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Research of Methods, Technologies and Materials for Drainage Water Treatment at the Municipal Solid Waste Landfill in Salaryevo

Elena Gogina [1,*], and *Alexey* Pelipenko[1]

[1]Moscow State University of Civil Engineering, 129337 Yaroslavskoe sh. 26, Moscow, Russia

Abstract. The article deals with innovative methods, technologies and materials intended to reduce the adverse ecological impact of human waste and various industrial waste situated in municipal solid waste landfills (MSW), on water bodies, soil, and atmosphere. The existence of these factors makes the region less attractive for urban development. A comparison has been made of the methods intended to reduce the damage caused to the environment, in order to provide for sustainable development of cities, using the example of an actual landfill situated in the territory of Moscow. A scheme of reconstruction is recommended for the drainage water treatment plant at this landfill, which will lead to improvement of the environmental situation and contribute to the development of territories in the adjacent districts, and to reduction of pollution load on the river and atmosphere.

1 Introduction

It is known that human waste is removed to municipal solid waste landfills. Officially, the total number of registered landfills is 865, of which 37 are located in the Moscow region [1]. The largest operating landfills include Dmitrovsky, Khmetyevo, Levoberezhny, and Saburovo landfill. Decommissioned landfills and those in the process of reclamation include Nekrasovka and Salaryevo.

The main problem is the treatment of MSW landfill drainage flows with elevated concentrations of organic and mineral contamination as well as heavy metals [2].

There are three major sources of leachate formation at solid domestic waste landfills:

- Precipitation infiltrating through the landfill body in contact with the surface of solid waste (the main source of leachate formation);

- Initial moisture content of certain types of waste;

- The moisture released from the section as a result of biochemical processes involving the formation of water at the anaerobic decomposition of organic components [3].

In practice, there is "young" and "old" leachate. "Young" leachate is formed at the initial stage of landfill operation after 2-7 years of storage and burial of solid domestic waste and lasts for 5-10 years. This leachate has an average value of pH, high values of COD and BOD, and high content of ammonia nitrogen and iron; the composition of organic

* Corresponding author: goginaes@mgsu.ru

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compound is represented by volatile organic fatty acids. “Old” leachate is formed mainly on the post-operational stage of landfill life [4-6].

The aim of the research work is the reconstruction of the existing drainage water treatment plant at the Salaryevo landfill with minimal capital investments both for the refurbishment of the existing buildings, and for the construction of new buildings and the purchase of new equipment. The main task is to find the optimal scheme, which will ensure the proper indicators of active substances for their subsequent discharge to the river Setun. At the moment, the discharge is made to the relief. As of recent, the need to reduce the environmental impact of leachate, both on the relief and on ponds, has been the most urgent. The Russian government has been carrying out a set of measures aimed at improving the quality of treating various wastewaters by increasing the fees for discharge of polluted waters both to the municipal sewage system, and to ponds; in addition, measures have been implemented to refuse using relief as the site for wastewater discharge.

Implementation of the authorized discharge of solid domestic waste landfill leachate to the relief has the following negative effects:

- Change in the degree of soil salinity
- Change in the chemical composition
- Possibility of toxic pollutants entering the ground water, thus contributing to their change
- Formation of dangerous gases released into the atmosphere during decomposition of organic contaminants [7-8].

Disposal of drainage water into fishing industry waters contributes to the change of water chemical composition, resulting in:

- Threat to human life upon further use as a source of drinkable water;
- Increased level of water pollution causing water body eutrophication;
- Changes in the microbiological composition of water;
- Reduction of pond’s self-cleaning ability;
- Possibility of toxic pollution spreading in the range of 50-60 km;
- Disposal of unfiltered contaminants into the pond [9-10].

The landfill is currently under reclamation; however, the drainage water will continue to flow during the next few decades, which is why it was decided to renovate the existing treatment plant.

The current diagram of drainage water treatment consists of the following facilities: reception chamber combined with bar screen building, primary sedimentation tanks, bag filters, sand filters, cartridge filters, and reverse osmosis plant.

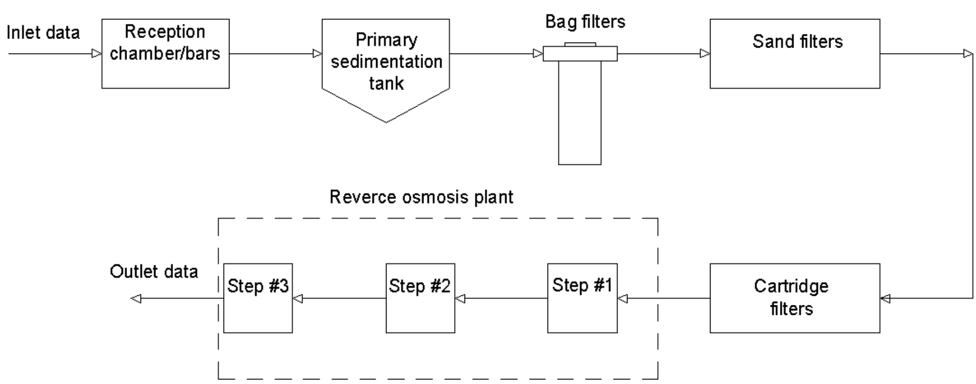

Fig. 1. Diagram of Leachate Treatment Plant before Reconstruction.

