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Approaches to the selection of measures to ensure the safety of closed landfills for the disposal of solid municipal waste

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Abstract. The approaches to the choice of measures to ensure the environmental safety of closed facilities for the disposal of solid municipal waste (MSW) are considered. Laws of the Russian Federation in terms of requirements for ensuring the safety of waste disposal facilities during the operational and reclamation periods have been studied. Scenarios of the conduct of processes at MSW landfills after reclamation are presented. The article presents the results of engineering and geological research: a comprehensive study of engineering and geological and hydrogeological conditions of the site, composition, condition and properties of soils, the activity of geological processes for making design decisions. Field engineering and geological work, soil sampling from wells have been carried out. Laboratory research of soil samples has been carried out in a soil laboratory. The project of reclamation cover of MSW landfill has been completed, including geosynthetic materials and natural soils, a network of pipelines supplying filtrate for recirculation has been calculated, and a set of work and selection of vegetation at the biological stage of reclamation have been justified. Scenarios of the conduct of processes in the course of reclamation of a waste disposal facility are considered in the case of application of the filtrate recirculation technology with preliminary pH-regulation by changing the structure of the landfill in the first year after reclamation and according to the scheme of the section of the reclaimed landfill upon reaching the stage of destruction of the biodegradable part of the waste. The advantages of the developed reclamation pavement are shown: high cultivation capacity, preservation of drainage properties at high loads, reduced costs for excavation and crushed stone laying, high chemical resistance and environmental friendliness of the material.

1. Introduction

According to the Audit Chamber of the Russian Federation, 65 million tons of solid municipal waste (MSW) has been generated. |Of these more than 90% are buried at MSW landfills. In 2020, there were about three thousand landfills in operation. MSW landfills as well as unauthorized landfills require environmental safety after their closure for a long-term period.

The purpose of this article is to develop approaches to the selection of measures to ensure the safety of closed facilities for the placement of MSW. Based on the existing regulatory framework of the Russian Federation, the methods of ensuring safety at closed facilities for the placement of MSW can be divided into preventive and active. Preventive measures to ensure the safety of the closed landfill are the methods which can be taken during the period when the facility is still active in priority order. First and foremost, it is necessary to strive to prevent the generation of waste. If it is impossible to process, the waste is subject to disposal and, as a last resort, burial.

However, along with the adoption of preventive measures, it is necessary to take active measures and solve the current security issues of closed and operating landfills. Safety indicators of a reclaimed waste disposal facility are considered to be its accident-free operation, ensuring compliance of the land quality with environmental quality standards and sanitary and epidemiological requirements.

The technology of landfill reclamation, in which a sealed cover is created over the compacted waste, which will prevent the formation of leachate and minimize the impact of the landfill on the environment, is widespread. The result of this technology is the conservation of waste under a waterproofing coating, but there is enough moisture inside the array to maintain the anaerobic process of biodegradation of waste without atmospheric precipitation and oxygen, accompanied by the release of concentrated acidic filtrate and biogas. The effect of biomass and temperature on the rate of ammonia oxidation during filtrate purification was studied in the following work [1]. If, under conditions of atmospheric precipitation penetrating into the landfill body, biodegradation processes last from 10 to 50 years, then with a lack of moisture they are in process more slowly, the achievement of a safe state of the waste disposal facility is postponed for a long period. If critical temperatures are reached during the anaerobic decomposition of waste and oxygen penetration through defects in the sealing of the screen, local spontaneous combustion is possible, which are difficult to extinguish.

An alternative group of methods for bringing a closed waste disposal facility to a safe state is based on the accelerated achievement of a stable state by the massif when the mass of waste passes into the stage of methanogenesis, which is characterized by an increase in pH to 7.2–8.6 and a noticeable decrease in the formation of acid hazardous leachate [2, 3].

