SRPSKO DRUŠTVO ZA ZAŠTITU VODA

53. konferencija o aktuelnim temama korišćenja i zaštite voda

VODA 2024

The 53rd Annual Conference of the Serbian Water Pollution Control Society

WATER 2024

Conference Proceedings

Palić, 27. – 29. maj 2024.

www.sdzv.org.rs

SRPSKO DRUŠTVO ZA ZAŠTITU VODA

SERBIAN WATER POLLUTION CONTROL SOCIETY

INŽENJERSKA KOMORA SRBIJE

IZDAVAČ (*PUBLISHER*):

Srpsko društvo za zaštitu voda, Kneza Miloša 9/1, Beograd, Srbija,
Tel/Faks: (011) 32 31 630

UREDNIK (*EDITOR*): Dr Aleksandar ĐUKIĆ, dipl. građ.inž.

TIRAŽ (*CIRCULATION*): 150 primeraka

ŠTAMPA: "Akademska izdanja", Zemun, 2024

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

502.51(082)
556.11(082)
628.3(082)
628.1(082)

ГОДИШЊА конференција о актуелним проблемима коришћења и заштите вода (53 ; 2024 ; Палић)
Voda 2024 : zbornik radova 53. godišnje konferencije o aktuelnim problemima korišćenja i zaštite voda = Water 2024 : conference proceedings 53rd Annual Conference of the Serbian Water Pollution Control Society, Palić, 27-29. maj 2024. / [urednik, editor Aleksandar Đukić]. - Beograd : Srpsko društvo za zaštitu voda, 2024 (Zemun : Akademska izdanja). - X, 372 str. : ilustr. ; 24 cm

Tiraž 150. - Str. IX: Predgovor / Aleksandar Đukić. - Bibliografija uz svaki rad. - Abstracts.

ISBN 978-86-82674-01-6

а) Воде -- Зборници б) Отпадне воде -- Зборници в) Снабдевање водом -- Зборници

COBISS.SR-ID 145168649

SRPSKO DRUŠTVO ZA ZAŠTITU VODA

ZBORNIK RADOVA

53. GODIŠNJE KONFERENCIJE O AKTUELNIM TEMAMA
KORIŠĆENJA I ZAŠTITE VODA

VODA 2024

53RD ANNUAL CONFERENCE OF THE
SERBIAN WATER POLLUTION CONTROL SOCIETY
"WATER 2024"
CONFERENCE PROCEEDINGS

Palić, 27. – 29. maj 2024.

ORGANIZATOR KONFERENCIJE (*CONFERENCE ORGANISERS*):

Srpsko društvo za zaštitu voda (Beograd),

uz podršku

Ministarstva nauke, tehnološkog razvoja i inovacija Republike Srbije i Inženjerske komore Srbije

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ODRŽAVANJE KONFERENCIJE SU POMOGLI (*SPONSORED BY*):

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- Inženjerska komora Srbije

Slika na koricama: jezero Palić (fotografija A.Đukić)

Pregledni (naučni) rad
DOI: 10.46793/VODA24.037K

SOIL QUALITY CONTROL IN URBAN AREAS

Sonja Ketin*, Boban Kostic**

* *"Tamiš" Research and Devalopment Institute, Novoseljanski put 33, Pančevo, Serbia, email:ketin.sonja@gmail.com, ORCID: 0000-0002-2232-0529*
** *University of Bussines Academy in Novi Sad, Faculty of economics and management and engineering, Serbia, email:bobankosticbk@gmail.com, ORCID: 0000-0003-1134-5701*

ABSTRACT
The paper presents soil pollution on the territory of Belgrade, when a total of 66 soil samples from 33 locations were sampled and laboratory tested. Soil pollution on the territory of Belgrade was controlled with a special emphasis on the examination of the content of hazardous and harmful substances in the soil surrounded by public fountains with spring water. Tests of land in the zone of sanitary protection of the Belgrade water supply source, from communal areas and along traffic roads are also presented. The paper showed that at a certain number of locations there are deviations in terms of the content of hazardous and harmful substances in the soil in relation to the prescribed norms.

