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ISAE 2021

Belgrade, Serbia

30.September - 2.October 2021

УНИВЕРЗИТЕТ У БЕОГРАДУ · ПОЉОПРИВРЕДНИ ФАКУЛТЕТ · ОСНОВАН 1919. ГОД

ISBN 978-86-7834-386-5

The Fifth International Symposium on
Agricultural Engineering
ISAE-2021

30st September-2nd October 2021, Belgrade – Zemun, SERBIA
http://www.isae.agrif.bg.ac.rs

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– Research Network on Resource Economics and Bioeconomy Association – RebResNet

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Acknowledgements: This publication is published with the financial support of the Ministry of Education, Science and Technological Development, Republic of Serbia

Published by: University of Belgrade, Faculty of Agriculture, The Institute for Agricultural Engineering, Nemanjina 6, 11080 Belgrade, Serbia

Editors: Prof. Dr. Aleksandra Dimitrijević
Prof. Dr. Ivan Zlatanović

Technical editor: Msc. Mitar Davidović

Printed by: University of Belgrade, Faculty of Agriculture, Beograd

Published: 2021

Circulation: 100 copies

ISBN 978-86-7834-386-5

SOME POSSIBLE EFFECTS OF CONSTRUCTION AND DEMOLITION WASTE LANDFILL ON THE ENVIRONMENT

Katarina B. Samurović[1]*, Ivana Ž. Vukašinović[2], Vladimir B. Pavlović[2], Lidija Amidžić[1]

[1] University Singidunum, The Environment and Sustainable Development Department, Belgrade, Serbia

[2] University of Belgrade, Faculty of Agriculture, The Institute for Agricultural Engineering, Belgrade-Zemun, Serbia

E-mail: katarina.samurovic.20@singimail.rs

Abstract: *In cases of inadequate waste management, there is a tendency for inappropriate disposal of construction and demolition (C&D) waste, especially when its production surpasses the capacities of official disposal sites. By disposing of C&D waste on the edge of the protected natural area during the spring of 2021, a C&D landfill was formed near Reva pond, Belgrade. In this work, the qualitative composition of C&D waste in the field was assessed, including chemical analysis of landfill soil which was investigated by comparing its elemental composition with the control soil by utilizing SEM-EDS analysis. The presence of various C&D waste components, typical (concrete blocks, bricks, armature, glass shards, wood, soil of various origin) and atypical (furniture, industrial-type glass shards, paint bottles and cans), indicated that waste disposal was only partially controlled. Due to the high heterogeneity of the disposed soil, analysis can neither confirm nor exclude the possibility of heavy metal contamination. Herbaceous plants are already naturally colonizing the landfill; also, the aggressively spreading, heavy metal accumulator, honey plant species - the False indigo bush (Amorpha fruticosa), is abundant in the area, and it is expected that it will recultivate the landfill site. To get a full assessment of the landfill's impact on local ecosystems, continuous monitoring is recommended.*

Keywords: *C&D waste; waste disposal; excavated soil; environmental pollution; heavy metals;*

1. INTRODUCTION

Construction and demolition (C&D) waste is generated in the process of building, as well as the preparation of building sites - which commonly includes demolition. Each construction project leaves significant amounts of C&D waste in the form of inert waste, non-hazardous (brick, concrete, wood, and other materials) and hazardous (asbestos, materials containing heavy metals, etc.). Urban development and related construction create various pressures on the environment, including waste generation and changes in land use. When it comes to C&D landfills, these two issues overlap. The disposal of C&D waste has become a pressing global issue, especially due to the low recycling rates, and its full effect on the environment remains largely unknown 1.. In cases of inadequate local C&D waste management, there is a tendency for inappropriate disposal of C&D waste, especially when its production surpasses the capacities of official disposal sites. Because there is a tendency for illegal or badly managed C&D waste disposal on uninhabited land in close proximity of the city, forestry and agricultural sectors are especially exposed to pressures from C&D waste generation, adding to the already high pressures from the construction industry in general 2.. Projects across the world are considering repurposing of soil found in C&D waste, but with caution due to the possible pollution of these soils 3..

