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Remediation of the Technogenic Soils

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ABSTRACT

A number of studieshave been carried out worldwide to investigate the state of anthropogenicsoil degradation during the environmental impacts caused by chemical industry, thermal power industry, oil and gas, coal and mineral deposits, and therefore to develop appropriate remediation approaches. The paper identifies the main factors of pollution in the area of anthropogenic degraded soils, distinguishes the level of soil contamination by protection and contamination zones, reveals the mechanism of changes in soil fertility in terms of physical, chemical, biological properties of soils. Anthropogenic degradation of soils around two different sources of pollution in one area depends on the variability in soil genetic layers with the amount of heavy metals and ash waste. A remediation algorithm based on biological and technical measures has been developed to restore the fertility of the irrigated soils. After remediation of anthropogenic disturbed soils, the indicators of recovery of the ecological condition and fertility of the soils and the existing coefficients for them have been developed. A three-stage remediation technology based on technical and biological methods has been developed for anthropogenic degraded irrigated dark gray soils. The following sequence of anthropogenic degradation and ecological changes of soils in the study area has scientifically been justified: damaged of soil microbiological world - disturbed physical properties - changed chemical properties - alteration of air and water regimes) - decreased soil fertility. For further technology development onthe remediation of sites it is suggested to consider above mentioned sequence in order to adjust given parameters.

KEYWORDS

Anthropogenic Impact, Heavy Metals, Soil Fertility, Ash Waste, Microorganisms.

Introduction

There are plenty of thermal power plants (TPPs) operated around the world, those activities have been caused impact on ecosystem including soils, through processing ofthe coal. Coal, slag and ash wastes from the TPPs had harmful effect on the growth and development of the plants (Abdel S. et al., 2007). Wastes from thermal power plants due to coal combustion, including heavy metals, dust, ash slag, hydrocarbons, carbon monoxide, have affected not only the biosphere but also the ozone layer and thus accelerated climate change (Arnab I.Z. et. Al., 2013;Safty B.E., et al., 2013).

Chemical pollution during the operation of the metallurgical industry accounted for 48% of the total pollution. Residual accumulations in the soil cover and atmosphere have caused significant damage to the region's soils and groundwater, and most importantly, the recycling level of the wastes generated around the industrial plants is still insignificant (Cirtina et al., 2014). Across the thermal power plants operating in France, 26 elements, including 13 rare heavy metals were found in the soil, which were distributed in different amounts in soil and transmitted to the cultivated crops (Oral R. et al., 2019). The Elbason Metallurgical Complex is the largest industrial center in Albania,

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and the chemicals emitted from there have affected soil, atmosphere, and water cover in a large extent. As a result, trace metals such as Zn, Ni, Cd, and Pb exceeded REChU, thus adversely affecting soil properties and the quality of crop yields (Fatbardh 2003). Also, as a result of the activities of that industry, gases such as SO_2, SO_3, CO, CO_2 were released into atmosphere, contaminating the surrounding soil and water bodies, which have negatively effect to the chemical, biological, and physical properties of soil and thus deterioratethe soil fertility (Ben Sasi, 2013).

Traditional restoration is the most preferred and cost-effective method worldwide (Agamuthu et al., 2013). Several researchers suggestedthe removal of organic compounds from anthropogenic degraded soils by water flow to identify contaminants and biologically treat them (Cirtina et al., 2014). The growth of cereals in anthropogenic degraded soils has led to good results, in which the chemical properties of the soil have been improved (Jankovic et al., 2012). Other researchers have proven that usinglocal species in the remediation process demonstratedsome hope for bioremediation (Gromova et al., 2018). The creation of artificial forests has been recognized as an effective method of rehabilitating the degraded lands (Didur et al., 2018; Trindade et al., 2005; Didur et al., 2018).

Materials and Methods

The objective of the study the irrigated sierozem-meadow soils and dark sierozem soils scattered around the joint-stock company "Uzbekistan Metallurgical Union" in Bekabad district of Tashkent region and the new and old thermal power plants in Angren city.

