ENVIRONMENTAL ASPECTS OF POST-OPERATIONAL BIOREMEDIATION OF THE TYPICAL MUNICIPAL SOLID WASTE LANDFILL OF THE ADMINISTRATIVE DISTRICT

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ABSTRACT

The article deals with the environmental consequences of testing the method of biological remediation of the closed typical municipal solid waste landfill of the administrative district. The essence of the method consists in the introduction of adapted composites from aboriginal, adapted or modified biological systems, primarily microorganisms for catalysis of the decomposition process of the organic component of waste landfills and subsequent separation of valuable recyclable materials. The article presents the results of the impact assessment of a typical solid municipal waste landfill at the final stages of its life cycle, in the process of bioremediation technology application and after its completion. Experimentally proved the effectiveness of this nature-like biotechnology of reclamation of waste landfill. The tendency to decrease the content of pollutants at different stages of biotechnology implementation and as the distance from the landfill body is revealed. Proposed the method for controlling the flow of filtration water of the landfill by creating geochemical barriers to achieve environmental safety in the implementation of this technology.

Keywords: municipal solid waste landfill, filtrate, volumetric bioremediation, biotechnology, environmental safety

INTRODUCTION

3-4 billion tons of waste is generated annually In Russia, with about 95% of this volume is sent to landfills [1]. Most of the existing landfills were put into operation in the middle of the XX century. At that time there were no requirements for the construction and recultivation of landfills, landfills were located close to residential areas of inhabited localities. Currently old closed landfills have negative environmental aspects too. The composition of the gases at the landfills contains methane, carbon dioxide and

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carbon monoxide, ammonia, hydrogen sulfide and many others. Fires often occur at landfills in hot and dry weather. The presence of the landfill creates an extremely dangerous sanitary and epidemiological situation. A filtrate is formed, which is formed under the influence of infiltration of atmospheric precipitation into the thickness of waste, it enters underground and surface water bodies. The soil of the landfills contains cadmium, cobalt, arsenic, iron, nickel, lead and mercury in ten times higher than the maximum permissible concentrations. Currently, there is a need for the recultivation of old closed landfills, extraction of useful fraction from them and return the territory to use for various needs.

One of the methods of recultivation of old landfills is bioremediation. Bioremediation is a complex of soil and water purification methods based on the use of the biochemical potential of living organisms. The most important advantage of these technologies is their safety for the environment: they are based on the processes of self-purification of wildlife and, as instilled, there is no secondary waste generated by other methods of remediation (mechanical, hydrodynamic, thermal, physic-chemical) [2], [3]. Successful development of bioremediation technologies for remediation of contaminated soils began in the 1970s.

The experimental typical municipal solid waste landfill of the administrative district implemented the method of volumetric bioremediation. This article discusses environmental aspects of post-operational volumetric bioremediation of the experimental landfill.

DATA AND METHODS

The technology of volumetric bioremediation was tested at the experimental closed Borisovsky solid municipal waste landfill. The landfill is located in the Belgorod region of the Russian Federation in the Borisovsky administrative region in large rural settlement called Borisovka. This landfill does not have a license for waste disposal, and is not included in the state register of waste disposal facilities. There are no engineering solutions for waterproofing at the landfill, because the landfill was created on the site of an unauthorized city dump, which was formed in the middle of the twentieth century. For this reason, the operation of the landfill was stopped and it was closed in 2018.

The Borisovsky solid municipal waste landfill is a typical representative of numerous ranges for large rural settlements of the Belgorod region and, to a certain extent, for all Central Chernozem Region of Russia.

Geomorphologically, the landfill is located on the second terrace above the floodplain of the Vorskla river (the Dnieper river basin). The area of work is located in the forest-steppe zone of the Central Chernozem Region. Vegetation reflects the features of the Northern forest-steppe [4]. The climate is temperate continental. The average rainfall is 480-550 mm per year. The terrain of the landfill is hilly, characterized by sharp changes in height. The absolute level of the surface is 168.0 – 204.61 m above sea level. At the base of this landfill there is a natural outlet of groundwater. The soil cover of the territory consists of gray and dark gray forest soils, podzol and leached chernozems. In gully net presents complex girder soils. [5]. Vegetation is represented by two types: zonal (steppe meadows) and extra zonal.

Among the waste placed at the Borisov landfill, the following types prevail: construction waste, rags, household items, food waste, polypropylene products, polyethylene products, plastic containers, glass.