The actual contaminant indicators obtained during laboratory tests were used during the research work. The results show that the drain water is characterized by high values of COD, suspended solids, and ammonia nitrogen.

2 Theory

At the moment, there is a large number of SDW landfills leachate treatment methods on the market. Current trends have formed two main areas on which all the developments are based. There is a variety of modular systems, which are placed in the shipping containers or the existing facilities. In addition, there is stratification by the treatment methods. Thus, there are biochemical (aerobic and anaerobic) and physicochemical (oxidation, ion exchange, adsorption) methods [11-12].

For example, Osmotics Company proposes a method based on the reverse osmosis membrane technology in combination with ozonization and electrochemical machining technologies [13].

Moscow State Environmental Engineering University presented the MSW landfill leachate chemical treatment and detoxication technology, under which the active substances are treated in the following order: chemical treatment with lime milk to pH 11-12; ammonia air stripping; use of coagulant along with feeding into a thin-layer elements sedimentation tank; filtration through the contact with silica sand (particle size 1-3 mm); electrofrothcoagulation; 30% hydrogen peroxide treatment for organic dissolved substances decomposition; heavy metals adsorption on the natural sorbent (tripoli powder, particle size 200-300 mkm) with final additional purification at the membrane module. The limited version of the plant with the use of deep desalination is available at Dmitrovsky Solid Domestic Waste Landfill, Moscow.

BMT CJSC (Vladimir) has developed a technology comprising of the following stages:

- pre-treatment – chemical treatment, electrochemical oxidation, sedimentation, ultrafiltration treatment
- deep purification and desalination of waste water using two-stage reverse osmosis and subsequent disposal of reverse osmosis concentrate to the landfill body;
- sorption purification from low-molecular organics;
- UV disinfection of purified water (ultraviolet spectroscopy) [14].

The following method developed by MIS Company presents wastewater filtration using ultrafiltration vacuum plant (without pretreatment) with subsequent ozone treatment. In this case, the concentrated precipitation from the ultrafiltration step is fed back to the landfill. The initial ultrafiltration uses surface treated (to reduce sludge production) membranes based on ether sulfones. Water ozonation occurs in the vortex reactor. At the low volumes of inlet drainage water, this method can be carried out in standard sea containers.

Ekologicheskaya gruppa LLC (Kaliningrad) offers its own vision of the effective drainage water purification technology. Its development is based on electrical chemisorption method, which includes various stages of other processes (flotation, filtration, electrooxidation, and chemisorption). At the core of the reaction is the mechanism of electro-initiated free radical chain oxidation. The initiation occurs through the generation of electrons with electrodes in an aqueous medium. In contrast to other processes, both anode and cathode function in this method.

Due to the high oxidation potential, the reaction occurs at a high speed, thus catalyzing other purification processes of organic matter; as a result, the organics oxidize to carbon dioxide and water [15].

Another development by BMT CJSC is based on the use of sequential purification process comprising of the following steps: mechanical cleaning of mechanical and colloidal particles, fine purification unit on a mechanical barrier filter with retention potential of up to 20 microns, deep purification unit, two-stage desalination with a membrane module, and final purification using ion exchange filters with the concentrate return to the landfill body for participation in the biochemical processes [14].

In addition, there were found various advanced methods that are currently being developed, but have not been applied at the actual landfills, so there is no realistic assessment of their effectiveness . This includes active substance flow evaporation method (Kimo-business, Kiev), laser beam water treatment (Bauman MSTU, Kaluga Branch), contaminant extraction using biological sorption filters (PermGTU, Perm), as well as the biological method of drainage water treatment in a system of cascade biofilters and slowly flowing ponds (Ecoprom CJSC, Samara).

Institute of Colloid Chemistry and Water Chemistry (NIKTI GH, Kiev) has developed a scheme based on the use of reverse osmosis method with a preliminary two-stage anaerobic-aerobic biological treatment, chemical treatment, setting-out, disinfection with sodium hypochlorite, and filtration through sand and charcoal filters. This scheme also includes ion exchange steps with Na-cation exchange filters and electrodialysis.

However, it is worth noting that the current technologies are mainly based on the foreign experience, which is often not adapted to the climatic conditions and a specific site, and is often economically unjustified in view of the more stringent requirements of the Russian legislation on the quality of purified active substances sent for drainage into the waterways [16-18].

3 Experimental part

Based on the review results of the existing methods, we selected three methods that constitute complete solutions for further work on MSW landfill drainage water purification and are the most optimal in terms of the applied technologies.

Method #1 is the development of BMT CJSC. It includes membrane technology with pretreatment of heavily contaminated drainage water.

Method #2 – Alpha mobile complex by Ekologicheskaya gruppa LLC.

Method #3 by BMT CJSC consisting of several purification steps aimed at removing pollutants of various sizes.