The geographical coordinates of the study area can be seen from the table below (Table 1).

Table 1. Geographical coordinates of the surveyed areas

Angren city	
north point	N $41^{o}06^{I}81^{II}$north latitude, E $70^{o}08^{I}53^{II}$east longitude
south point	N $40^{o}96^{I}60^{II}$north latitude, E $70^{o}04^{I}83^{II}$ east longitude
east point	N $41^{o}02^{I}23^{II}$ northern latitude, E $70^{o}98^{III}$ east longitude
west point	N $40^{o}98^{I}11^{II}$ northern latitude, E $69^{o}99^{I}$ 08^{II} east longitude

For the study, soil profiles were made and samples were taken at a total of 14 points at distances of 1.6, 2.5, 5, 8, 12, 16, and 23 km around the thermal power plants in Angren city. Laboratory analysis of soil samplestaken from the disturbed fertile layer were analysed according to the Interstate Standard (GOST: 17.4.2.02–83), determination of soil pHby ISO 10390 (ISO 10390: 2005), mechanical and microaggregate composition of soil by NA Kachinsky method using pycnometer, the organic carbonbyTyurin method, NPK byMesheryakov method, heavy metals and other chemical elements in soil samples were performed by the guidance of MP 003: 2015, statistical analysis by “Statgraphics Centurion XVII” software.

Results and Discussion

Soilmorphological characteristics showed that the soil features were altered in the study area, and soil morphological markings were made. The morphological features of the soil horizons and soil samples excavated in the study area are shown below:

Profile KA-16-2.5. It was taken from 2.5 km northeast around the IES in Angren city. The area soil is irrigated dark sierozem, previously wheat was planted followed by corn, and there were willow and mulberry trees around. The impact of the source of pollution on the environment was visibledirectly in the field, with a thin layer of ash dust on top of the soil.

0-5 cm. Dark gray, weakly moist, fine-grained, moderately dense, texture was medium-loam, plant roots were common. Invertebrate nests, tracks, and new lesions were rare. The ash occurred in the form of dust, there also were small amount of stones, which transferred to the next layer together with changing humidity.

5-20 cm. Dark gray, high humidity relative to the top soil, fine-grained, moderately dense, texturewas heavy-loam, plant roots were rare. Invertebrate nests, tracks, and new lesions were rare, and remnants of ash debris werefew. Went to the next layer with color change.

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20-60 cm. Light gray, strongly moistened, finely structured, highly dense, the texturewas sandy, plant roots were absent. There were no invertebrates, no roads, no new creations, and no evidence of ash dust. Passed to the next layer with density.

60-100 cm. Light gray, strongly moistened, finely structured, strongly compacted, the texturewas heavy loam, plant roots were absent. There were no signs of invertebrates, roads, new creations, and no remnants of ash dust. Passed to the next layer with density.

100-140 cm. Dark gray, high humidity, fine structure, weakly compacted, the texturewas heavy sandy loam, plant roots were absent. There were no invertebrate animal nests, tracks, and new creations, no remnants of ash waste. Transferred to the next layer with moisture. Contaminants were not visible in lower layers of the soils.

During the excavation of the soil horizons, it was revealed that the morphological features of the soils were mostly observed around the TPPs in Angren city. This is due to the fact that, soil horizons A, B, C, and D from the area close to the source of contamination were disturbed and mixed with gravel, and secondly, the ash elements emitted in the smoke were collected in top soil. It can be seen that the processes of contamination were affected. The morphological features of many othersoilsanalyzedin study areawere similar.

There were various chemicals in the soil cover as a result of anthropogenic impact, some of which exceeded the maximum acceptableconcentration(MAC) level(Table 2).