KEY WORDS: pollution, soil, quality, testing, pollutants, urban area

КОНТРОЛА КВАЛИТЕТА ЗЕМЉИШТА У УРБАНИМ СРЕДИНАМА

РЕЗИМЕ
У раду је приказано загађење земљишта на територији Београда, када је узорковано и лабораторијски испитано укупно 66 узорака земљишта са 33 локације. Контролисано је загађење земљишта на територији Београда са посебним акцентом на испитивање садржаја опасних и штетних материја у земљишту окруженом јавним чесмама са изворском водом. Приказана су и испитивања земљишта у зони санитарне заштите изворишта Београдског водовода, са комуналних површина и дуж саобраћајница. Рад је показао да на одређеном броју локација постоје одступања у погледу садржаја опасних и штетних материја у земљишту у односу на прописане норме.

КЉУЧНЕ РЕЧИ: загађење, земљиште, квалитет, испитивање, загађивачи, урбано подручје

INTRODUCTION

Soil or soil is a thin surface layer of the Earth's crust that has direct contact with the air and water environment, where dynamic processes are constantly taking place under the influence of chemical, mechanical, physical, biological and climatic factors as well as human activities. It was created by processes of decomposition and degradation of rocks under the influence of mechanical, physical-chemical, thermal and erosion, biological and other factors. It is the youngest layer of the Earth's crust and its age is estimated at several tens of thousands of years.

It consists of layers, profiles-horizons, each of which has its own specificities. The surface layer is a layer of humus, and its thickness ranges from a few centimeters to almost 2 m. The humus layer is created over many years by stacking plant materials and other decomposed organic substances. The transitional layer of the soil consists of mineral material from which the dissolved components have been washed, and the deeper layer is clay in which water is deposited and organic and inorganic substances brought by leaching accumulate. Beneath the layer of clay are the parent rocks from which the soil became.

Soil is a mixture of organic and inorganic substances. Although the organic part is in the composition with a maximum of 5% and it is very important for plants as a reservoir of nutrients. Soil is a polyphase heterogeneous system consisting of solid, liquid and gaseous substances and living organisms. All these components are in dynamic balance. The soil ecosystem is made up of different forms of life, such as bacteria, fungi, molds, plants, etc. Land is a prerequisite for life and has great importance for human survival and the beginning of civilization. It is a source of energy, minerals, microelements, nutrients for plants. Because of this, soil as a limited natural resource must not be degraded and polluted, but must be constantly renewed and revitalized.

SOIL CHARACTERISTICS

Soil is the most complex heterogeneous system in the lithosphere. It is an open dynamic system where the processes of circulation and exchange of substances and energy with the environment take place continuously. Polluted substances enter the soil from the environment, degrading it and disrupting the dynamic balance. It is disrupted: by excessive cropping, irrigation, impoverishment of the seed fund, exploitation of mineral and ore wealth, dumping of communal, industrial and hazardous waste, organization.

Land characteristics: Morphological features, Composition and structural-mechanical properties, Physical features and Chemical properties. The characteristics of the soil depend on the relief, geological structure, climate and vegetation, hydrological parameters and the age of the soil itself.

MORPHOLOGICAL FEATURES

The soil profile shows the external morphological appearance of the soil. The morphological characteristics of the profile are the basis for testing the soil in the field.

- The composition of the soil is the general appearance of the soil profile and shows its division into genetic horizons

- Genetic horizons are horizontal zones on the soil profile that differ in color, thickness, mechanical composition, chemical composition and other properties.
- Horizons were named after the pedogenetic process that led to their formation. Land horizons are marked with capital letters O, A, E, B, C, R

O-surface horizon, contains organic substances; A- humus accumulative layer is located on the upper surface layer and has the highest content of humus and mineral elements; E-eluvial horizon is located below the O or A horizon. Humus and mineral substances are washed out of it. Gobat is made of clay and is lighter in color. The B-horizon is a zone of accumulation of organic substances - humus from the A and E horizons as well as mineral substances. C- horizon is a loose part of the parent substrate-rock. The lowest soil horizon. The R-horizon is the parent rock from which the soil was formed

Division of soil by depth

The characteristics of the soil depend on the relief, geological structure, climate and vegetation, hydrological parameters and the age of the soil itself.