Accelerated stabilization of the landfill mass can be carried out by such methods as forced aeration, moistening of waste, recirculation of the leachate without preliminary preparation, recirculation of the leachate with preliminary pH control, as well as their combination [4, 5].

Forced aeration is the delivery of pressurized air into the waste mass. Aerobic conditions are favorable for accelerated biodegradation of waste. To prevent waste ignition, aeration should be carried out in conjunction with humidification [6].

The final coating of the landfill, which includes layers of various functional purposes (leveling, drainage, reclamation, waterproofing), is one of the most important stages of reclamation. The device for reclamation cover is provided from geosynthetic materials and loamy soil layers, preventing the flow of atmospheric precipitation into the landfill body and the release of landfill gas (biogas) of the landfill into the atmospheric air, as well as a device over the materials to overlap the fertile soil layer.

2. Methods and equipment

Engineering and geological research was carried out in accordance with the requirements of the current regulatory documents (SP 47.13330.2016 “Engineering survey for construction. Basic principles”, SP 320.1325800.2017 “Polygons for solid communal waste. Projecting, operation and reclamation”). A topographic survey plan at a scale of 1:500 was used as a topographic basis for engineering and geological research. Break-down and horizontal and vertical tie-in of engineering and geological workings have been carried out.

Drilling of wells up to 12 m deep was carried out by a mechanical core method using a URB 2A-2 machine with a diameter of 131 mm. Wells after drilling and observations were liquidated (plugged) with cut rock.

Laboratory research of soil samples has been carried out in accordance with GOST 30416-2012 “Soils. Laboratory testing. General”, GOST 12536-2014 “Soils. Methods of laboratory granulometric (grain-size) and microaggregate distribution”.

3. The results of the study and their discussion

Before the start of the work, the materials of the engineering and geological research carried out at the study site were studied. According to archival materials, the geological structure of the site to a depth of 22 m includes quaternary alluvial deposits overlain by technogenic soils. Alluvial deposits are represented by alternating sands of medium size, sandy silt of small, medium degree of water saturation, saturated with water, medium density and dense, loams from refractory to fluid consistency and sandy loam. At a depth of 9–11 m, there are gravelly sands saturated with water. A groundwater horizon was also encountered at a depth of 10.2–12.5 m in gravelly sands and gravelly soils. The sand filtration coefficient varied in the range 1.2–5.7 m/day.

The research results have shown that the most effective way to accelerate the achievement of a stable state of the waste disposal facility is to collect the leachate and recirculate it multiple times through the waste mass with preliminary pH regulation, for example, by means of $Ca(OH)_2$ milk of lime. The scheme of application of the leachate recycling method is shown in figure 1.