Table 2. Contamination status of anthropogenic degraded irrigated soils

Contaminants/ Trace elements	Objects and soils		
	In the soils scattered around JSC "Uzbekistan Metallurgical Combine", mg / kg	In soils scattered around Angren TPP, mg / kg	In soils scattered around New Angren TPPs, mg/kg
Ag	<0,1	0,0030	<0.001
As	8.4	5.7	8.4
Ce	96	69	74
Ba	940	-	-
Ni	0.001	110	140
Mo	0.002	1.2	4.0
Sn	0.0004	420	-
Co	17	9.8	8.2
Cr	94	52	28
Cs	9.1	1.0	25
Eu	1.5	12	1.3
Zh	0.003	-	-
Hf	6.5	5.8	-
La	81	17	19
Lu	0.35	0.12	0.12
Cu	0.01	-	-
Pb	0.01	170	170
Tb	-	0.82	1.83
Th	-	24	29
Sr	-	420	1000
Cs	-	12	25
Sm	-	2.3	2.3
Sc	-	10	12
W	-	<1.0	5.5
U	-	2.4	3.7
Nd	-	8.0	7.8
Rb	-	170	170
Sb	-	6.4	7.0

TheMAC values of some heavy metals are described here: Sb - 4.5; Mn - 1500; V - 150; Pb - 32; As - 2.0; Hg - 2.1; Cu - 55; Ni - 85; Zh - 100; Cd - 0.5.

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Certain heavy metals were detected in Bekabad district, where they exceeded the MAC levels in soil, for instance, As - 4.2 times, Cr - 16 times, Ni - 2.5 times, Rb - 3.7 times, and Zn by 4.8 times. Long term accumulation of the trace elements in soilhas been affected on the living community of soil and processes like chemical composition and physical properties of soil. Around fourpoint-sources that were investigated, within 2 km radius, the ecological condition was significantly altered.Results suggest that anthropogenicdisturbance of the soil properties may undergoas following sequence (Table 3).

Table 3. Changes in soil properties affected anthropogenically

Impacton microbiological community	Alteration of soil enzyme activity	Deterioration of physical properties	Changes in chemical processes	Disbalance in air and water regimes	Lossof the soil fertility

More and more technical forms of remediation are used around the world in the remediation of anthropogenic disturbed soils, but this has been done by manufacturing enterprises, ecology and environmental organizations, with little attention paid to aspects related to soil fertility. In this regard, biological remediation activities were carried out jointly within the remediation activities carried out in the study area. Accordingly, depending on the level of anthropogenic impact, some agricultural cropswere planted, additional fertilizers and nutrients were applied, and agro-technical measures were implemented. An algorithm of all activitiesof theremediation measures was developed, with individual approach to each of the parameters in charge. The remediation algorithm consists of 18 stageswithin 3 groups (Figure 1).

I. Problem statement in the research area:
I.1. Study of the geographical location (coordinates) of the research area;
I.2. Study of hydrological conditions of the study area;
I.3.Study of the geological location of the study area;
I.4. Study of climatic conditions and irrigation conditions of the study area;
I.5. Study of soil cover in the study area;
I.6. Identification of the main flora and main crops grown in agriculture, distributed in the study area;
I.7.Identify sources that affect the ecological condition of soils and anthropogenic degradation in the study area.
I.8. Excavation of soil sections from the study area, sampling for laboratory experiments.
I.9. Morphological and micromorphological structure.
II. Performance of the laboratory analysis:
II.1. II.1. Determining the increase of chemicals in the soil relative to the REChU indicator, i.e. the state of contamination;
II.2. Determination of texture and aggregate condition, density of soil;
II.3. Determination of nitrogen, phosphorus, potassium, nutrients and humus in the soil;
II.4. Study of changes in soil microorganisms;
II.5. Choice of plants with phytoremediation properties;
III. Field application of the remediation measures:
III.1. 0-5 cm of soil, depending on the area of contamination and the degree of contamination. and 0-15 cm. layer removal;
III.2. Land leveling, laying clean soil, application and driving of manure and mineral fertilizers;
III.3. Planting of plants with phytoremediation properties, including alfalfa, barley, etc.
III.4. Plants cultivation before the vegetation process will be succeededwith land improvement.