Reva is part of a former distributary of the Danube floodplain, which extends in an east-west direction. The C&D landfill is located between the protected natural area "Reva pond" and the protective embankment in the flood zone of Danube (municipality Krnjača, Belgrade) and, according to the environmental inspection, spans across 7 hectares. The formation of the landfill in early 2021 was marked by many irregularities, and the official cease of all disposal activities happened in June 2021. The vegetation on the terrain is characterized by hybrid poplar plantations, hydrophilic deciduous mixed forest, wetland vegetation and ruderal flora along the embankment, with 84 species total recorded 4.. All these habitats are infested with False indigo bush, *Amorpha fruticosa*, an invasive species introduced and renowned as a quality honey plant. Thus, the location may be an important forage area for bee hives in 2.2-10 km radius 5.. Additionally, Reva pond is a part of the internationally recognized Important Bird Area "Usce Save u Dunav" (The confluence of the Sava and the Danube), and also represents a legal hunting ground.

This paper compares the chemical composition of soil found on C&D waste landfill "Reva", Belgrade with the natural soil sampled in the same area by utilizing SEM-EDS spectral analysis as a comparison method. The overall goal of the study was to gain insight into the properties of the landfill material and the native soil in order to predict the possible future influences on the natural ecosystem.

2. MATHERIALS AND METHODS

Field observation was conducted before samples collection which included the basic visual environmental assessment of the state of the landfill, with the focus on the disposal method, present materials, present vegetation, and the state of original vegetation (specifically, trees) on the site. Soil samples were collected by using standardized soil sampling methods for monitoring pollutants 6, 7., slightly modified due to the location's specifics. For the landfill sample, forty-seven individual samples were obtained from 0-10 cm depth, taking into account both the leveled material and the unleveled, separate piles of C&D waste (mostly soil) that could be safely reached. Collected individual samples were well-mixed and further mixing with removal of large particles and quartering was used to obtain a representative sample. The control sample was taken from a meadow in a close proximity of the landfill, but still physically separated from the landfill. The layer of vegetation was removed and the representative sample was obtained in the same manner as the for the landfill sample, only with a fewer number of individual samples (four), due to the habitat's uniformity.

In order to compare the morphology of two types of samples, scanning electron microscopy (SEM) was applied using JEOL JSM-6390 LV Scanning Electron Microscope at electron beam acceleration voltage of 30 kV. To attain electroconductivity, the samples were coated with gold before analysis in a sputtering chamber (BAL-TEC SCD 005 Sputter Coater, 100 s at 30 mA). Elemental composition was performed using X-Max Energy Dispersive X-ray Spectrometer (EDS) (Oxford Instruments, UK) and AZtecEnergy software (Oxford instruments, UK).

3. RESULTS AND DISCUSSION

3.1. Field observations

The greatest part of the C&D waste was deposited and leveled, rising 4-5 m above the original ground level matching the height of the nearby embankment. On the leveled surface, many aggregations of C&D waste are present in the form of separate piles. These include various types of soil, clay, demolished brick and concrete. Besides the typical C&D waste, the presence of discarded furniture, paint and spray cans, glass bottles and other non-C&D waste was noted, but not in prevalent numbers. Industrial-type chunks of broken glass were present throughout the site, and their origin is unknown. The presence of informal scrap metal collectors was noted, as well as the traces of fire and burning possibly related to their activities. The damage to the surrounding forests is visible at the edges of the landfill, where waste dumping has knocked over trees, indicating that the site wasn't properly prepared for the waste disposal. At the time of sampling, the herbaceous vegetation has already started to colonize the landfill. This novel plant community mostly consisted of ruderal vegetation. Separate unleveled aggregations of soil contained different plant species and communities, leading to a conclusion that the seeds of these plants were brought along with the excavated soil, allowing introduction of plant species not native to the area. Since the invasive False indigo bush (*Amorpha fruticosa*) is abundant in the area, it can be expected to cultivate the landfill in the upcoming years.

