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SOIL QUALITY OF THE WILD LANDFILL ON THE TERRITORY OF THE TOWN OF GRDELICA

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Abstract. *Soil protection is carried out by monitoring soil quality, while preventing it from emissions of harmful and hazardous substances. Soil analysis at closed landfills includes soil quality testing, as well as detection of potentially harmful substances. This paper presents the results of the analysis of soil samples at a wild landfill on the territory of the town of Grdelica. The purpose of this paper is to determine soil quality, detect possible contamination, and identify potentially harmful and hazardous substances in samples using key aspects of Serbia's regulatory policy.*

Key words: *soil quality, wild landfill, Maximum Permissible Value (SWsb), Remediation Value (IWsb), regulatory policy*

1. INTRODUCTION

According to the Law on Agricultural Land of the Republic of Serbia, hazardous and harmful substances are groups of inorganic and organic compounds that include corrosive, toxic, flammable, self-igniting and radioactive products. Hazardous and harmful substances include waste in liquid, solid or gaseous aggregate state, which has hazardous and harmful effects on the soil [1]. Some substances, even in large quantities, have negligible effects on the environment, while occasionally very small amounts of a particular substance can have a strong negative effect. Short-term emissions of some chemicals do not have a significant effect on the environment or human health but their negative impact is noticed after daily exposure [2]. For this reason, in order to protect the population and the environment from a negative impact, it is necessary to take appropriate measures. For that purpose, appropriate

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legal regulations were adopted which were based on experimental results and the evaluation of opinions. The Maximum Permissible Value (SWsb) represents the limit value of polluting, harmful and hazardous substances in the soil, the exceeding of which indicates the level of contamination that disturbs the ecological balance [3].

Regulation on systematic monitoring of condition and quality of soil ("Official Gazette of the RS", No. 88/2020) determines the content of the Soil Monitoring Program, methodology for systematic monitoring of soil quality and condition, criteria for determining the number and arrangement of measuring points, list of parameters for a specific type of soil, list of methods and standards used for soil sampling, sample analysis and data processing, scope and frequency of measurements, indicators for soil degradation risk assessment, deadlines and method of data submission. The general parameters for soil characterization at site include a number of basic soil properties and knowledge about the effect of pedogenetic factors that enable soil characterization at a locality. The list of parameters for a certain type of soil includes physical, chemical and microbiological parameters for determining the quality and condition of the soil. Furthermore, the list of methods and standards includes a list of reference methods and standards used for soil sampling, sample analysis and data processing. The regulation determining the limit values of polluting, harmful, and hazardous substances in soil as well as the regulation determining the limit values of hazardous and harmful substances in groundwater are the two main sources of information used to determine the degree of chemical pollution hazard to the soil [4].

The Regulation on limit values of polluting substances, harmful and hazardous substances in the soil (Official Gazette of RS, no. 30-2018 and 64-2019) determines the limit values of polluting, harmful and hazardous substances in the soil. Limit values of polluting, harmful and hazardous substances in soil are determined by measurement and/or calculation based on the measurement results. Further testing of the soil is required when threshold values for harmful, polluting, and hazardous substances are exceeded because it suggests a level of contamination that disturbs the ecological balance [5].

The paper presents the results of the analysis of soil samples at the landfill on the territory of the city of Grdelica with reference to the legislation of the Republic of Serbia. It aims to determine soil quality, detect possible contamination and identify potentially harmful substances in the soil samples.

2. MATERIALS AND METHODS

2.1. Sampling locations

Grdelica is an urban settlement in the Jablanica District. Figure 1 shows a satellite view of the sampling points. Table 1 shows the labels of the samples and their GPS coordinates.

2.2. Sampling procedure

Accredited methods were used for soil sampling and analysis. The soil sampling procedure was performed according to ISO 18400-105:2020. Laboratory analyses of soil samples were performed using the methods given in Table 2.