Figure 1. Algorithm of the remediation measures foranthropogenic disturbed soils

Results revealed that for more efficient work, the remediation approach should be considered individually despite the variations in the soil type and properties along with the anthropogenic disturbed area. Simultaneously, levels of

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pollution and therefore pollution rate are also matter of individual consideration when the technology applied to the targeted site (Jabbarov et al., 2019).

The state of recovery of soil fertility indicators in the study area wererevealed as post remediation. Indicators of recovery of soil fertility were determined according to the interstate standard “GOST 17.4.2.02-83.-Nomenclature of the indicators of suitability for degradation of fertile soils for agriculture”. According to the requirements of this normative document, soil fertility indicators include: moisture, specific gravity, bulk density, porosity, granulometric (mechanical) content, water absorption, aqueous pH, salinity pH, exchangeable cation content, hydrolytic acidity, alkali saturation, salinity, humus, total nitrogen, assimilated nitrogen and lightly hydrolysable nitrogen, total phosphorus, mobile phosphorus, total potassium, exchangeable potassium, mobile form of trace elements, gypsum, carbonates, water-soluble, toxic salts, sanitary condition. Thus,the pre-remediation and post-remediationindicatorsof the soils were compared in order to studythe soil fertility condition (Table 4).

Table 4. Minimum coefficients to increase the soil fertility indicators for the post remediation of the anthropogenic disturbed soils

Indicators	Coefficients
The total number of microorganisms	1.80
Humidity	1.22
Aggregates (0.25 mm and 0.5 mm)	2.62
pH	1.21
Humus	1.08
Humification degree of organic matter, Sgk./Sum. × 100%	1.10
Organic carbon	1.02
Gross nitrogen	1.15
Available phosphorus	1.20
Available potassium	1.11
Germination degree of the plant seeds	1.30
Bulk density	1.20
Available form of the micronutrients	1.25

The number of total microorganisms found in the anthropogenic soils may indicate as the parameters for determining the recovery level of the soil fertility. In this case, it is necessary to determine the number of total microorganisms in the soil after certain remediation practice.Consequently, it was found that the coefficient of growth in the total number of the microorganisms in irrigated meadow soilswas 1.80, which was the minimum quantity.
The restoration of soil fertility is the result of a reduction in the amount of chemicals, the application of fertilizers, mineral fertilizers and the planting of phytoremediation crops used as green fertilizers. The indicators such as the total amount of microorganisms, enzyme activity, soil respiration, aggregation and germination rate of plant seeds are highly improved, the recovery of the remaining indicators is relatively low, their recovery increases over time, chemical, oxidation-reduction reactions were stated the recovery rate of the soil fertility.
After remediation practice, improvement of agrochemical and chemical properties of the soils were also observedincluding an increase in soil pH and nitrogen, phosphorus, potassium nutrients(Table 5).

Table 5. Improvement of nutrients and pH-environment in the soil after remediation

Soils of the study area	pH H_2O		% Of total nitrogen		Moving K_2O mg/kg		Moving K_2O мг/кг	
	Before	After	Before	After	Before	After	Before	After
KA-16-0,9	6,20±0,17	6,9±0,19	0,065±0,18	0,070±0,11	21,28±0,51	22,67±0,58	199,74±3,99	202,5±6,05
KA-16-2,5	6,1±0,17	6,8±0,10	0,070±0,21	0,081±0,20	21,94±0,30	23,41±0,60	201,78±5,05	205,9±4,17
KA-16-5	6,5±0,18	7,0±0,11	0,068±0,15	0,075±0,19	25,42±0,66	28,91±0,80	203,5±5,08	206,4±5,19
KA-16-23±	7,2±0,18	7,2±12	0,074±0,20	0,075±0,19	33,01±0,89	36,41±1,82	214,10±5,42	216,4±5,49

An important role in the anthropogenic degradation of the soils of the study area was played by the burning of coal in the form of large amounts of ash, small piles of coal, atmospheric waste. As a result, the pH of the soil changed to an acidic medium, only at a point 23 km far from Angren IEs, the pH was 7.2, which can be explained by partial salinity

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of soil. As a result of the remediationpractice, the pHof the soil has neutralized, which was due to the reduction of chemical contaminants in the soil medium.