Table1. Division of soil by depth

Very shallow	< 15 cm
shallow	15-30 cm
Medium deep	30-60 cm
deep	60-100 cm
Very deep	> 100 cm

The depth of the soil is very important for the process of absorption, adsorption, dissolution, water infiltration and penetration of polluting substances into the soil.

Soil color is an important morphological feature. It is an indicator of many chemical and biochemical processes in the soil. Soil compaction is a very important morphological feature and depends on its composition, porosity, state of aggregation, activity of soil fauna (highly compacted, compacted, loose and loose).

Tabel 2. Composition and structural mechanical properties of soil

Basic constituents of the solid phase of the soil	Dimensions
loam	up to 0.002mm
powder	from 0.002mm - 0.2mm
Fine sand	from 0.002mm - 0.2mm

The percentage share of certain particle fractions in the soil is the mechanical composition of the soil and is called soil texture

Physical properties of soil

Density of the solid phase-Specific mass of the solid phase of the soil

- Soil density Volumetric mass of soil
- Soil porosity

- Soil moisture
- Water permeability of the soil
- Capillarity

Chemical and physical-chemical properties of soil

Chemical composition of the soil
- Sorptive properties
- Ion exchange characteristics of the soil
- Soil acidity
- Trace elements in the soil
- Organic substances in the soil
- Content of heavy metals
- Harmful substances in the soil

Representation of elements in the Earth's crust

Microelements such as Cu, Zn, As, Co, Se, Ni, Pb, Mo and others enter the composition of the soil.

Harmful substances in the soil

Due to the presence of humus and clay, the soil binds very high concentrations of harmful substances and elements. They reach the soil with water or air that carries dust and aerosols rich in polluting substances. Pesticides (fungicides, herbicides, insecticides), Unused artificial fertilizers, Organic waste, Drainage and waste water, Chemical compounds, Heavy metals, Radioactive elements.

SOIL ANALYSIS

According to its chemical composition, the soil is a multiphase system. Solid phase about 50%. 45% of which is mineral matter and about 5% organic matter. The liquid phase of the soil, i.e. the soil solution and the gaseous phase each make up 25% of the total composition.
Analyses: common organoleptic properties - describe the appearance of samples on cross-section.
Complete analysis - physical parameters (density, specific density, particle size and water content).
Electrochemical measurements - the pH, conductivity and redox potential of the sample are measured, and the alkalinity of the soil, the concentrations of dissolved organic matter, nitrogen, phosphorus, sulfur and heavy metals are determined. It is done by known standard methods.
Legal bases of the established program of soil pollution testing in the Law on Environmental Protection, Ordinance on the manner of determining and maintaining zones and zones of sanitary protection of water supply sources, Ordinance on permitted quantities of hazardous and harmful substances in soil and irrigation water and methods of their

testing, systematic monitoring of soil quality, indicators for assessing the risk of land degradation and methodology for the development of remediation programs and other legal provisions. Sampling and laboratory testing was performed in accordance with the provisions of the Ordinance on permitted quantities of hazardous and harmful substances in soil and irrigation water and their testing methods and requirements of SRPSISO 17025. Interpretation of results was performed based on comparisons with regulations given in the Regulation on , indicators for assessing the risk of land degradation and methodology for the development of remediation programs (Ketin et al. 2010, Ketin et al. 2015).

Table 3. Recommended procedures for dissolving soil samples

metal	process
Heavy metals	HF-HClO4 digestion
Zn	HF-HClO4 digestion
Na	HF-HClO4 digestion
Si	Melting with $NaCO_3$ or NaOH or HF-$HClO_4$ digestion
K	Melting with $NaCO_3$ or NaOH or HF-$HClO_4$ digestion
Mg	Melting with $NaCO_3$ or NaOH or HF-$HClO_4$ digestion
Ca	Melting with $NaCO_3$ or NaOH or HF-$HClO_4$ digestion

