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PLANNING AND LAND USE AND LANDFILLS IN TERMS OF SUSTAINABLE DEVELOPMENT AND NEW REMEDIATION TECHNOLOGIES

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SIMULTANEOUS BIOREMEDIATION AND SOILIFICATION- NEW TECHNOLOGY FOR RECOVERY ASH DUMP OF THERMOELECTRIC POWER PLANTS

Jelena Avdalović[1*], Jelena Milić[1], Mila Ilić[1], Srđan Miletić[1], Vladimir Beškoski[1,2], Gordana- Gojgić Cvijović[1], Snežana Spasić[1], Branislav Potkonjak[1], Dragica Jakovljević[1], Miroslav M.Vrvić[1-3*]

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Soilification of degraded areas of anthropogenic origin is high importance for the environment, since this process can reduce negative influence of industrial activities on the environment. The role of "silicate bacteria", within formation and maintaining of soil characteristics is very well known. Combination of this bacteria and oil-degrading microorganisms in artificial soil layered applied to ash dump, could have high importance in bioremediation and generation of the primary soil.

Key words: bioremediation, soilification, humification, silicate bacteria, consortium microorganisms, ash dump

INTRODUCTION

Remediation is a term generally used for cleaning or renewal (recultivation, regeneration) of the polluted area or in the other way endangered environment, as a result of the human activities. In Serbia, more than 1500 ha of fertile agricultural land are occupied with ash and cinder landfills. Besides that, ash is one of major source of air pollution, due to content of harmful substances and influence of wind, and nearby watercourses.

Planting trees and bushes on the ash and cinder landfills, as well as planting grass, is the most important measure in the process of remediation and recovery of the ash landfill in stopping the pollution and further degradation of the environment. Biological recultivation (greening), is the most human way of protection, because it provides stabilization of steep slopes, ecological protection and aesthetic improvement. For the success of re-cultivation, besides types and concentration of contaminants, characteristics of the soil, very important factor are the number and the type of microorganisms in the soil.

Plants and microorganisms, represent important "biological agents" for the remediation (bioremediation). Interaction of plants and microorganisms is reflected in the joint action, where microorganisms create suitable life conditions for the plants with detoxification of phytotoxic compounds and improvement of accessibility of nutritious substances, while the plants provide nutritious substances for the microorganisms through root exudates. Virtually, there is no such pollutant, that could not be more or less successful transformed by microbiological actions. Interaction of microorganisms with the pollutant as a substrate represents a biotechnological process, which provides recycled soil, e.g. the soil with using value [8].

The object of our research has been examination of physical- chemical and microbiological parameters of the ash dump in Kostolac (composite sample taken from
different places from the active ash dump), with the goal of establishing the possibility of
use of the bioremediation for the reparation of the degraded area.

MATERIAL AND METHODS

X-ray diffraction (XRD) analysis: The XRD patterns were obtained on a Philips PW-1710 automated diffractometer using a Cu tube operated at 40 kV and 20 mA. The diffraction data were collected in the 2θ Bragg angle range from 5 to 60°, counting for 0.5 s at every 0.02° step. The divergence and receiving slits were fixed at 1 and 0.1 units, respectively [2] .The minerals were determined using MPDS software and JCPDS diffraction library.

Chemical analysis of sample from ash dump: Silicate analysis of sample from ash dumps was conducted using the conventional method, by alkaline fusion with $NaKCO_3$ and dissolution in HCl [3]. From the filtrate Fe, Al, Ti, Ca and Mg, were determined while the residue was further treated with HF in order to obtain volatile SiF_4, from which the SiO_2 content was determined. The remaining precipitate was treated again as silicate material. For the determination of alkaline metals, the sample was decomposed with a mixture of $HClO_4$ and HF, while for the determination of phosphorus, the sample was decomposed with a mixture of aqua regia and $HClO_4$. The alkaline metals were determined by atomic emission flame spectrophotometry; Fe, Al, Ti, Ca, Mg by atomic absorption flame spectrophotometry, while phosphorus was determined by spectrophotometry, as yellow phosphomolybdate complex [3].

Microbiology: The total number of aerobic mesophilic hemoorganoheterotrophic bacterias, anaerobic mesophilic hemoorganoheterotrophic bacterias, yeasts and moulds, alkalophilic bacterias and bacterias of genus *Bacillus* has been determinate by microbiological analysis.
Standard microbiological methods have been applied for the isolation and identification of "silicate bacteria", as well as API testing and apiweb™ program for identification of the species [8].

RESULTS AND DISCUSSION

X-ray diffractogram of sample from ash dumps is shown on Figure 1.