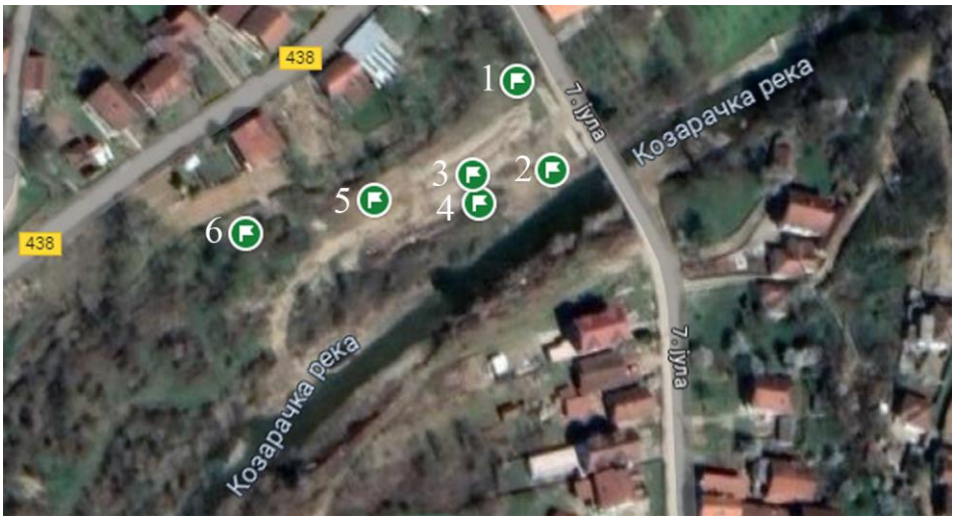

Fig. 1 Satellite view of sampling points

Table 1 Sample labels and GPS coordinates

Sample label	GPS coordinates	
	N	E
01	42.898800	22.071782
02	42.898579	22.071902
03	42.898569	22.071633
04	42.898500	22.071656
05	42.898506	22.071300
06	42.898424	22.070866

Table 2 List of methods used for soil analysis

Parameter	Methods
pH	SRPS ISO 10390 [6]
moisture content	ISO 11465 [7]
organic matter content	EN TC WI:2003 [8]
granulometric composition	SRPS EN ISO17892-4 [9]
mineral oils C_{10}-C_{40}	BS ISO 16703 [10]
metals	EPA 3051A/ EPA6010c [11]
mercury	EPA 3051A:2007/ SRPS EN ISO12846:2013 [12]
polychlorinated biphenyls	ISO 10382 [13]
aromatic hydrocarbons	EPA 5021 [14]
polycyclic aromatic hydrocarbons	ISO 18287 [15]
pesticides	ISO 10382 [13]

3. EXPERIMENTAL RESULTS

The results of the laboratory analysis are presented in Tables 3, 4, 5 and 6.

Table 3 Results of testing samples for the content of polychlorinated biphenyls, polycyclic aromatic hydrocarbons, BTEX and mineral oils

Parameter	01	02	03	04	05	06
Polychlorinated biphenyls, $mg \cdot kg^{-1}$						
PCB 28	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
PCB 52	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
PCB 101	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
PCB 138	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
PCB 153	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
PCB 180	<0,002	<0,002	<0,002	<0,002	<0,002	<0,002
$PCBs_{total}$	<0,015	<0,015	<0,015	<0,015	<0,015	<0,015
Polycyclic aromatic hydrocarbons, $mg \cdot kg^{-1}$						
Naphthalene	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Acenaphthylene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Acenaphthene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Fluorene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Phenanthrene	0,007	0,007	0,008	0,006	0,006	0,007
Anthracene	0,007	0,003	0,003	0,003	0,003	0,003
Fluoranten	0,003	0,004	0,005	0,003	0,005	0,003
Pyrene	<0,001	<0,001	0,004	0,004	0,005	<0,001
Chrysene	0,006	0,008	0,006	0,006	0,010	0,007
Benzo(a)anthracene	0,004	0,003	0,004	0,004	0,004	0,003
Benzo(b)fluoranthene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Benzo(k)fluoranthene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Benzo(a)pyrene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Indeno(1.2.3-c,d)pyrene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Dibenzo(a,h)anthracene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
Benzo(g,h,i)perylene	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
PAH_{total}	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05
Aromatic hydrocarbons (BTEX), $\mu g \cdot kg^{-1}$						
Benzene	0,070	0,070	0,077	0,060	0,048	0,049
Toluene	0,121	0,114	0,128	0,146	0,135	0,101
Ethylbenzene	0,021	0,020	0,020	0,013	0,017	0,011
Styrene	0,092	0,068	0,064	0,058	0,100	0,058
Xylene	0,083	0,071	0,085	0,071	0,079	0,062
$BTEX_{total}$	0,385	0,342	0,374	0,348	0,380	0,282
Mineral oils, $mg \cdot kg^{-1}$						
	1,3	1,5	1,4	9,3	7,9	1,3

Based on the obtained soil test results shown in Table 3, it can be concluded that concentrations of aromatic hydrocarbons and polycyclic aromatic hydrocarbons were detected in the tested samples. However, the obtained values of these parameters do not exceed the limit values.