3.2. Soil samples analysis

Microstructure of soil samples collected at control and disposal site is presented at Figure 1. It is known that soil is built from mineral particles that differ in terms of size, shape, agglomeration and organic matter in different phases of degradation 8.. It can be seen from the upper micrograph at Figure 1 (a) that such a description can be attributed to the control sample whose aggregates vary in size, shape and inner structure indicating natural origin of soil. On the other hand, a micrograph of soil from the disposal site at Figure 1 (b) is showing a rough surface texture consisting of larger irregularly shaped agglomerates, separated from each other whose dimensions do not vary significantly. It can be noticed that these particles could be compared to the coarser soil particles such as sand whose specific surface area is small and chemical activity weak. Coarse textured soils have weak waterproof ability which increases water circulation and consequently spread of contaminants 8.. Such a structure is evidently related to the disposed construction waste since C&D waste is a heterogeneous mix of cement and clay-based composite building materials. Its largest portion is made out of concrete waste, different kinds of brick and asphalt, with impurities such as ceramic and roof tile. Production and further crushing of C&D waste leads to the formation of a rough fractions consisting of primary aggregates such as gravel, stone, crushed brick, but also, fine particles of sizes smaller than 5 mm are generated 9..

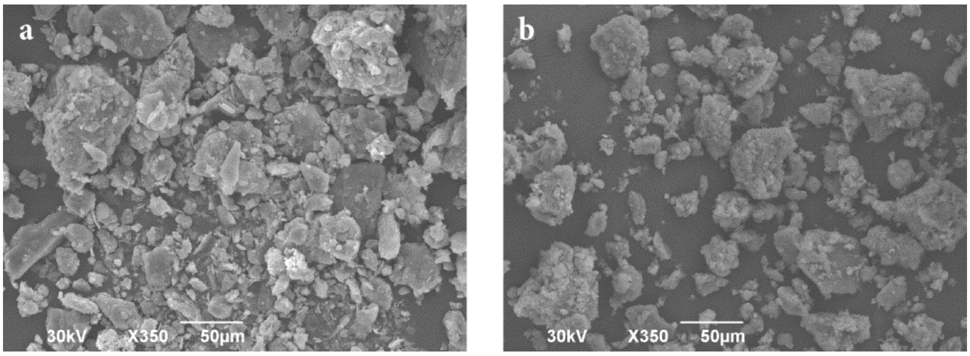

Fig. 1 SEM micrographs of soil samples from: a) control and b) disposal site.

A semi-quantitative chemical analysis of the surface layer of samples collected at control and disposal site was done by SEM-EDS method. The results of the analysis in this paper are considered as an estimation that is used to compare the elemental composition of the samples. In Table 1, the chemical composition is presented as a sum of elemental content given in weight percentage normalized at 100%. The limit of detection of examined elements was 0,1%. Concerning carbon as a light element, it is usually excluded from SEM-EDS analysis because during the collection time of EDS spectrum contamination of the specimen could occur as a normal part of detection process, however, carbon wasn't excluded here since the results are used for comparative analysis. From Table 1, it can be seen that percentages of carbon (of organic or inorganic origin) are much higher than its natural value in the Earth's crust (0,03%) 10.. The differences of its percentages between samples could originate from the organic matter present in samples or from the construction material which is known to be the source of organic (asphalt, plastic, wood) and inorganic (mortar, concrete) carbon 11..

The most abundant elements in the Earth's crust are oxygen (46,6%) and silicon (27,7%) and the silicates containing both elements are the most abundant minerals 10.. The similarity in percentages of these two elements between investigated samples (Table 1) is related to their common origin in soil. Quartz (SiO_2) is dominant compound of each mechanical fractions of the naturally occurring soil 8.. On the other hand, in construction waste samples, quartz is attributed to sand particles used for concrete and brick production. Concrete is usually made out of quartz and amorphous carbonates, and quartz and calcite with the addition of clay minerals represent the most common compounds of brick material. However, in the production process that involves high temperatures clay minerals decay and crystal structure is lost leading to the formation of silicon dioxide at the end 9.

