://doi.org/10.3390/plants10071426;

Jian Wang., Xiaofang Zhang., Xian Zhou., Michael Gatheru Waigi., Fredrick Owino Gudda., Chaolan Zhang., Wanting Ling. (2021). Promoted oxidation of polycyclic aromatic hydrocarbons in soils by dual persulfate calcium peroxide system. *Science of The Total Environment*. Volume 758;

Jomolca Parra Y., Oyebayo O.O., Guilherme M.P., Henrique P.A., Lima A., Ellenda S., Caumo S., Olajumoke A.M., Perolade C.V. (2020). Polycyclic aromatic hydrocarbons in soils and sediments in Southwest Nigeria. *Environmental Pollution*. Vol. 259;

Makhammadiev S, Sattarov D., Atoev B., Jabbarov Z., Jobborov B., Turgunov M., Muydinov K. (2021). The Formation of the Nutrient Medium in the Soil is Influenced by Varieties and Fertilizer and Its Impact on Grain Yield of Winter Wheat. *Annals of R.S.C.B.*, ISSN: 1583-6258, Vol. 25, Issue 4, 2021, Pages. 5218 – 5230;

Maksimova E.Yu., Tsibart A.S. Abakumov E.V.(2013). Polycyclic aromatic hydrocarbons in soils affected by upstream and downstream fires. *Bulletin of the Samara Scientific Center of the Russian Academy of Sciences.* Vol. 15, No. 3., p. 63-68.;

Naglova, Z., Boberova, B., Horakova, T., & Smutka, L. (2017). Statistical analysis of factors influencing the results of enterprises in dairy industry. *Agricultural Economics*, Vol. 63, No. 6, p. 259-270

Nidhi Kundariya., Swayansu Sabyasachi Mohanty., SunitaVarjani, Huu Hao Ngo, Jonathan W. C. Wong., Mohammad J. Taherzadeh., Jo-ShuChang., HowYong Ng., Sang-Hyoun Kimk., Xuan-Thanh Bui. (2021). A review on integrated approaches for municipal solid waste for environmental and economical relevance: Monitoring tools, technologies, and strategic innovations. *Bioresource Technology*, Vol. 342,. https://doi.org/10.1016/j.biortech.2021.125982.

Pakkattil A, Muhsin M, Ravi Varma M. (2021). COVID-19 lockdown: Effects on selected volatile organic compound (VOC) emissions over the major Indian metro cities. *Urban Climate*. p. 37.

Pastukhov A.V., Kaverin D.A., Gabov D.N. (2017). Polycyclic aromatic hydrocarbons in permafrost hilly peat bogs in the European north-east. *Soil science*, vol. 7, p. 814-823;

Ram Swaroop Meena., Sandeep Kumar., Rahul Datta., Rattan Lal., Vinod Vijayakumar., Martin Brtnicky., Mahaveer Prasad Sharma., Gulab Singh Yadav., Manoj Kumar Jhariya., Chetan Kumar Jangir., Shamina Imran Pathan., Tereza Dokulilova., Vaclav Pecina., Theodore Danso Marfo. (2020). Impact of Agrochemicals on Soil Microbiota and Management: *A Review. – Land*. 21. doi:10.3390/land9020034.

Randazzo A., Assensio-Ramos M., Melian G., Venturi S., Pardon E., Hermandez P., Perez N., Tassi F. (2020). Volatile organic compounds (VOCs) in solid waste landfill cover soil: Chemical and isotopic composition vs. degradation processes. *Science of The Total Environment*. 15 July, Volume 726.

Renju Babu, Patricia M. Prieto Veramendi, Eldon R. Rene. (2021). Strategies for resource recovery from the organic fraction of municipal solid waste. *Case Studies in Chemical and Environmental Engineering*. –P. 8. https://doi.org/10.1016/j.cscee.2021.100098.

Romanova E.M., Lubomirova V.N., Shadyeva L.A. (2017). Assessing the level of biological hazard of soils from unauthorized dumps of household waste. *Bulletin of the Ulyanovsk State Agricultural Academy.* P. 68.

Ryabchenko, O., Golub, G., Turčeková, N., Adamičková, I., & Zapototskyi, S. (2017). Sustainable Business Modeling of Circular Agriculture Production: Case Study of Circular Bioeconomy. *Journal of Security and Sustainability Issues*, 7(2), 301-309.