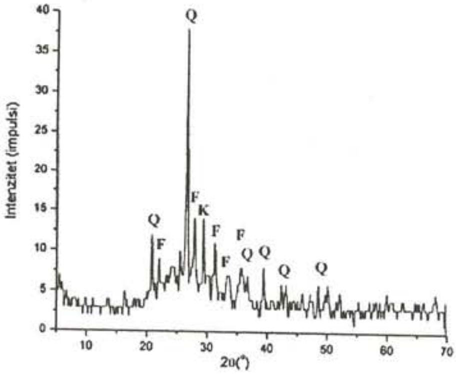

Figure 1. XRD diffractogram of ash dump (Q-quartz, F-feldspar, C-calcite)

Chemical composition of the ash obtained during combustion of coal depends mostly of geological and geochemical factors which conditioned the existence of the coal trestle, combustion conditions, as well as the efficiency of the other characteristics of the devices which are used for removing the ash from the gases released during the combustion. Following mineral components were identify in the samples of the ash: quartz, minerals of the feldspar, calcite and amorphous base (alum-silicate), which is in accordance with the high pH value of the sample (pH=10,8) as well as with the fact that mineral groups rich with silicon, as well as carbonates and sulfides prevail in coals.

Chemical and microbiological analyses of ash dumps are shown in Table 1. and Table 2.

Table 1. *Silicate analysis of the ash dump*

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	MnO	Na_2O	K_2O	P_2O_5	SO_3	LOI	Total
%												
45,41	23,15	7,15	12,24	3,27	1,08	0,12	0,23	1,10	0,15	1,40	4,66	99,96

Table 2. *Microbiological analyses of the ash dumps*

Total number microorganisms (CFU/g original sample)				
Total number of aerobic mesophilic hemoorganoheterot ro phic bacterias	Total number of anaerobic mesophilic hemoorganoheterotr o phic bacterias	Total number of yeasts and moulds (dance s)	Total number of alkalophil ic bacterias	Bacte rias of genus *Bacill us*
$3,7x10^4$	$4x10^4$	$5,5x10^4$	$2 x10^2$	$1,5x10^2$

The results of chemical analysis showed that ash dump is alkaline environment with a negligible content of organic matter, which predominantly comes from unburned coal. As well, microbiological profile indicates that the ash dump can be characterized as an extreme environment [7]. Following bacteria has been isolated and identified from the ash dump: *Bacillus subtilis/amiloliquefaciens*, *Bacillus circulans* and *Bacillus megaterium*.

Obtained results showed the existence of microbial activity on the ash dump. Identified and isolated *Bacillus circulans,* which is traditionally known as "siliceous bacteria" and has confirmed role in pedogenesis [1,5,9], is good indicators for potential application of ash dump bioremediadion.

Our earlier research showed that humification occurs during the bioremediation of the crude oil contaminated soil [4]. That is probably the consequence of the fact that the organic components are the most resistant to the biodegradation and they transform and involve in complicated polymer structures analogue to the humic substances. This kind of residue material after degradation of crude oil and oil derivates doesn't represent danger for the environment, on the contrary, it contributes to the fertilization of the obtained unstructured soil.

Results of our earlier research in the combination with the new research related to the "silicate bacteria" showed thate remediation of the ash dump could be carried out through several phases in the following way:

1. Antrophogenic-technogenic mineral substrate (ash and cinder) which was produced by combustion of the lignite would represent the basic rock with the zymogenous organic substance and microorganisms, from which the „silicate" bacteria are the essential for the creation and maintenance of the soil.
2. Ash, as the basic rock, should be covered with layer of „artificial soil material" with crud oil pollutants and inoculated with consortium of zymogenous microorganisms for the bioremediation.
3. Mineralisation of oil pollutants, multiplication of microorganisms and humfication with the simultaniuos soilification (primary pedogenesis) of the basic material as a technogenic rock will take the place during the bioremediation.
4. Formation of the layer of undeveloped soil (man-made-soil[6]) and spontaneous colonization of plant „pioneers" which are grasses, with stumulated greening.

CONCLUSION

The crucial importance of this research is in the application of biological agents (microorganisms) in remediation, protection and preservation of degraded areas that result from exploitation of coal for thermo-electric power plants, and the occurrence of solid combustion products that are deposited on large surfaces. By simultaneous *ex/in situ* bioremediation of natural and artificial soil substrates, polluted by oil derivates and/or off balance hydrocarbon materials on ash dumps, the selected active zymogenous consortia perform a complete biodegradation-mineralization of the pollutants, including soilification thus transforming, primarily by humification, the pedological sterile substrate into fertile lend, and immobilizing toxic metals.

An additional benefit of this process is that fertile land as a cover is protected from being "used up" and the created soilifed substrate is good for plants.

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