For each of the selected schemes we found published results on the leachate treatment of solid domestic waste landfills with contaminant indicators on the inlet and outlet. Based on this, the contaminant removal efficiency for each method was found. Based on the efficiency values, the purification results with respect to the Salaryevo landfill were calculated through analytic determination.

We also evaluated the environmental damage from the discharge of untreated and treated leachate into the pond. When conducting the analysis, we calculated the fee for the discharge of pollutants by four parameters: BOD, suspended solids, petroleum products and ammonia nitrogen. The comparison on the four indicators owed to the fact that there were results for a variety of substances for the selected schemes in the public domain; however, it was on these indicators that two methods coincided.

4 Results and discussion

By the results of the outlet pollutant indicators simulation, and after applying each method, two methods with the best results of solid domestic waste landfill leachate treatment were selected (methods #2 and #3). There were requested commercial offers and conducted economic comparison of each method.

The cost of method #2 amounted to RUB 10 million; that of method #3 – RUB 14 million.

Method #3 includes capital costs for the construction works and purchase of new equipment. Therefore, it is fair to reduce the cost of this method to RUB 10 million.

By the results of comparing the fee for discharge of pollutants into a water body, method # 3 provides the lowest payment. It is 5 times less than that for the second method and 220 times less than the fee for discharge without reconstruction.

Upon selection of method #3, the economic effect on the four contaminants will amount to 49,341.7-224.41=49,117.29 RUB/year.

It is expected to reconstruct the current treatment plants using method #3. It allows the fullest use of the available facilities and includes the following steps during the reconstruction:

- Reception chamber combined with the bar screen building are not reconstructed; however, it is necessary to take into account the bar spacing in the existing grids, as well as the basic requirements for the reconstruction, such as the availability of engineering systems (water supply, ventilation, plumbing, heating, electricity)
- Primary sedimentation tanks are converted to storage tanks for matching the incoming wastewater and leachate flow offset
- Bag filters are decommissioned
- As part of reconstruction, sand filters are upgraded by removal of the old medium and its replacement by a larger medium, i.e. granular bed, for the implementation of rough mechanical treatment stage
- Cartridge filters are decommissioned and replaced with mechanical filters for the fine purification of waste water
- Reverse osmosis plant is subjected to the reconstruction only in terms of membrane replacement and stage #3 decommissioning.
- Ion exchange filters are added to the scheme after the reverse osmosis plant stage #3.

The diagram of leachate treatment plant before and after the reconstruction is shown in Figures 2 and 3.

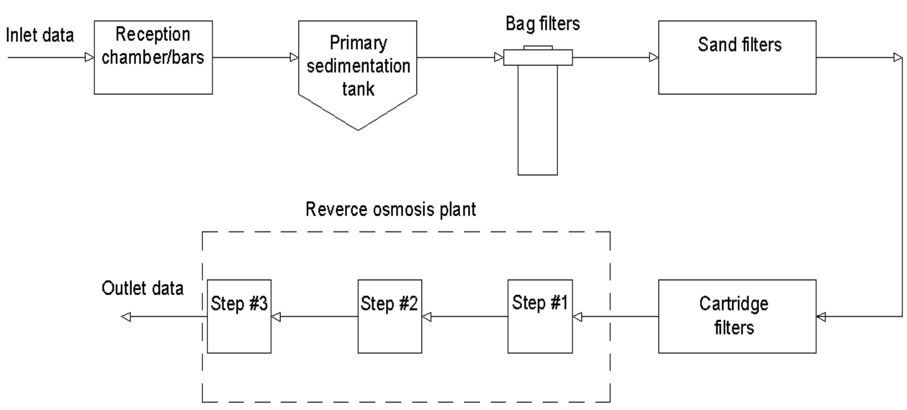

Fig. 2. Leachate Treatment Plant before Reconstruction.

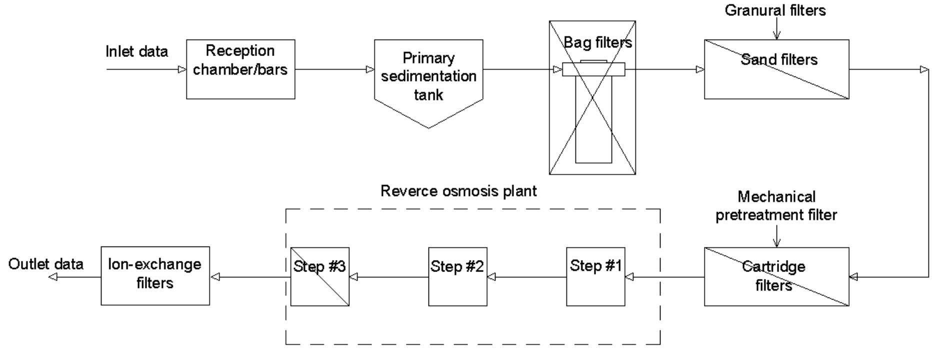

Fig. 3. Leach ate Treatment Plant after Reconstruction.

5 Conclusion

By the results of economic comparison and the analytical results of drainage water purification by different methods, the best solution is method #3, which is a sequence of various leachate treatment stages aimed at obtaining the best treatment results and requiring minimal capital expenditures for the reconstruction due to the possibility of using the existing facilities.

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