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Investigation of Hydrosphere Contamination by Untreated Landfill Infiltrates and Cleaning Agents to Improve Environmental Protection

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ABSTRACT

Landfill infiltrates cause contamination of surface, ground, and groundwater. In order to minimize this danger, it is necessary to implement technical measures for collecting and cleaning infiltrates. The subject of the study involved the processes of biological treatment of landfill infiltrates in aerobic lagoons and urban wastewater treatment plants. The content of nutrients necessary for plants in wastewater sediments makes it possible to use them as organic fertilizer. The fertilizing value is largely determined not only by the content of nitrogen, phosphorus, and potassium in them but also by the microelements necessary for plants, i.e. boron, molybdenum, manganese, zinc, magnesium, iodine, copper, iron, sulfur, etc. It was found that compacted excess activated sludge is a valuable complex mineral fertilizer with a high content of N and P. The possibility of converting sediment into a complex fertilizer by neutralizing wastewater sludge under biosulfidogenesis conditions during dissimilation reduction of poorly soluble sulfates was considered. The results obtained are consistent with the experimental data corresponding to the dynamics of the biogenic gas released from the bioreactor. By the nature of changes in the kinetics of biogenic carbon disulfide yield, changes in the acetate concentration and the rate of sulfate absorption, it is possible to predict the process of biosulfidogenesis and find the most optimal parameters of the system. This indicates the possibility of its use in biotechnology for the neutralization of wastewater sludge with the production of a complex organometal fertilizer.

Keywords: development, environmental protection, ecology, waste, infiltrates.

INTRODUCTION

The infiltrate treatment is based on the reverse osmosis method with preliminary deep preparation to increase the service life of the membranes and reduce the need for cleaning solutions. In order to bring the concentration of the salt solution to the values that allow their disposal, a special electrodialysis concentrator-separator is provided. The concentration of organic pollutants is reduced by two-stage biological purification with suspended and attached microflora. Further, colloidal and mechanical impurities are coagulated in the thin-layer sump, iron-free, and decontaminated with sodium hypochlorite. By filtering through a sand filter, carbon filter and microfilter, the Infiltrate is further cleaned of organic and mechanical impurities (Gupta, 2014).

After further decalcification and post-treatment of heavy metals in a Nacationite filter, the infiltrate enters the electrodializer for partial desalination and salt concentration is brought to a value of 250 g/dm^3 (Rathod, 2013). Afterwards, the infiltrate enters the reverse osmotic apparatus, after which the permeate can be discharged into the reservoir. From the brine formed in the electrodializer, $CaCO_3$ and $MD(OH)_2$ can be obtained by means of the reagent method for use in construction and coagulation, while NaCl and Na_2SO_4 salts can be removed by crystallization. The resulting sodium sulfate Na_2SO_4 corresponds to the technical product of grades 1 and 2, and the NaCl table salt solution can be used to produce dry salt or electrochemical production of chlorine and caustic soda or sodium hypochlorite. The quality of the infiltrate, which is the raw material for obtaining the above products, changes over time, which significantly affects the purification process (Wijesekara, 2014).

AEROBIC METHODS OF REDUCING INFILTRATES

The aerobic methods of biological purification of infiltrates have a number of indisputable advantages over the anaerobic ones: they are flexible in use, quickly enter a stationary mode of operation, as well as quickly adapt to the variable composition and consumption of infiltrates. Aerobic reactors are much simpler in design and much cheaper than anaerobic ones, and they are also much easier to automate and operate.

In the work of Robinson H.D., Grantham G. presents the results of successful application of a natural aerated lagoon for cleaning the infiltrates of the Bryn Posteg landfill (Wales), the operation of which began in 1982. During 30 months of continuous operation (from July 1983 to January 1986), about 26,000 m^3 of infiltrates were cleared in the aerated lagoon, which is an average of 900 m^3/month or 30 m^3/day. The maximum daily influx of infiltrate was 150 m^3/day (Nagarajan, 2012).

The volume of the aerated lagoon was 1000 m^3. The bottom and walls of the lagoon were covered with a waterproof membrane made of low-pressure polyethylene (pent). The lagoon was equipped with two floating surface aerators with a capacity of 11 kW each. The period of purification of infiltrates in the aerated lagoon was usually at least 10 days, the process was carried out almost completely in automatic mode (Akinbile, 2011).

The wastewater treated in the aerated lagoon by an automated sewage pumping station (CNS) was reassembled into the sewer through a 3 km long pressure pipeline and then delivered to the small rural municipal wastewater treatment plants Llanidloes. After joint treatment with domestic wastewater, the return water was discharged into the Severn Powys River (a small river of a fishery type of water use inhabited by salmon) (Kanmani, 2013). For 30 months of operation, the average value of BSC5 infiltrates at the entrance was 3700 mg O_2/dm^3, while purified infiltrates − 18 mg O_2/dm^3, that is, the average effect of purification of infiltrates according to BSC5 was 99.5%. The maximum values of BSC5 in the input infiltrates reached 10,000 mg of O_2/dm^3, and at the output rarely exceeded 50 mg of O_2/dm^3, which also corresponds to a 99.5% purification effect.