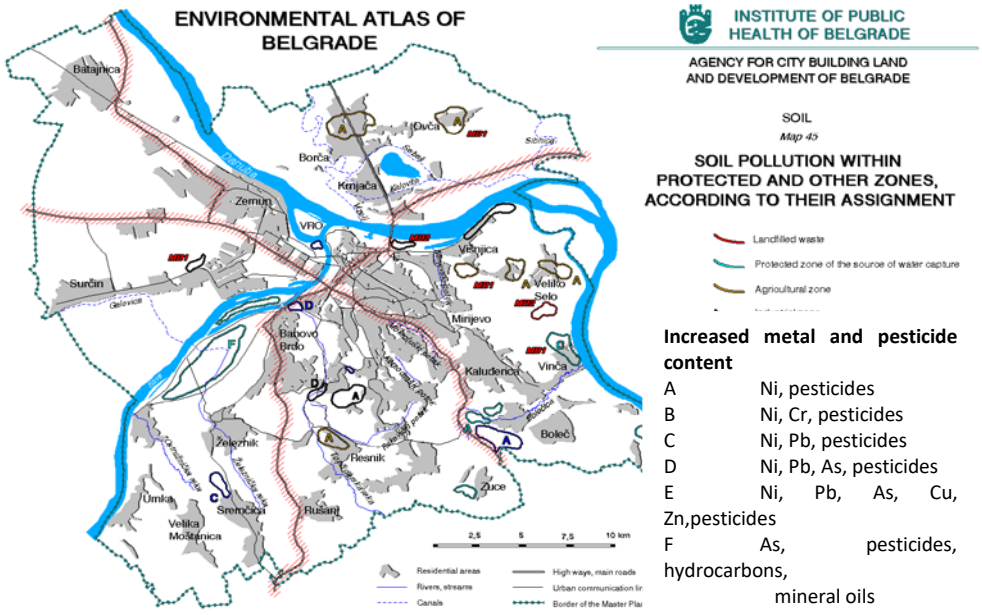

Fig. 1 Map of soil pollution in source protection zones
Source *https://www.zdravlje.org.rs/ekoatlas/volbe/45ev.gif*

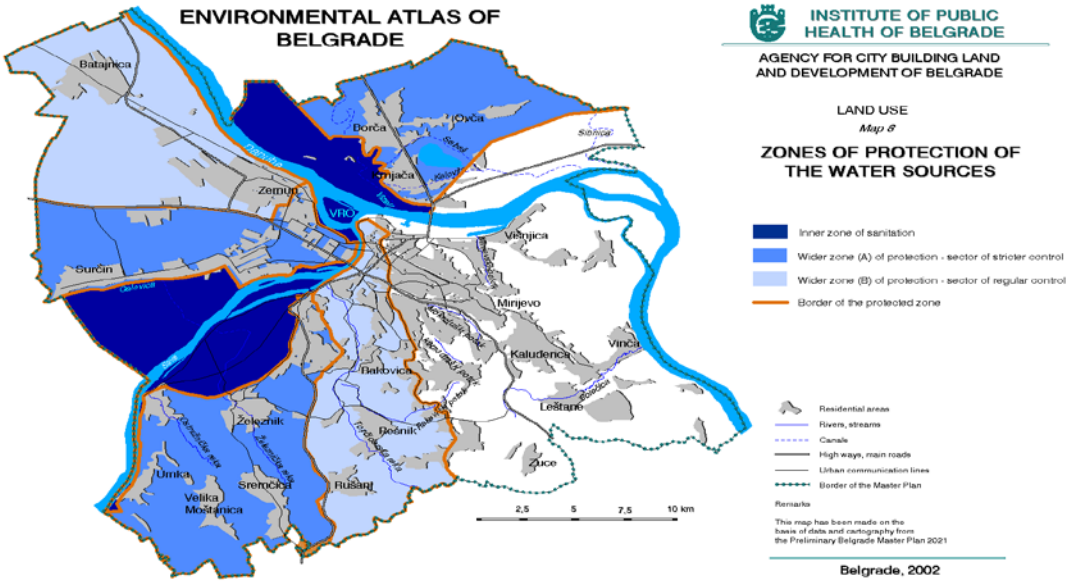

Fig. 2 Map of land use water supply source protection zones
Source: https://www.zdravlje.org.rs/ekoatlas/volbe/08ev.gif

The aim of soil pollution testing

The program of systematic testing of soil pollution on the territory of Belgrade enables the achievement of the following goals: determination of the concentration of hazardous and harmful substances in the soil; monitoring the state of soil pollution in urban zones, especially in the narrower zone of sanitary protection of the Belgrade water supply source; processing information and supplementing the database on the degree of pollution and land characteristics and proposing measures to reduce pollution in the territory of Belgrade(Peric-Grujicic 2009).