Anaerobic decomposition of organic substances under the influence of methanogenic bacteria and anaerobic microbiological reactions with organic components of household waste occurred in the depth of the landfill for a long time. Landfill gas which mainly contained methane, carbon dioxide, hydrogen sulfide, ammonia, mercaptans and nitrogen departed from the landfill. The concentrations of hazardous components of landfill gas significantly exceeded the maximum permissible concentrations in the depth of the landfill and it led to regular fires. The landfill was creating an extremely dangerous sanitary and epidemiological situation for residential areas of inhabited locality Borisovka. The nearest residential area is located at a distance of 380 m from the landfill. The filtrate was formed in the depth of the waste under the influence of infiltration of atmospheric precipitation. This filtrate penetrated into ground and surface waters. There was no waterproofing of the landfill. The content of metals such as cadmium, cobalt, arsenic, iron, nickel, lead and mercury in the filtrate of the landfill was ten times higher than the maximum permissible concentrations.

The elimination of the accumulated negative impact of the closed Borisovsky landfill was carried out from July to November 2018 by the method of volumetric bioremediation. Method of the volumetric bioremediation implemented through the introduction of life support systems remediation of biocenoses, including immobilization of the components of the biocenosis, the input of enzymes penetration of nutrients in the regulation of the reaction medium to accelerate the decomposition of organic components of waste deposited on Borisovsky landfill. This led to a decrease in landfill gas. The decrease in the reactivity of the filtrate was carried out with ozonized air, which allowed switching the anaerobic processes in the body of the landfill to aerobic. The biochemical decomposition of the organic part of the waste was stimulated by introducing a composite organic catalyst (COC-5) into the substrate together with nutrients to increase the growth and metabolism of microorganisms that destroy the organic matter of the landfill. The composition of COC-5 for injection into the substrate of the landfill was selected in such a way as to maintain the activity of microorganisms in the aerobic process, artificially created technologically.

COC-5 is an aqueous solution for the processing of municipal solid waste containing protease, catalase, amylase, trypsin, pentose, pepsin, betaine, dimexide, hydrogen peroxide, dextrose, process water. All components included in the COC-5 are natural products of organic origin and they are easily decomposed. The majority of the components of COC-5 are enzymes of the multi-enzyme composite of the oxidoreductase class. The exception is dimexide (DMSO, Dimexidum, C2H6O). Dimexide performs the function of a penetrant that enhances the interaction of enzymes with oxygen, as well as their penetrating abilities, and these abilities lead to an increase in the degree of processing and a significant reduction in the time of destruction of organic substances in landfill waste. A specific feature of DMSO is an unusually high ability to diffusion. Solvates hydroxides, CH-acids, organic and inorganic cations, thereby greatly increasing the rate of many reactions. A good solvent for many organic and inorganic compounds [6].

Injection wells were created in the depth of the landfill for which COC-5 was introduced in the summer of 2018. COC-5 was also sprayed on the soil around the wells. As a result of the introduction of COC-5, an initial population of approximately 100 billion microorganisms per ton of waste was obtained. This was carried out to start the self-purification processes, and the main agents of the self-purification processes are aboriginal hydrocarbon-oxidizing microorganisms. Through the injection wells to the depth of the polygon evenly poured 600 000 liters of a composite COC-5 pressure 315 PA. Then all the wells were included in the cyclic bio-ventilation system with chemical oxidative treatment of the substrate.

Reduction dehalogenation was carried out twice with an interval of 10 days by the method of saturation of the landfill substrate with a 5% solution of hydrogen peroxide with dimethyl sulfoxide in equal parts in the amount of 50 000 liters.

As a result, the use of volumetric bioremediation technology reduced the concentration of landfill gas components below the maximum permissible values. This indicates the successful implementation of works on the transition of processing of organic matter of the landfill mainly in the aerobic process. Improved sanitary and hygienic condition of the landfill (almost disappeared odor), significantly reduced the amount of waste placed on the landfill due to the destruction of the organic component of the landfill hydrocarbon oxidizing microorganisms. At the final stage, the head of the working wells was dismantled. The territory of the landfill was leveled and compacted with special equipment. The area of the landfill became suitable for recultivation and further involvement in land use.

In order to assess the environmental safety of the technology of volumetric bioremediation of the landfill, we did research within the landfill body and on the territory adjacent to the landfill, and within the regulatory sanitary zone of the landfill (500 m in the Russian Federation). Researches were conducted in the period of application of this technology (10 October 2018), and after the completion of the application of technology (6 November 2018 and 28 November 2018). The sampling points of soil (S) and filtrate of the landfill (F) were located along the thalweg of the beam, the top of which beam is adjacent to the Borisovsky landfill (Figure 1).