Table 1. The chemical composition given as wt.% of samples analyzed in this study

Element	Line Type	C&D-1	Error	C&D-2	Error	Control	Error
C	K series	54.76	0.13	44.17	0.17	38.29	0.34
O	K series	32.47	0.11	38.31	0.13	40.65	0.25
Na	K series	-	-	0.34	0.01	-	-
Mg	K series	0.42	0.01	0.55	0.01	0.88	0.02
Al	K series	2.09	0.01	2.75	0.01	4.32	0.03
Si	K series	4.86	0.02	7.12	0.03	10.38	0.06
K	K series	0.50	0.00	0.57	0.00	0.98	0.01
Ca	K series	2.16	0.01	3.09	0.01	1.67	0.01
Fe	K series	1.17	0.01	1.75	0.01	2.83	0.02
Cu	K series	0.57	0.01	0.47	0.01	-	-
Zn	K series	0.45	0.01	0.39	0.01	-	-
Mo	L series	0.36	0.02	0.33	0.02	-	-
Ba	L series	0.18	0.01	0.16	0.01	-	-
Total:		100.00		100.00		100.00	

Figure 2 and Figure 3 are showing elemental mapping images of soil collected from control and disposal sites, respectively. Elemental mapping of samples microstructures by SEM-EDS method was possible if the element’s weight percentage was above 0.1%. It can be seen from Figure 2. that in the control soil five elements other than O, C, and Si could be detected: Al, Fe, Ca, K, Mg which natural distribution in the Earth’s crust is significant (8.1%; 5.0%; 3.6%; 2.6%, 2.1%; respectively) 10.. It was noted that elements weight fractions of the control sample which was in descending order (%): Al<Fe<Ca<K<Mg (Table 1) exactly corresponded to their presence in the Earth's crust. Trace elements which were most likely present in the control sample could not be detected here due to limit of detection of examined elements of 0,1% and hence difficulties to separate their characteristic X-ray peaks from the background spectrum. Based on the Al and K elemental mapping, their uniform distribution in the control sample could be observed, while Ca, Mg, and Fe are found in the distinct agglomerates containing their characteristic minerals (Figure 2). Overlapping maps of all detected elements generated one dominant color indicating natural origin of examined soil.

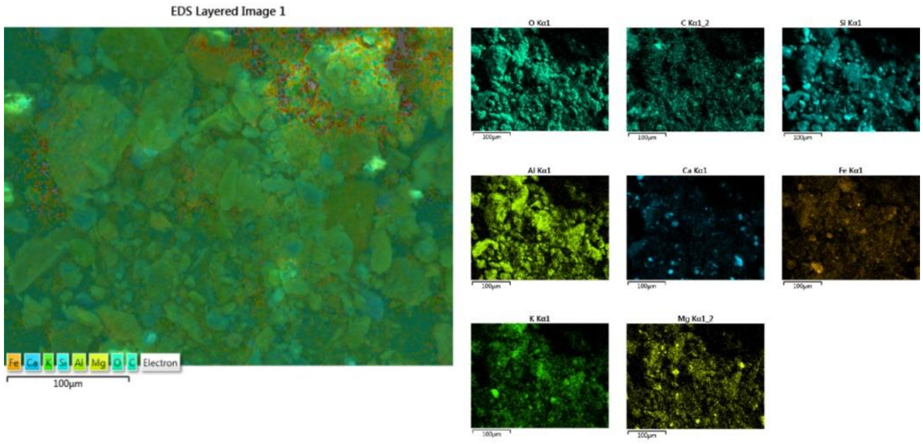

Fig. 2 SEM-EDS elemental mapping images for O, C, Si, Al, Ca, Fe, K, Mg of the control soil sample.

In the sample collected from the disposal site (Table 1, Figure 3), besides major elements Al, Fe, Ca, K, Mg, the traces of Cu, Zn, Mo, Ba were also detected. In the Earth's crust, the sum percentage by weight of all trace elements is 1,5 % 10.. Elements from the C&D-1 sample were aligned in the decreasing order by weight (%): Ca<Al<Fe<Cu<K<Zn<Mg<Mo<Ba (Table 1). It can be noticed that alignment like that is suggesting some soil modifications. The EDS elemental map (Figure 3) revealed homogeneous dispersion of Mg, Cu, Zn within the sample while Al, Ca, K, Fe, Mo and Ba have shown heterogeneous behavior and were concentrated in individual particles (agglomerates) of the sample. Overall mapping of the sample is showing significant differences in the chemical composition and structure compared to the sample from the control site. It could be concluded that there was an evident modification of natural soil due to introduction of C&D wastes. However, the exact origin of introduced material by waste disposal cannot be exactly quantified since all the various inputs were integrated in the soil over time.