One of the important indicators of soil fertility is the change in the number of exchangeable cations. After remediation, exchangeable cations were increased in the irrigated meadow soils (Fig. 2).

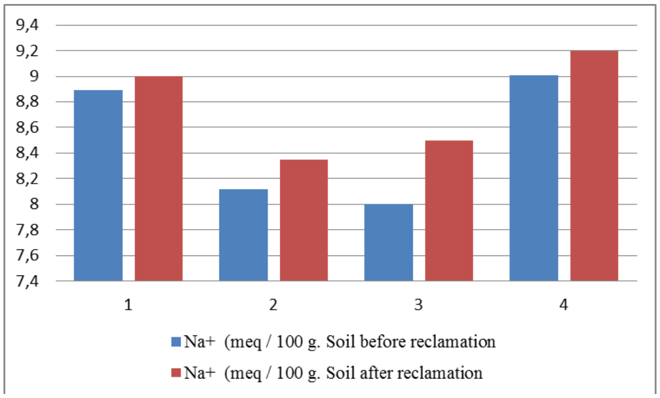

Figure 2. The amount of exchangeable sodium cation in the soils of the study area

The amount of sodium cation in the soil was partially increased after remediation, which was caused by the removal of the topsoil during process with the application of organic and mineral fertilizers. We assume that continuous practical application of the remediation measures may positively affect to the recovery rate of the soil fertility.

Similarly, the amount of ammonium and magnesium cations increased comparing to the pre-remediation amount, including 1.4 to 1.6 mg.eq / 100g of soil at point 1 and 1.47 to 1.62 mg.eq / 100g of soil at point 2 (Figure 3, 4).

After remediation, there was a change in soil chemical composition, which added to the number of exchangeable cations, including Na^+, NH_4^+, $Mg2^+$, K^+, Ca^{2+}, although the number of cations did not go up significantly, all cations tend to increase. This indicates the balanced elemental content in soil, which resulted in the amount of organic and mineral fertilizers applied, as well as the agrotechnical measures.

One of the ecological indicators of the soil is the activity of the biological processes in soil, post remediation studies in the research area confirmed the improvement in soil fertility. Accordingly, in both regions' rapid growth in the number of total soil microorganisms was observed post remediation (Table 6).

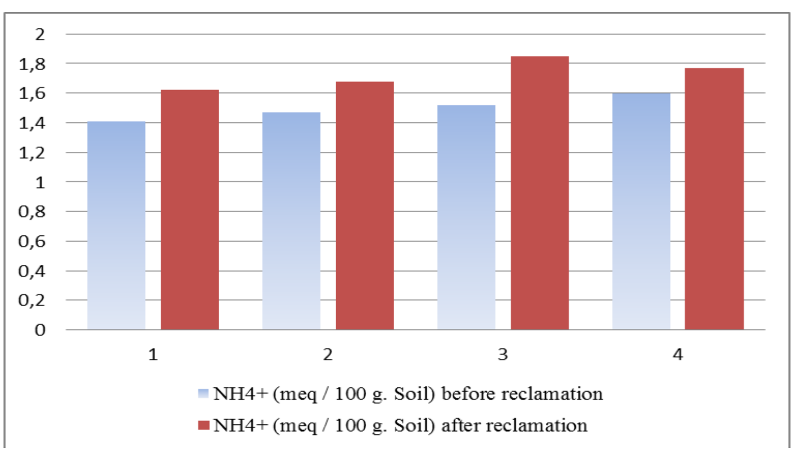

Figure 3. The amount of exchangeable ammonium cation in the soils of the study area