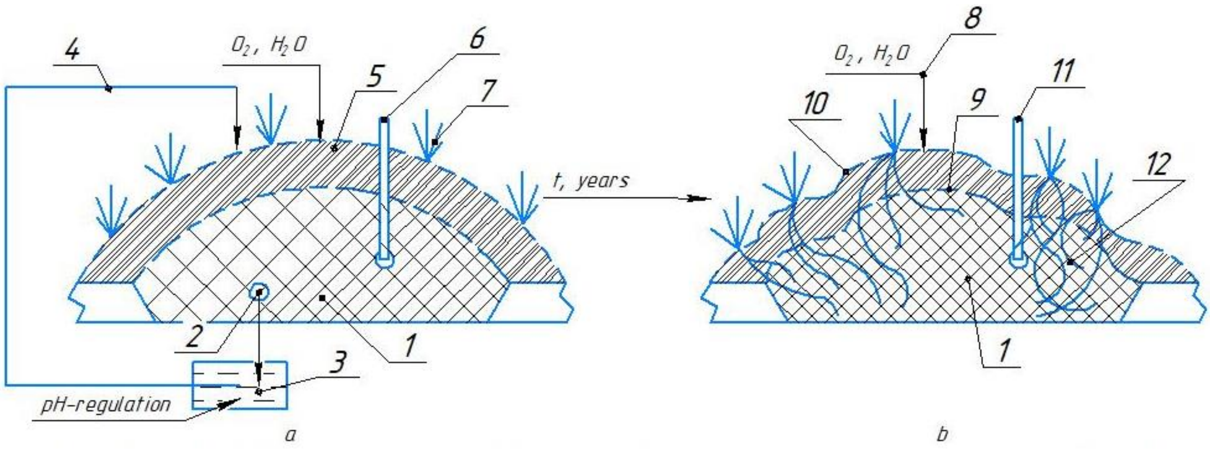

Figure 1. Flow chart of the processes during reclamation of the MSW landfill when using the leachate recirculation technology with preliminary pH-regulation: a - layout of the landfill section in the first year after reclamation; b - diagram of the section of the reclaimed landfill upon reaching the stage of destruction of the biodegradable part of the waste: 1 - waste; 2 - collection of leachate; 3 - accumulation ponds, pH control station for leachate; 4 - leachate recirculation system with preliminary pH-regulation along the landfill surface; 5 - permeable reclamation layer; 6 - biogas removal; 7 - plants; 8 - penetration of oxygen and atmospheric precipitation; 9 - subsidence of the polygon body; 10 - deformation of the permeable layer; 11 - silting, clogging of the degassing well; 12 - penetration of plant roots into the mass of waste.

The construction of a recultivation screen up to one meter thick has been accepted for the landfill of MSW “Ledyanaya gora” (Kungur, Perm Krai), which includes geosynthetic materials (geotextile, geomembrane, hydromat); sand as a leveling layer with a thickness of 0.25 m; loam as a remediation layer 0.5 m thick; fertile soil layer 0.25 m.

Backfilling, leveling and compaction of the leveling layer is carried out in the following sequence: laying of geotextiles over the landfill body, previously leveled and compacted; delivery of sandy soils; leveling sand on the surface of the screen with a bulldozer. Next, the hydromats are laid, which are a drainage geocomposite mat. The advantages of the hydromat are high culverting capacity; preservation of drainage properties at high loads; reducing the cost of excavation and laying rubble; light weight and high chemical resistance. The final stage includes backfilling and compaction of the vegetation layer. The design of the reclamation screen is shown in figure 2.

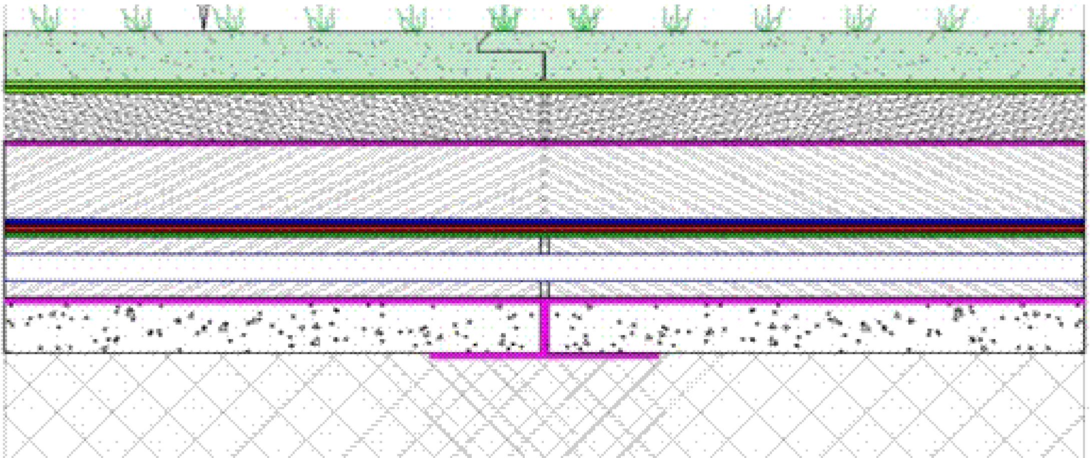

Figure 2. Reclamation screen of the MSW landfill surface.