Table 4 Results of testing samples for pesticide content

Pesticides, $mg \cdot kg^{-1}$	01	02	03	04	05	06
DDT/ DDD/ DDE (total)	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Sum: aldrin, dieldrin, endrin	<0,005	<0,005	<0,005	<0,005	<0,005	<0,005
Aldrin	<0,00006	<0,00006	<0,00006	<0,00006	<0,00006	<0,00006
Dieldrin	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005	<0,0005
Endrin	<0,00004	<0,00004	<0,00004	<0,00004	<0,00004	<0,00004
α–HCH	<0,003	<0,003	<0,003	<0,003	<0,003	<0,003
β–HCH	<0,009	<0,009	<0,009	<0,009	<0,009	<0,009
γ–HCH	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005	<0,00005
HCH total	<0,01	<0,01	<0,01	<0,01	<0,01	<0,01
Chlordane	<0,00003	<0,00003	<0,00003	<0,00003	<0,00003	<0,00003
Endosulfan	<0,00001	<0,00001	<0,00001	<0,00001	<0,00001	<0,00001
Heptachlor	<0,0007	<0,0007	<0,0007	<0,0007	<0,0007	<0,0007
Heptachlorepoxide	<0,0000002	<0,0000002	<0,0000002	<0,0000002	<0,0000002	<0,0000002
HCB (Hexachlorobenzene)	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Pentachlorobenzene	<0,001	<0,001	<0,001	<0,001	<0,001	<0,001
Endosulfan sulfat	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001	<0,0001

In all of the analyzed samples shown in Table 4, the concentrations of polychlorinated biphenyls and pesticides do not exceed the limit and remediation values.

Table 5 Analysis results - granulometric composition, organic matter content, pH value, moisture content and $CaCO_3$ content

Parameter	01	02	03	04	05	06
Granulometric composition						
Clay, %	27,2	5,9	17,4	8,6	21,4	11,2
Sand, %	45,4	64,4	63,9	61,9	44,5	63,5
Powder, %	27,4	29,7	18,7	29,5	34,1	25,3
Content of organic matter	6,3	4,9	3,4	1,3	3,7	5,7
pH	6,5	6,5	6,4	6,6	6,4	6,5
Moisture content, %	17,8	14,1	15,8	14,1	18,9	27,4
$CaCO_3$, %	0,61	2,8	0,42	1,8	0,77	0,32
Soil hardness, MPa	0,44	0,32	0,39	0,20	0,24	0,20

According to the results shown in Table 5, soil samples have a relatively high sand content, while the clay content ranges in a wider range. The content of organic matter is low in all samples, and the pH indicates a slightly acidic soil. Soil hardness ranges from 0.20 to 0.44 MPa, which indicates relatively soft soil.

Table 6 Results of testing samples for the content of heavy metals

Metals, mg·kg^{-1}	01	02	03	04	05	06
Antimony (Sb)	2,8	2,4	2,4	2,2	2,1	2,3
Arsene (Ace)	7,6	7,1	8,1	5,3	6,4	8,1
Copper (Cu)	24	**35**	24	18	23	**29**
Barium (Ba)	119	**171**	80	61	109	6
Zinc (Zn)	107	**199**	100	64	100	**141**
Chromium (Cr)	41	42	33	25	36	37
Cadmium (Cd)	**1,8**	**1,9**	**1,4**	**1,0**	**1,5**	**1,7**
Cobalt (Co)	**14**	**9,2**	**9,9**	**8,3**	**13**	**9,9**
Nickel (Ni)	31	**25**	21	**20**	24	**23**
Molybdenum (Mo)	1,5	1,2	0,71	0,64	0,64	0,45
Lead (Pb)	26	30	32	20	23	5
Mercury (Hg)	0,042	0,064	0,031	0,026	0,029	0,031

The presence of heavy metals was observed in soil samples and given in Table 6. The concentrations of cadmium and cobalt exceeding the Maximum Permissible Value were observed in all samples. The most contaminated soil samples are samples 02 and 06, which, in addition to the increased concentration of cadmium and cobalt, have an increased concentration of copper, zinc and nickel. In sample 02, an increased concentration of Barium was also observed.