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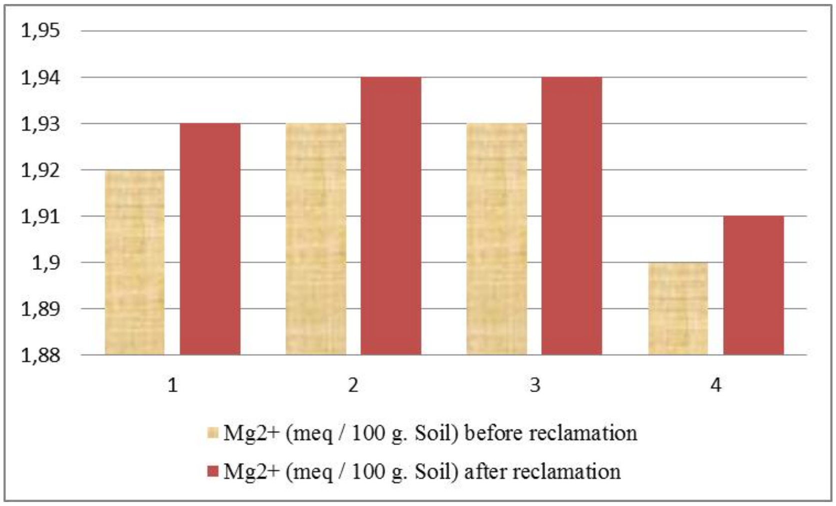

Figure 4. The number of exchangeable cations in the soils of the study area

The purpose of this experiment was to determine if there wasfavorable condition for soil microorganisms, therefore, the actinomycetes, fungi, and bacteria were not considered.

The prevalence of total microorganisms increased before remediation, based on two factors, firstly, the concentration of chemicals in soil, secondly, the increased irrigation culture, i.e. in areas far from the source of contamination - KA-16- 5, KA-16-23, KB-16-5, KB-16-23 were planted twice a year. In all soil and water samples studied, there was a tendency increasing the number of total microorganisms, which indicates that the ecological condition of the surrounding area has been being restored.

Table 6. Post remediation number of total soil microorganisms in study area

Profiles	Before remediation (1 CFU/ 1g soil)	After remediation (1 CFU/ 1g soil)
IES in Angrencity		
KA-16-0,9	$3.2x10^5$	$8.0x10^5$
KA-16-2,5	$3.9x10^5$	$2.4x10^6$
KA-16-5	$4.8x10^6$	$6.5x10^6$
KA-16-23	$7.1x10^6$	$9.4x10^6$

Conclusion

Soil type of the research area were classified as irrigated dark sierozem soils and the soils which were spread around Angren TPP were classified according to the level of anthropogenic disturbance as follows: weak anthropogenic (ATS), medium anthropogenic (ATV), strong anthropogenic (ATV) soils. The irrigated sierozem meadow soils around JSC "Metallurgical Union" were classified as weak anthropogenic (ATS). The ash source in the irrigated dark sierozem soils around Angren TPP mainly came from the combustion of coal (SiO_2, Al_2O_3, CaO, Fe_2O_3, Na_2O), K_2O, MgO, P_2O_3, BaO, SrO, Mn_2O_7, CuO, PbO, As_2O_7, Mo_2O_7, LiO) with wastes, as well as As, Ag, Br, Ba, Ce, Co, Cr, Cs, Eu, Hf, Mo, Ni With heavy metals and other elements such as, Rb, Sb, Sc, Sm, Sr, Zn.Irrigated sierozem-meadow soils around JSC "Uzbekistan Metallurgical Union"were contaminated with above mentioned heavy metals, resulting in alteration of the biological processes in the soil. The following sequence of anthropogenic degradation and environmentalpollution of the soils in the study area was scientifically discussed: damage of soil microbiological community in soil, deterioration of physical properties, change of chemical processes, disbalance in air and water regimes that leading to the loss of soil fertility.

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References

[1] Elgazwy, A.S.S.H., & Bhanger, M.I. (2007). Overview of the Environmental Impacts of the Uses of Coal, Thermal, Hydroelectricity, Oil, Gas, Fuel & Wood etc. in Pakistan. *Global Journal of Environmental Research*, *1*(1), 01-06.

[2] Arnab, I.Z., Ali, T., Shidujaman, M., & Hossain, M.M. (2013). Consideration of environmental effect of power generation: Bangladesh perspective. *Energy and Power Engineering*, *5*(04), 1521.-1525.