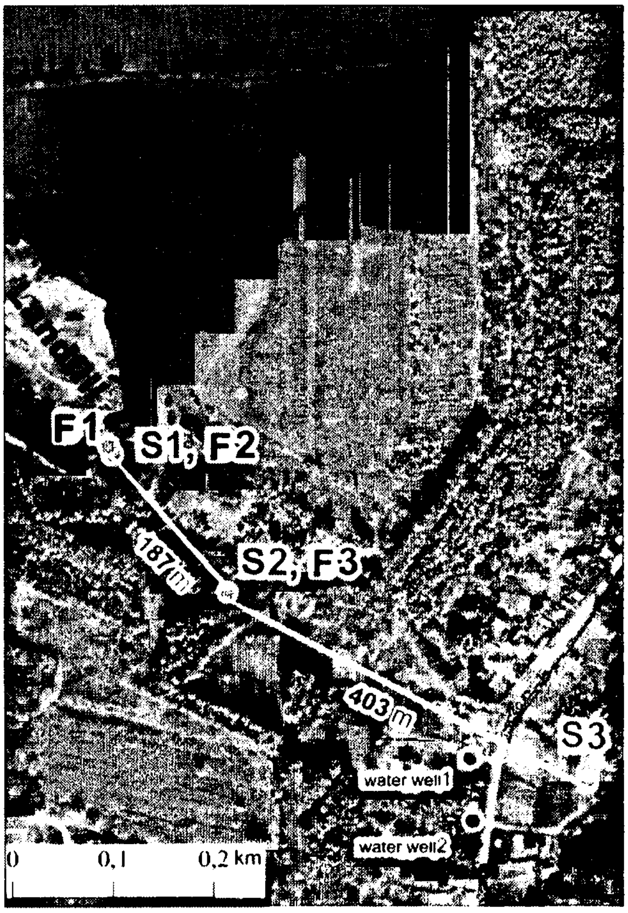

Figure 1. Scheme of the research

The conditions of the thalweg of the beam contribute to the formation of small streams of filtrate flowing out of the body of the landfill. The soil was taken as mixed samples in places exposed to filtrate, which flowed out on the terrain (at depths of 0-10 cm, 10-20 cm, 20-60 cm, 60-100 cm, 170-200 cm). The soil texture at sampling sites is defined as clay and loam (for S1 and S2), and sand and sandy loam (for S3). Also, the filtrate of the landfill flowing out on the terrain was selected. Filtrate flowed at a distance of 300 m from the landfill in thalweg of the beam (the point of taking a filtrate F1, F2, F3). The presence of DMSO was checked in two water wells located in residential area of nearest inhabited locality.

RESULTS AND DISCUSSION

One of the components of COC-5 is DMSO. It performs the function of a penetrator, which enhances the interaction of enzymes with oxygen, as well as enhances their penetrating ability. DMSO also leads to an increase in the degree of processing and a significant reduction in the time of decomposition of organic substances in landfill waste. Since the landfill is not equipped with devices of protection of the adjacent territory, DMSO migration is possible over long distances and depths, and it can also penetrate aquifers. In this regard, conducted a study of the filtrate, flowing out of the body of the landfill. Also studied the water of household consumption for the presence of DMSO from the wells of residential area of nearest inhabited locality. According to the results of the research the following data were obtained (Table. 1).

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Table 1. The content of DMSO in the filtrate, which flows from the landfill to the terrain, and in well water

Sample	DMSO content, mg/liter			Maximum permissible concentration, mg/liter
Sampling date	10.10.2018	11.06.2018	11.28.2018	
F1	33	195	not found	10
F 2	21	96	not found	10
F 3	14	57	not found	10
Water from wells	did not hold	23	not found	0,1

From the data of table 1 it can be seen that in the filtrate of the landfill detected the presence of DMSO in the samples of 10.10.2018 and 06.11.2018. Also, laboratory studies have established the presence of DMSO in the waters of the wells. It indicates the penetration of DMSO into aquifers. DMSO could come from the filtrate flowing out from the landfill, and thus could pass through all layers of landfills and could seep through the soil. The content of DMSO in the filtrate and in the well water exceeded the maximum permissible concentration by dozens of times in the period from 10.10.2018 to 11.06.2018. The content of DMSO in the filtrate was increasing, on average, by 4.9 times from 10.10.2018 to 11.06.2018. This may be due to a drop in ambient temperature, and the flow and amount of effluent filtrate increased due to the absence of evaporation. However, on 11.06.2018, DMSO was not detected in the samples under study.