METHODS AND METHODOLOGY

Research area

The program of soil pollution testing on the territory of Belgrade focused on the following areas of testing:

1. Land in the zone of sanitary protection of the Belgrade water supply source - soil samples from 6 locations, in the area of Usce, were processed.
2. Land near busy roads - at 3 locations next to the roads where intensive road traffic takes place: New Belgrade, Mirijevo, Lestane.
3. Land within the communal environment - 5 locations: New Belgrade, Konjarnik, Karaburma and Cubura.

4. Land surrounded by public fountains - 19 locations: Topcider, Kosutnjak, Rakovica, Miljakovac, Jajinci, Beli potok, Resnik, Zarkovo, Visnjicka Banja, Kaludjerica, Lestane, Bolec and Mali mokri lug.

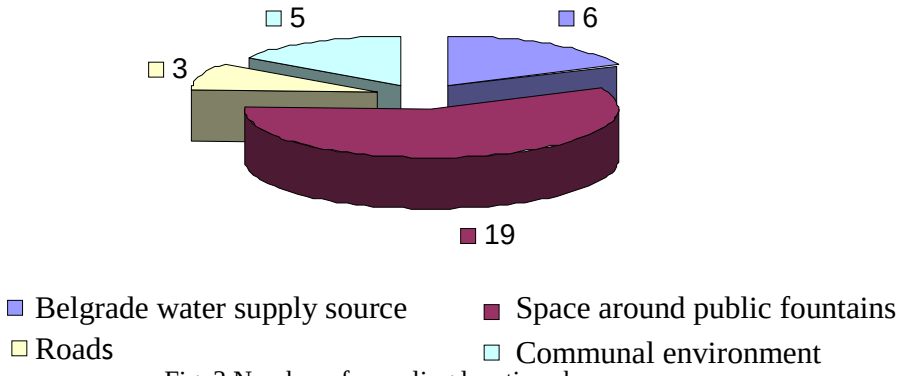

Fig. 3 Number of sampling locations by purpose zones

RESULTS

Test results

In order to implement the Program of soil pollution testing on the territory of Belgrade, a total of 66 soil samples were sampled and laboratory tested at 33 locations.

The results of laboratory testing of soil pollution on the territory of Belgrade show in the surface layer of soil (up to 50 cm), in some locations, there is an increased concentration of certain test parameters, as follows:

I Within the sanitary protection zone of the Belgrade water supply source

1. in 9 out of 12 soil samples, the content of nickel (Ni) was increased in relation to the norms of the regulation on the program of systematic monitoring of soil quality, indicators for risk assessment of soil degradation and methodology for development of remediation programs. The excess of nickel concentration in the tested soil samples ranged from 37.5-99.4 mg⁄kgNi (Limit value for nickel - 35 mg⁄kg).
2. In 3 soil samples in the area of the estuary, the presence of DDT walls in low concentrations (17.0-85.0 mg⁄kg) was registered (limit value for DDT and its metabolites -10 μg⁄kg).

II Land near busy roads

1. Nickel content was increased in all 6 soil samples taken along busy roads. The concentration of nickel in the tested soil samples ranged from 43.4 to 72.7 mg⁄kg Ni.

2. In one sample of land at the location of New Belgrade, across from the gray building, an increased concentration of copper was registered, amounting to 53.2 mg / kg (limit value for copper - 36 mg / kg).
3. in 2 samples the increased content of C10-C40 hydrocarbon index in these samples was 132.0 - 51.9 mg⁄kg (limit value for hydrocarbon index C10-C40 -50 mg⁄kg).