Shiv Shankar and Shikha. (2020). Management and Remediation of Problem Soils, Solid Waste and Soil Pollution. *Principles and Applications of Environmental Biotechnology for a Sustainable Future*, pp 143–171.

Sipos, G., Urbányi, B., Vasa, L., Kriszt, B. (2007). Application of by-products of bioetanol production in feeding, environmental and feeding safety concerns of utilization. *Cereal Research Communications* 35(2), 1065-1068. ,

Smutka, L., Steininger, M., Maitah., M., Skubna. (2015). The Czech agrarian foreign trade - ten years after the EU accession. *Agrarian perspectives XXIV: Global agribusiness and the rural economy*, Czech Univ Life Sci Prague, Fac Econ & Management, 385-392. ISSN: 1213-7960 Online ISSN: 2464-4781

Sonam Paliya., Ashootosh Mandpe., Manukonda Suresh Kumar., Sunil Kumar., Rakesh Kumar. (2022). Assessment of polybrominated diphenyl ether contamination and associated human exposure risk at municipal waste dumping sites. *Environ Geochem Health* 44:4437–4453.

Suaad Hadi Hassan Al-Taai. (2021). Soil Pollution - Causes and Effects. *First International Virtual Conference on Environment & Natural Resources. IOP Conf. Series: Earth and Environmental Science* 790 012009 IOP Publishing doi:10.1088/1755-1315/790/1/012009.

Suleimanov R.R., Abdrakhmanov T.A., Zhabbarov Z.A., Tursunov L.T. (2007). Enzymatic activity and agrochemical properties of meadow-alluvial soil under conditions of oil pollution. *Samarskaya Luka.* Vol.16, No. 3(21), p. 575-580.

Tsibart A.S. (2011). Polycyclic aromatic hydrocarbons in pyrogenic soils of protected areas (Khakassky nature reserve). *Moscow State University*. p. 50-55.;

Tsibart A.S., Gennadiev A.N. (2011). Associations of polycyclic aromatic hydrocarbons in fire-affected soils. *Vestn. Moscow University*. No. 3. p. 13-19;

Uttpal Anand , Bhaskar Reddy, Vipin Kumar Singh, Amit Kishore Singh, Kavindra Kumar Kesari, Pooja Tripathi, Pradeep Kumar, Vijay Tripathi and Jesus Simal-Gandara. (2021). Potential Environmental and Human Health Risks Caused by Antibiotic-Resistant Bacteria (ARB), Antibiotic Resistance Genes (ARGs) and Emerging Contaminants (ECs) from Municipal Solid Waste (MSW) Landfill. *Antibiotics*, p. 374. https://doi.org/10.3390/antibiotics10040374.

Vitalii Ishchenko., Igor Vasylivskyi. (2022). Environmental Pollution with Heavy Metals: Case Study of the Household Waste. *Sustainable Production: Novel Trends in Energy, Environment and Material Systems*, pp 161–175.

Xin Sun., Mingjie Sun., Ying Chao, Xiaoyang Shang, Hui Wang, Hong Pan, Quangang Yang, Yanhong Lou, Yuping Zhuge. (2023). Effects of lead pollution on soil microbial community diversity and biomass and on invertase activity. *Soil Ecol. Lett*. Vol. 5(1), 118−127 https://doi.org/10.1007/s42832-022-0134-6.

Yuanxin Liu., Xiangyang Sun., Song Li., Suyan Li., Wenjie Zhou., Qixue Ma., Jiali Zhang. (2020). Influence of green waste compost on Pb-polluted soil remediation, soil quality improvement, and uptake by Pakchoi cabbage (Brassica campestris L. ssp). *Environmental Science and Pollution Research*. p. 27:7693–7701. https://doi.org/10.1007/s11356-019-07505-9.

Zhabbarov Z.A., Atoeva G.R., Sayitov S.S. (2010). Soil pollution with heavy metals around the landfill of solid household waste of Tashkent. *Scientific Review,* No. 2, 2021. p. 17-23;

Zomarev A.M. (2010). Sanitary and hygienic monitoring of solid waste landfills at the stages of the life cycle. // Abstract. Perm, p. 50.