The final protective (reclamation) screen (figure 2) is a structure with the following layers (from bottom to top): geotextile is laid on top of the waste, then a leveling layer 45 cm high (sandy loam - 20 cm, hydromat and loam - 25 cm), then a mineral waterproofing a layer (bentonite mats), a geosynthetic waterproofing layer (geomembrane), a drainage layer for the drainage of surface waters (geogrid RM-300), on top of which a reclamation layer 50 cm high is laid (loam - 30 cm, 3D hydromat, sandy loam - 20 cm) and vegetation soil (20 cm high), the anti-erosion geomat 3D/150 is laid between them.

In places where recirculation networks are installed under the pipe, instead of a layer of loam, limestone sifting is carried out to lower the acidity level of the supplied filtration water (back to the landfill body). The node for the device of a protective (reclamation) screen at the passage points of recirculation networks is shown in figure 3.

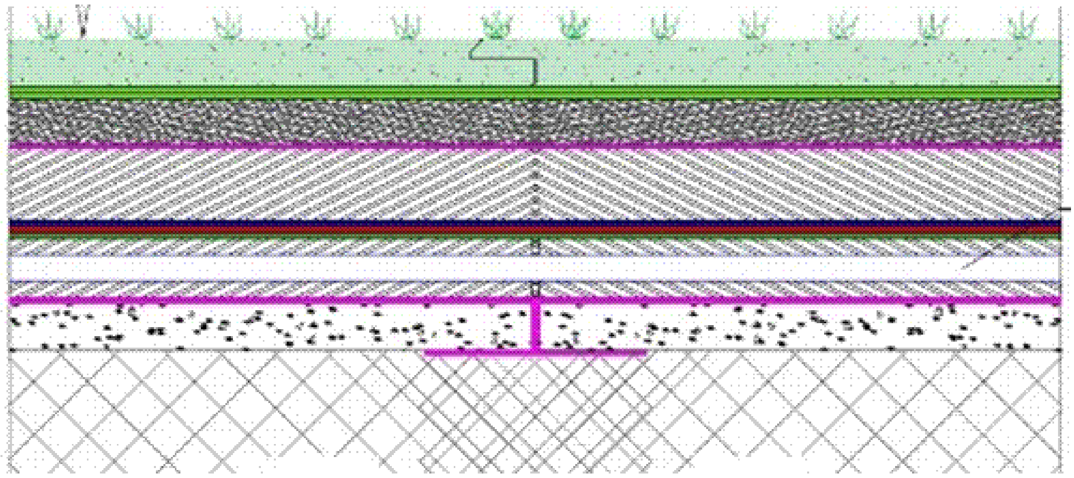

Figure 3. Protective (reclamation) screen of the landfill surface in the passage points of recirculation networks.

The structure consists of the following layers (from bottom to top): geotextiles are laid on top of the waste, then a leveling layer with a height of 45 cm (sandy loam - 15 cm, 3D/M hydromat and limestone screening - 30 cm), then a mineral waterproofing layer (bentonite mats), geosynthetic waterproofing layer (geomembrane), drainage layer for drainage of surface waters (geogrid RM-300), on top of which a recultivation layer 50 cm high (loam - 30 cm, 3D hydromat, sandy loam - 20 cm) and vegetation soil (20 cm high) is laid, the anti-erosion geomat 3D / 150 is laid between them.