III Land within the communal environment

1. In 11 out of 20 soil samples, nickel limit values were exceeded. The increased concentration of nickel in the tested soil samples ranged from 35.4-68.3 mg⁄kg Ni.
2. Increased zinc concentration - 123.0 and 222.0 mg⁄kg (limit value for zinc - 140 mg⁄kg) was registered in 2 soil samples.
3. in one sample, an increased concentration of copper was registered - 64.1 mg/kg.
4. in addition to metals, increased values of organic pollutants were registered, as follows:
    a. polycyclic aromatic hydrocarbons PAHs in 2 samples - 2792.0 and 8038.0 mg⁄kg.
    b. DDT residues in 3 samples - concentration range 21.0-1188.0 mg⁄kg.
    c. Hydrocarbon index C10-C40 in 2 samples - 64.0 and 79.4 mg⁄kg.
5. Land surrounded by public fountains
    a. In 32 out of 38 soil samples, the limit value for nickel was exceeded. The increased concentration of nickel in the tested soil samples ranged from 37.5-87.6 mg⁄kg Ni.
    b. In 6 soil samples, an increased concentration of zinc was registered, which in these samples ranged from 139.0-290.0 mg⁄kg (limit value for zinc - 140 mg⁄kg).
    c. In 4 soil samples, an increased concentration of copper was registered, which ranged from 36.3-66.9 mg⁄kg.
    d. An increase in the content of lead (290.0 mg⁄kg) (limit value for lead - 85 mg/kg) and cadmium (3.2) (limit value for cadmium - 0.8 mg⁄kg) was registered in one sample.
    e. In addition to metals, increased levels of organic pollutants were registered, as follows:
        • Polycyclic aromatic hydrocarbons (PAHs) in 3 samples - concentration range 1118.0-3074.0 mg⁄kg.
        • DDT residues in 13 samples - concentration range 12.0-834.0 mg⁄kg.
        • Hydrocarbon index c10-c40 in 9 samples-concentration range 54.6-209.7 mg⁄kg.
        • Polychlorinated biphenyls (PCBs) in two soil samples-15.2-42.0 mg⁄kg.

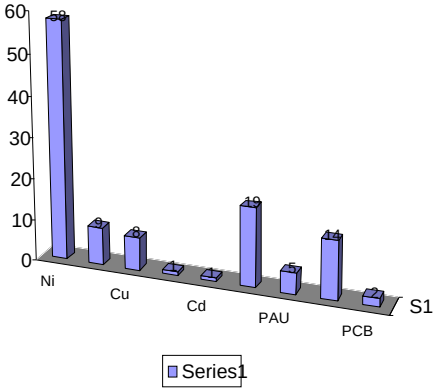

Fig. 4 Deviation according to parameters

Fig. 4 shows the number of soil samples in which the exceeding of some of the test parameters was registered, in relation to the total number of examined samples.

DISCUSSION OF RESULTS

Based on the research of soil pollution within the 4 zones of the urban area, we can conclude that in a number of locations there are deviations in terms of the content of hazardous and harmful substances in the soil in relation to the prescribed norms.

Taking into account all the results of soil testing on the territory of Belgrade, the most common deviation was related to the increased nickel content in the soil.

The Decree on the program of systematic monitoring of land quality, indicators for risk assessment of land degradation and methodology for the development of remediation programs, etc., entered into force. Ch. RS 88⁄2010, in which the limit values for certain parameters are lower than in the rulebook on permitted quantities of hazardous and harmful substances in soil and water for supply and methods of their testing, fig. RS 23⁄94, which was previously used to compare the obtained results. This is one of the reasons why the number of soil samples in which an increased content of nickel and other metals (zinc and copper) has been registered is higher than in previous years.

The increased nickel content in the soil is related to the specific geochemical composition of the soil surface layers in this area, and is not directly caused by contamination of anthropogenic origin, although the contribution of pollution cannot be completely ruled out. This conclusion is reached on the basis of the analysis of a large number of samples and the annual monitoring of soil pollution in the observed area.

At the locations located within the sanitary protection zone of the Belgrade water supply source, no significant deviations of the concentrations of the examined parameters were registered (Fig.2). Within the narrower zone of the soil protection zone, residues (residues)

of pesticides DDT are registered even after several decades from the cessation of application, which imposes the need for further monitoring of this parameter in the soil. As well as water, it will burn after the purification procedure.