It can be assumed that the absence of DMSO in samples on 11.28.2018 is associated with the installation of a two-stage barrier for the treatment and filtration of wastewater. It was installed 11.11.2018. Filters installed in places of the most active filtrate flow. These are special tanks (barrels) that filter wastewater through special (with cation exchange) materials with continuous ventilation of atmospheric air through filter loading due to the difference in temperature between the waste water and air (Figure 2).

Figure 2. Two-stage barrier for cleaning and filtering wastewater

In the first stage of the filter is loaded with a mixture of Zeolite act. 1N-1,25 and charcoal, in the second stage loaded with a mixture of Zeolite act. 2S-2.5, 20-60 wood chips and 0.5 charcoal. The use of sorption properties of zeolites can improve the effect of removing soluble impurities and organic compounds.

The presence of lower carboxylic acids in the filtrate stream flowing from the landfill was analyzed in order to identify hazardous products of incomplete biodegradation of contamination in the filtrate. The distillate was obtained from acidified filtrate and analyzed on Agilent 7890A gas chromatograph. Vinegar (ethane), propionic (propane), oil (butane), caproic (pentane) acid and sodium propionate were found. The concentration of lower carboxylic acids or their soluble salts in the filtrate was hundreds of times higher than the maximum permissible values. Figure 3 shows the distribution of the concentration of lower carboxylic acids outside the landfill by the example of butyric acid.

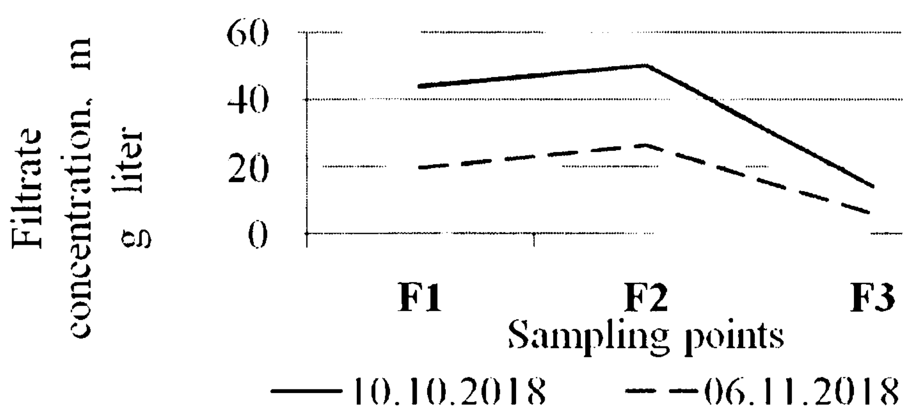

Figure 3. The concentration of nickel in the filtrate flowing out of the landfill on the terrain

The content of lower carboxylic acids decreases over time. It can be concluded that the oxidation processes are gradually completed. However, in places where the accumulation of organic substances was the most significant, very active oxidation processes continue.

Other intermediate products of aerobic oxidation, such as metal ions (cadmium, nickel, copper, tin, mercury, lead, etc.), as well as soluble compounds of nonmetals (arsenic, etc.).), nitrates, sulfates, phosphates, ammonium ions can also migrate with DMSO. Soil and filtrate samples taken outside the landfill to diagnose the migration of specified pollutants.

Cadmium, nickel, copper, tin, mercury, lead, arsenic, nitrates, sulfates, phosphates, ammonium ions found in the filtrate that flowed out from the landfill. The concentration of these pollutants exceeded the maximum permissible concentrations.

However, as the distance from the landfill increases, their concentrations gradually decrease. Also, the concentration decreased over time. How is this example of mercury (Figure 4).