2.3. Corrected maximum permissible / remediation value of harmful and hazardous substances in the soil

Based on the Regulation on limit values of polluting substances, harmful and hazardous substances in the soil (Official Gazette of the RS, no. 30-2018 and 64-2019), the correction of limit and remediation values for metals is shown in Table 7. Correction of limit and remediation values that may indicate significant contamination for metals and arsenic, except for antimony and molybdenum, is carried out depending on the clay and/or organic matter content in the soil.

Table 7 Corrected maximum permissible and remediation values for metals depending on clay and organic matter

No		(Sb)	(As)	(Cu)	(Ba)	(Zn)	(Cr)	(Cd)	(Co)	(Ni)	(Mo)	(Pb)	(Hg)
01	SWb	3	29	35	174	143	105	0,74	10	38	3	84	0,3
	IWb	15	54	187	679	733	401	11,1	260	226	200	524	10,1
02	SWb	3	19	21	73	78	66	0,51	4	18	3	60	0,23
	IWb	15	37	113	240	386	235	8,32	97	95	200	379	7,56
03	SWb	3	23	27	121	107	84,8	0,6	7	27,4	3	71	0,26
	IWb	15	44	145	472	552	322	9,07	183	164,4	200	441	8,77
04	SWb	3	19	22	75	79	67,2	0,52	4	18,6	3	61	0,23
	IWb	15	37	114	294	408	255	7,77	118	112	200	380	7,72
05	SWb	3	25	30	141	120	92,8	0,64	8	31,4	3	75	0,28
	IWb	15	47	159	552	616	353	9,59	213	188	200	468	9,24
06	SWb	3	22	25	89	92	72,4	0,61	5	21,2	3	67	0,25
	IWb	15	41	133	347	474	275	9,14	137	127	200	417	8,2

SWb - corrected maximum permissible value
Iwb - corrected remediation value

The analysis of the samples for the content of heavy metals showed that:

- The content of copper and zinc exceeds the limit value in samples 02 and 06.
- Also, the measured concentration of barium exceeds the limit value in the sample 02.
- The obtained values for nickel concentration exceed the limit values in the samples 02, 04 and 06.
- In all analyzed samples, the measured concentrations of cadmium and cobalt exceed the limit values.
- No metal concentrations were detected in all analyzed samples that exceed the remediation value.

Table 8 Corrected maximum permissible/remediation values for mineral oils

No.	SWb	IWb
01	31,5	3150
02	24,5	2450
03	17,0	1700
04	11,5	1150
05	18,5	1850
06	28,5	2850

Based on the results of laboratory analyses, the concentration of mineral oils does not exceed the corrected maximum permissible value and corrected remediation value.

4. CONCLUSION

Based on the test results, in accordance with the Regulation on limit values of polluting substances, harmful and hazardous substances in the soil (Official Gazette of the RS, no. 30-2018 and 64-2019), it was determined that the concentrations of various metals in the analyzed soil samples exceeded the limit values. The results of the analysis showed that concentrations of aromatic hydrocarbons and polycyclic aromatic hydrocarbons were detected in the tested samples. However, the obtained values of these parameters do not exceed the limit values. No concentrations of polychlorinated biphenyls and pesticides were detected in analyzed samples. In terms of the soil's physical properties, it is observed that all samples have a high concentration of sand and a greater range of clay content. All samples have a low content of organic matter. pH indicates that the soil is acidic. Soil hardness ranges suggest that the soil is relatively soft. The analysis of soil samples at the wild landfill in the town of Grdelica showed that the soil contains concentrations of various metals that exceed the limit values prescribed by the Regulation. This kind of pollution can have a negative impact on the environment. Further monitoring of the situation is required to prevent future contamination spread and to carry out soil remediation.

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KVALITET ZEMLJIŠTA DIVLJE DEPONIJE NA TERITORIJI GRDELICE

Zaštita zemljišta se sprovodi praćenjem kvaliteta zemljišta, ali i sprečavanjem emisije štetnih i opasnih materija. Analiza zemljišta na zatvorenim deponijama uključuje ispitivanje kvaliteta zemljišta, kao i otkrivanje potencijalno štetnih supstanci. U radu su prikazani rezultati analize uzoraka zemljišta na divljoj deponiji na teritoriji Grdelice. Ovaj rad ima za cilj da utvrdi kvalitet zemljišta, detekciju moguće kontaminacije i identifikaciju potencijalno štetnih i opasnih materija u uzorcima sa osvrtom na ključne aspekte regulatorne politike Republike Srbije.

Ključne reči: *kvalitet zemljišta, divlja deponija, granična maksimalna vrednost (SWb), remedijaciona vrednost (IWb), uredba*