[3] Jabbarov, Z.A., Jobborov, B.T., Xalillayev, S.A., & Sherimbetov, V.K. (2020). Oil Contaminated Soils And Their Biological Recultivation. *European Journal of Molecular & Clinical Medicine*, *7*(6), 2797-2810.

[4] El Safty, A., & Siha, M. (2013). Environmental and health impact of coal use for energy production. *Egyptian Journal of Occupational Medicine*, *37*(2), 181-194.

[5] Cîrțînă, D., & Traistă, E. (2014). Research on the influence of metallurgical industry waste on soil and groundwater quality. *Journal of Chemical Technology and Metallurgy*, *49*(3), 311-315.

[6] Oral, R., Pagano, G., Siciliano, A., Toscanesi, M., Gravina, M., Di Nunzio, A., & Trifuoggi, M. (2019). Soil pollution and toxicity in an area affected by emissions from a bauxite processing plant and a power plant in Gardanne (southern France). *Ecotoxicology and environmental safety*, *170*, 55-61.

[7] Sallaku, F., & Shallari, S. (2003). Environmental clean-up and sustainable development of contaminated areas around the metallurgical combine of Elbasani, Albania. *Options Mediterraneennes*, *57*, 55-62.

[8] Sasi, J.M.B. (2013). Air pollution caused by iron and steel plants. *International Journal of Mining, Metallurgy & Mechanical Engineering*, *1*(3), 219-222.

[9] Agamuthu, P., Tan, Y.S., & Fauziah, S.H. (2013). Bioremediation of hydrocarbon contaminated soil using selected organic wastes. *Procedia Environmental Sciences*, *18*, 694-702.

[10] Cîrțînă, D., & Traistă, E. (2014). Research on the influence of metallurgical industry waste on soil and groundwater quality. *Journal of Chemical Technology and Metallurgy*, *49*(3), 311-315.

[11] Jankovic, S., Rakic, S., Ikanovic, J., Drazic, G., & Malic, N. (2012). Possibility of growing rye on degraded soil of open pit mines in the process of biological recultivation. *In Third International Scientific Symposium" Agrosym 2012", Jahorina, Bosnia and Herzegovina, Book of Proceedings*, 225-229.

[12] Gromova, T., Ermolenko, A., Siraeva, I., Larionov, M., Larionov, N., & Zavidovskaya, T. (2018). The state of woody plants of natural and anthropogenic ecosystems of the european part of Russia and their bioindication value. *In International Conference on Contemporary Education, Social Sciences and Ecological Studies (CESSES 2018)*, 914-920.

[13] Didur, O.A., Kulbachko, Y.L., Maltsev, Y.I., & Konovalenko, T.V. (2018). Ecology of soil algae cenoses in Norway maple plantation in the recultivated territory of the Western Donbas (Ukraine). *Ukrainian Journal of Ecology*, *8*(1), 865-872.

[14] Trindade, P.V.O., Sobral, L.G., Rizzo, A.C.L., Leite, S.G.F., & Soriano, A.U. (2005). Bioremediation of a weathered and a recently oil-contaminated soils from Brazil: a comparison study. *Chemosphere*, *58*(4), 515-522.

[15] Didur, O., Kulbachko, Y., & Maltsev, Y. (2018). Impact of tropho-metabolic activity of earthworms (Lumbricidae) on distribution of soil algae within Acer platanoides L. plantation in recultivated territories of Western Donbass (Ukraine). *Ukrainian Journal of Ecology*, *8*(2), 18-23.

[16] Jabbarov, Z., Abdrakhmanov, T., Pulatov, A., Kováčik, P., & Pirmatov, K. (2019). Change in the Parameters of Soils Contaminated by Oil and Oil Products. *Agriculture (Pol'nohospodárstvo)*, *65*(3), 88-98.

[17] International standard. International Organization of Standardization // Standard of Soil quality. 2005. – ISO 10390:2005 (E).