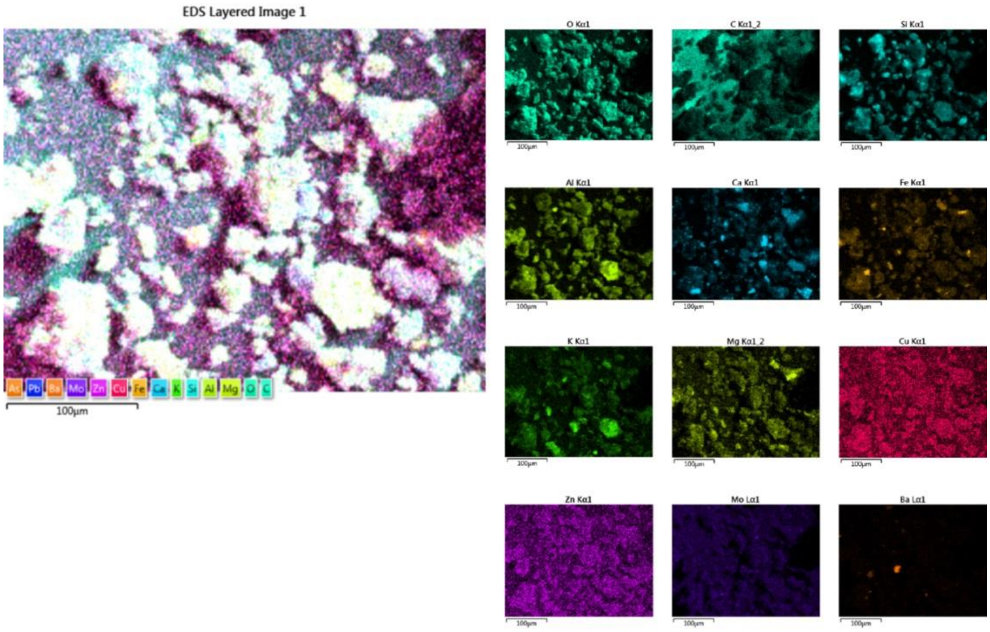

Fig. 3 SEM-EDS elemental mapping images for O, C, Si, Al, Ca, Fe, K, Mg, Cu, Zn, Mo, Ba of disposed soil sample (C&D-1).

A study of a large number of C&D waste samples in City of Skopje showed heterogeneous nature of the collected materials and consequently a high variability of major and trace elements. The highest concentrations there were always related to the SiO_2 present in silicate aggregates, constituents of concrete and mortars, followed by moderate concentrations CaO from lime, gypsum, and cement binders and by lowest concentrations of Al_2O_3 and K_2O from bricks, tails, ceramics, and soils containing clay minerals 11.. Results of another study of C&D waste samples showed Zn concentrations of up to 800 mg/kg and about 10 times higher maximum concentrations for Al and Fe, while Ba, which was also detected in examined samples, had concentrations less than 90 mg/kg 12.. Authors explained that characteristics and age of the concrete are related to the carbonation process which occurs when the cement hydrate phases react with CO_2, precipitate as calcium carbonate ($CaCO_3$) and develop carbonated material. As a result, aging and carbonation decreases the material pH which is why leachability of Si is increasing and for Ca, Ba and K is decreasing 12..

4. CONCLUSIONS

According to the conducted analysis, no chemical threats arising from the landfill were detected and abnormal presence of heavy metals cannot be confirmed, but cannot be fully excluded either due to the method’s limitations. The limitation of the analysis was also the highly heterogeneous content of the landfill. Many aggregations of excavated soil, demolished building blocks and other C&D waste were left as separate piles, some highly inaccessible, making the formation of a truly representative sample challenging. Some of the unsampled aggregations could still be contaminated, so multiple analyses should be performed. SEM-EDS method allowed gaining insight about the main physical and chemical properties of the soil, but to exclude the possibility of contamination, a standard chemical laboratory analysis should be performed, and should also include persistent organic pollutants (POPs), organometallic compounds, asbestos, oil-derived hydrocarbons (C^6-C^{40} fractions), radionuclides, and pathogenic organisms, as per Regulation on systematic monitoring of land condition and quality 13.. The return of the original vegetation is unlikely due to changed C&D landfill soil quality. In the future, sampling and analyzing of *A. fruticosa* plant organs can become one of the ways to check the content of heavy metals once it colonises the landfill, as the plant is a known heavy metal accumulator 14.. Also, using the accumulator properties of *A. fruticosa* for phytoremediation is a possibility to explore.