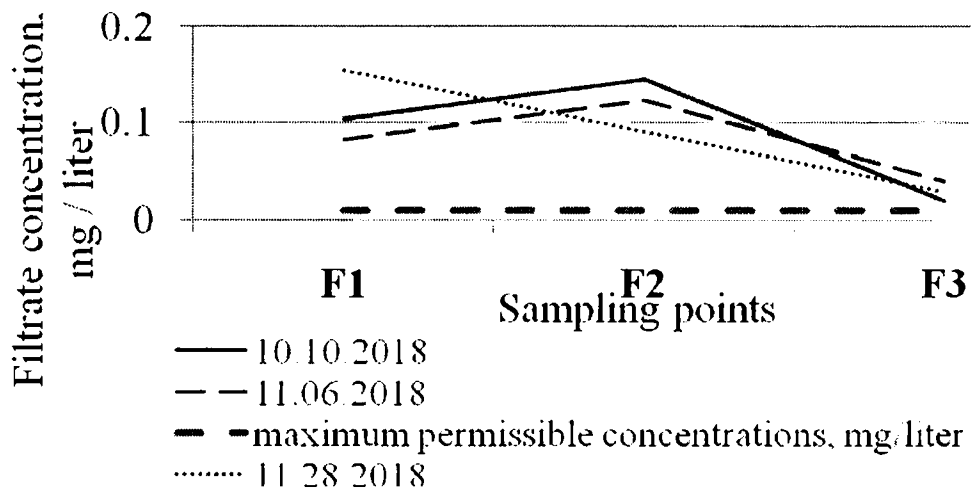

Figure 4. The concentration of nickel in the filtrate flowing out of the landfill on the terrain

Exceeding the maximum permissible concentrations of mobile forms of heavy metals in soils (maximum concentrations are reached at depths of 0-10 cm and 10-20 cm) are set outside the landfill. It is likely that heavy metals get into the soil along with the spillage of the landfill filtrate. The greatest excess of maximum permissible concentrations in soils is established for zinc, nickel and lead. However, as the distance from the landfill increases, their concentrations gradually decrease too.

The use of a two-step barrier for cleaning and filtering wastewater loaded with a mixture of zeolites, wood chips and charcoal led to a decrease in the concentration of pollutants to acceptable limits and below.

CONCLUSIONS

Assessment of post-operational volumetric bioremediation of the typical municipal solid waste landfill of the administrative district gave the following conclusions.

The Borisovsky landfill is not equipped with the necessary devices of protection of the adjacent territory (the absence of the concrete base of the landfill, the absence of concrete barrier screens around the perimeter of the landfill) therefore pollutants can be emitted into the soil to different depths. Even penetration into aquifers is possible. Emission of pollutants can actively contribute to one of the components of COC-5 - DMSO. A specific feature of DMSO is an unusually high diffusion capacity. DMSO is a marker substance with which you can trace the migration of the constituent parts of a COC-5. According to the results of the first stage of experiment, the presence of DMSO outside the area of the landfill was revealed. DMSO could get as from the filtrate flowing from the body of the landfill, and goes through the layers of landfill waste and leaks through the soil.

The presence of DMSO outside the site and in the well water was not detected after installing a two-stage barrier to clean the filtrate in the second stage of the experiment. The organization of a two-step barrier to clean the filtrate allowed to minimize the negative impact of the landfill on the environment. The barrier contained a mix of zeolites, wood chips and charcoal.

It is necessary to note a tendency to a decrease in the content of pollutants over time (for the majority of the studied indicators). And tendency to increases in the content of pollutants with the distance from the landfill.

As a summary of the research of environmental safety of the post-operational volumetric bioremediation of the typical municipal solid waste landfill of the administrative district using composite organic catalyst COC-5 can be concluded that this technology is an effective way of land recultivation after landfills. It is necessary to exclude the penetration of the landfill filtrate beyond its limits and equip the places of potential release of the filtrate of landfills (beams, ravines) with geochemical barriers (intercepting tanks and / or trenches) filled with aluminosilicates (zeolites). These actions are necessary to achieve environmental safety in the implementation of the volume bioremediation technology.

REFERENCES

[1] Velkov V.V. Bioremediation: principles, problems, approaches, Biotechnology, Russia, issue 34, pp. 20-27, 1995.

[2] Alexander M. Biodegradation and Bioremediation, USA, p. 453, 1999.

[3] Quintella C., Mata A., Lima L. Overview of bioremediation with technology assessment and emphasis on fungal bioremediation of oil contaminated soils, Journal of Environmental Management, vol. 241, pp. 156-166, 2019.

[4] Antimonov N.A. Nature of the Belgorod region, Russia, p. 239, 1959.

[5] Milkov F.N. Physical geography: the study of landscape and geographical zonality Russia, p. 224, 1986.

[6] Gad S. E., Sullivan D. W. Dimethyl Sulfoxide (DMSO), Encyclopedia of Toxicology (Third Edition), USA, pp.166-168, 2014.