In terms of the presence of harmful and hazardous materials in the land near traffic roads, the increased values of the hydrocarbon index c10-c40 (mineral oils) and copper can be related to the impact of motor vehicles on the condition of the land along traffic roads. At the locations located on communal areas, the registered deviations are smaller in scope and mostly common in relation to the results of many years of monitoring of soil pollution in the monitored area. Regarding the findings of the laboratory test, we can single out the location within the Chubur park, where an increased concentration of zinc, copper, DDT residues, hydrocarbon index and high concentrations of polycyclic aromatic hydrocarbons PAHs was registered at a depth of 50 cm. This finding can be related to environmental influences and historical pollution (traffic, pollution, home fireplaces, etc.), and the high values of PAHs are probably related to the material used to fill that part of the Chubur park. The focus of soil pollution control on the territory of Belgrade was placed on testing the content of hazardous and harmful substances in the soil in the vicinity of public fountains with spring water. The control was carried out in order to determine the impact of pollution sources in urban areas on the pollution of land in the supply zone of public fountains and to assess the possible impacts on water quality.

The results of the conducted research indicate that in the land that is surrounded by certain public fountains, there is an increased content of dangerous and harmful substances that can lead to deterioration of the quality of drinking water from these springs and potentially endanger the health of potential users.

The most significant deviations in terms of types and concentrations of pollutants were found in the vicinity of the hajduk fountain on Kosutnjak, where an increased concentration of lead, cadmium, zinc, copper and DDT residues in the soil was registered.

The increased metal content in the soil within the immediate protection zone of the source (catchment) of the hajduk fountain is related to the unfavorable influences originating from motor vehicles, ie the sweeping road that passes in the immediate vicinity as well as the raft with several parts of hives moving in the direction of the fountain.

In addition to this, a significant finding is the presence of polychlorinated biphenyl (PCB) in the soil near the Zelenjak fountain in Resnik.

Due to possible harmful effects from the environment on the quality of spring waters, through the program of water quality control of public taps on the territory of Belgrade, implemented by the city institute for public health, the content of metals in water taps along which traffic roads pass and pesticides in water taps larger green areas. Analyzes showed that the water from the Hajduk fountain did not exceed the content of pollutants registered in the soil, but the question is whether and when the contamination of the soil in the environment will negatively affect the quality of drinking water from this facility.

Regarding the degree of contamination, ie deviations from the prescribed values given in the regulation, we can state that the concentrations of all parameters that exceeded the limit value for unpolluted land were significantly lower than the values that would require land remediation procedures. that they have not reached the remediation value given in the said regulation.

CONCLUSIONS

The results of the research of soil pollution on the territory of Belgrade stated the following: the City Institute for Public Health sampled and laboratory tested a total of 66 soil samples from 33 locations;

Land pollution research (land testing within the sanitary protection zone of the Belgrade water supply source next to traffic roads) within the communal environment and in the vicinity of public fountains, it was found that at a number of locations there are deviations in terms of hazardous and harmful substances in the land;

Within the sanitary protection zone of the Belgrade water supply source, no significant deviations of the concentrations of the stitched parameters were registered. Registration of DDT pesticide residues at certain locations requires further monitoring of the presence of this pollutant in soil and drinking water;

The focus of control was placed on the examination of the content of hazardous and harmful substances in the environment of public fountains with spring water; the results indicate that in the soil surrounding public fountains, there is an increased content of hazardous and harmful substances that can lead to a deterioration in the quality of drinking water from polling stations and potentially endanger the health of users;

The most significant finding was found in the vicinity of the Hajduk fountain on Kosutnjak where the concentrations of Pb, Cd, Zn, Cu and DDT residues and the Zelenjak fountain in Resnik (presence of PCBs) increased and the concentrations of these parameters that exceeded the limit value were significantly lower than values that required the application of land remediation procedures (Remediation value according to the valid Regulation). Land quality was also monitored at the national level through national indicators. They give a more complete picture of the quality of soil.

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ISBN-978-86-82674-01-6