REFERENCES

1. Duan, H., Wang, J., Huang, Q. (2015) *Encouraging the environmentally sound management of C&D waste in China: An integrative review and research agenda, Renewable and Sustainable Energy Reviews*, Vol 43, 2015, Pages 611-620, ISSN 1364-0321,
2. Atmiş, E., Özden, S., Lise, W. (2007*) Urbanization pressures on the natural forests in Turkey: An overview*. Urban Forestry & Urban Greening, Vol. 6, Issue 2, 2007, p. 83-92, ISSN 1618-8667.
3. Hale, S.E., et al. (2021) *The Reuse of Excavated Soils from Construction and Demolition Projects: Limitations and Possibilities*. Sustainability 2021, 13(11), 6083;
4. Jovanovic, S. et al. (2014*) Flora of Belgrade surroundings (Serbia) 150 years after Pančić's monograph – a comparative overview*. Botanica Serbica, 38 : (2014) 201-207
5. Ratnieks, F. L. W. (2000) *How far do bees forage*. Bee Improvement 6: 10-11
6. Manojlović, M., Bogdanović D. et al. (2014) *Uzorkovanje zemljišta i biljaka za agrohemijske i pedološke analize* (priručnik). Univerzitet u Novom Sadu, Poljoprivredni fakultet, 2014, ISBN 978-86-7520-291-2
7. Nikolić., J. (2018) *Optimizacija postupaka pripreme uzoraka zemljišta za kvantitativnu analizu policikličnih aromatičnih ugljovodonika primenom metode gasna hromatografija-masena spektrometrija*. Doktorska disertacija/PhD Thesis. Prirodno-matematički fakultet, Univerzitet u Nišu 2018.
8. Nenadović, S., Nenadović, M., Kljajević, Lj., V. Pavlović, V., Đorđević, A., Matović, B. (2010) *Structure and composition of soils, Processing and Application of Ceramics* 4 (4): pp. 259–263.
9. Jelić, I. (2017) *Application of composite construction waste for immobilisation of radionuclides and heavy metals by sorption*, PhD Thesis, University Singidunum, Serbia, 130 p. 31.
10. Georgia State University. *Abundances of the Elements in the Earth's Crust*. http://hyperphysics.phy-astr.gsu.edu/hbase/Tables/elabund.html
11. Gianluca Bianchini, G., Ristovski, I., Milcov, I., Zupac, A., Natali, C., Salani, GM., Marchina, C., Brombin, V., Ferraboschi, A. (2020) *Chemical Characterisation of Construction and Demolition Waste in Skopje City and Its Surroundings (Republic of Macedonia)*, Sustainability 12(5): pp. 2055.
12. Diotti, A., Perèz Galvin, A., Piccinali, A., Plizzari, G., Sorlini, S. (2020) *Chemical and Leaching Behavior of Construction and Demolition Wastes and Recycled Aggregates*, Sustainability, 12(24): pp. 10326.
13. Službeni glasnik Republike Srbije br. 88 (2020) *Uredba o sistematskom praćenju stanja kvaliteta zemljišta / Regulation on systematic monitoring of land condition and quality.* Sl. glasnik RS, br. 88/2020, 22.06.2020. https://www.paragraf.rs/propisi/uredba-sistematskom-pracenju-stanja-kvaliteta-zemljista.html
14. Zhao, X., & Liu, J., & Xia, X., Chu, J., Wei, Y., Shi, S., Chang, E., Yin, W., Jiang, Z. (2013) *The evaluation of heavy metal accumulation and application of a comprehensive bio-concentration index for woody species on contaminated sites in Hunan, China*. Environmental science and pollution research international. 21. 10.1007/s11356-013-2393-3.