Among the well-known methods of cleaning the leachate of MSW landfills is the process of liming it with subsequent recirculation [5, 7]. It is proposed to create a layer of limestone screenings in the protective screen in the places where the leachate recirculation networks pass. The inclusion of this layer in the composition of the screen will ensure the deposition of heavy metals [8, 9]. Limestone screenings are planned to be transported from Sharashinskoye deposit, which is located near the landfill of MSW “Ledyanaya gora”. At the second biological stage of reclamation of the MSW landfill, a complex of agrotechnical and phytomeliorative measures is envisaged. It is proposed to use a ready-made grass mixture intended for reclamation of landfills located in the middle lane. The grass mixture contains herbs: smooth brome, red fescue, meadow fescue, wheatgrass, red clover and sweet clover. Quantity of seed sown is 40-50 kg/ha. It is proposed to apply mineral fertilizers (nitroammophoska) before and after sowing herbs. The main fertilizer (nitroammophoska) is applied when plowing or cultivating the soil before sowing - 400 kg/ha. After the emergence of seedlings, crops are fertilized with nitroammophoska at the rate of 40 kg/ha) and ammonium nitrate - 30 kg/ha. Subsequently, in the 2nd, 3rd and 4th years of growing perennial grass, it is fed with nitrogen fertilizers in spring, harrowing to a depth of 3-5 cm, mowing to a height of 5-6 cm, fertilizing with mineral fertilizers at the rate of 140-200 kg/ha and watering based on the provision of 35–40% soil moisture.

The envisaged creation of vegetation cover on the territory of the recultivated area will strengthen the surface of these areas by sodding the sown grass with the root system.

4. Conclusion

The justification of measures to ensure the safety of closed facilities for the placement of MSW through preventive and active measures is shown in the article. Preventive measures involve reducing the amount of waste generated, which leads to a reduction in the number and capacity of newly formed landfills. The proposed active measures are aimed at engineering and technological measures for operating and closed landfills, contributing to the early achievement of a stable state of landfill masses through the use of leachate recycling technology and the creation of a special reclamation screen on the surface of the MSW massif. The results of the project of recultivation coverage of the landfill of MSW “Ledyanaya gora” in the Filippovsky rural settlement of the Kungursky municipal district, consisting of two stages: technical and biological, including geosynthetic materials, natural soils (layers of sand, loam, fertile layer), a distinctive feature of which is setting cap of a layer of limestone from the Sharashinskoye deposit under the network of pipelines supplying the leachate for recirculation, which will help to clean the leachate from heavy metal ions and neutralize acidic effluents, are shown.

References

[1] Zhang Y *at el* 2021 The combined effects of biomass and temperature on maximum specific ammonia oxidation rate in domestic wastewater treatment *Frontiers of Environmental Science and Engineering* **15(6)** 123

[2] Huang C *at el* 2021 Environmental effects and risk control of antibiotic resistance genes in the organic solid waste aerobic composting system: A review *Frontiers of Environmental Science and Engineering* **15(6)** 127

[3] Zhang T, Shi J, Wu X, Lin H and Li X 2021 Simulation of gas transport in a landfill with layered new and old municipal solid waste *Scientific Reports* **11(1)** 9436

[4] Barrios J A, Cano A, Rivera F F, Cisneros M E and Durán U 2021 Efficiency of integrated electrooxidation and anaerobic digestion of waste activated sludge *Biotechnology for Biofuels* **14(1)** 81

[5] Kostarev S N and Sereda T G 2013 Automated process control of sanitary municipal solid waste landfill *World Applied Sciences Journal* **22(SPL.ISSUE2)** 64–9

[6] Sereda T G, Kostarev S N, Elantseva E N and Oshchepkova O F 2014 Developing a safe technological process on the remediation of solid oily waste using means of industrial

control *Neftyanoe khozyaystvo - Oil Industry* **6** 67–9
[7] Pat. 2162059 RU Method for cleaning waste water of solid waste lands from heavy metals (in Rus)
[8] Nursetiawan Shaylinda N M Z *at el* 2020 Investigation of heavy metals pollution in Piyungan Landfill underground and surface water *IOP Conference Series: Earth and Environmental Science* **498(1)** 012080
[9] Malovanyy M *at el* 2019 Perspective technologies of the treatment of the wastewaters with high content of organic pollutants and ammoniacal nitrogen *Journal of Ecological Engineering* **20(2)** 8–15