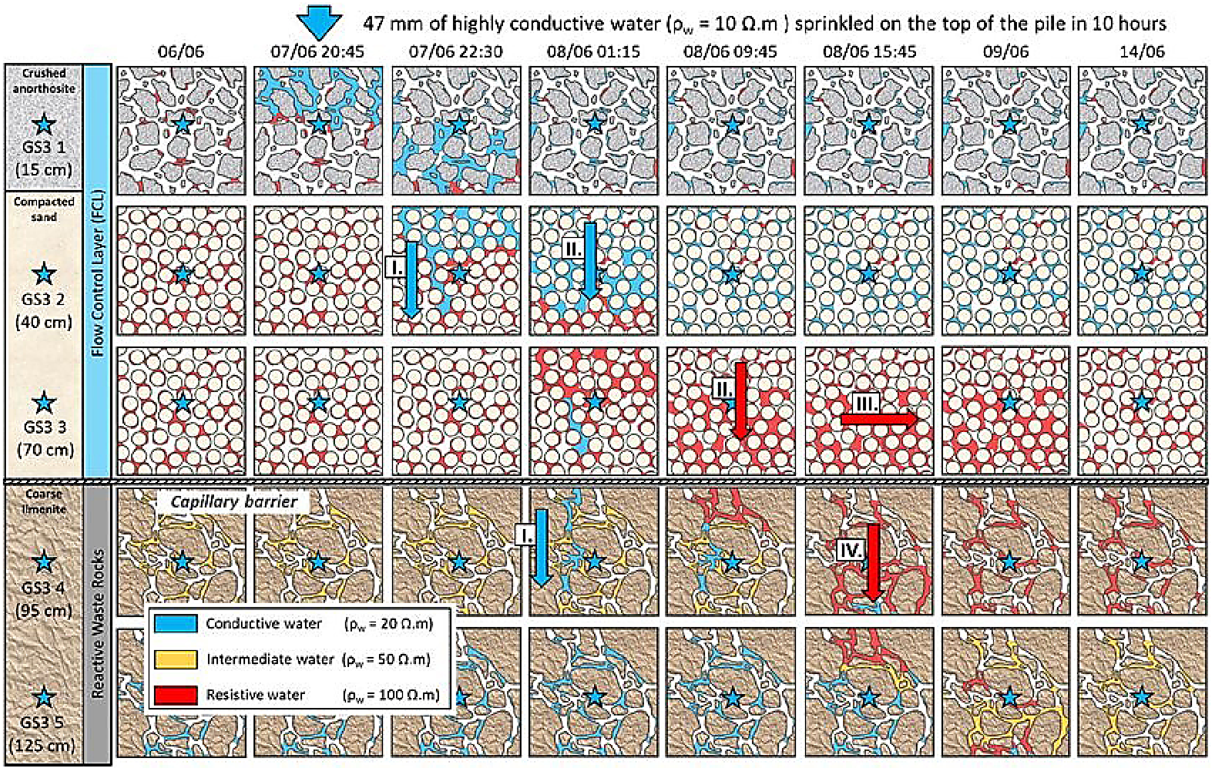

Figure 1. Conceptual model of water infiltration

The HSC of infiltrates at the entrance of the aerobic lagoon averaged 5500 mg of O_2/DM^3, with maximum values in the summer months up to 15–20 g of O_2/dm^3. The average value of HSC at the output of 153 mg O_2/dm^3 was obtained, i.e. the effect of HSC purification exceeded 97%. The average content of ammonium nitrogen in the incoming infiltrate during the study period was 130 mg/dm^3, during the summer months − in the range of about 400–500 mg/dm^3, and the maximum value was 600 mg/dm^3. At the exit of the aerated lagoon, an average value of ammonium nitrogen concentration of 9.4 mg/dm^3 over 30 months was obtained (the average purification effect is 92.8%). As a result of purification in the aerated lagoon, consistently high rates of removal of iron and manganese ions were also achieved. The average concentration of iron ions in the infiltrate was 242 mg/dm^3, and after purification it decreased to 3.2 mg/dm^3, i.e. by 98.7%. For manganese ions, a decrease in the average concentration was obtained by 94.0%: from 40 mg/dm^3 to 2.4 mg/dm^3 (Abdel-Shafy, 2018).

Among toxic heavy metals, only zinc ions with an average concentration of 4.9 mg/dm^3 were found in significant amounts in polygon infiltrates. In the purified infiltrate, the concentration of zinc ions averaged 0.2 mg/dm^3, which corresponds to a 95.9% purification effect.

The temperature of the infiltrate in the aerated lagoon varied from 0-7 in winter to 5–15 in spring and autumn, as well as up to 15–22 about in summer. The lagoon even froze and the ice thickness was several inches, but within 2–3 weeks after the ice melted, it again showed a high quality of cleaning the Infiltrate (Abedin, 2015).

A typical example of using aerated lagoons to clean up "old" infiltrates is the Bell House landfill treatment plant (England), which was put into operation in 1995. The results of a systematic study of the parameters of this station operation for the period from May 1999 to December 2000 are given in the work (Ganesh, 2013). Cleaning took place in four series-connected aerated lagoons with a total volume of 254 m^3, the bottoms and walls of which were covered with foam. Infiltrate aeration was performed for 4–6 hours a day using blowers and aeration pipes laid near the bottom of lagoons (Ferronato, 2019).

The flow of infiltrate to the treatment plant varied in a very wide range − from 1.0 m^3/day to 22.1 m^3/day, and on average amounted to about 11 m^3/day. Accordingly, the time of hydraulic retention of infiltrates in the complex of four lagoons varied from 254 days to 11.5 days, and on average amounted to 23 days. The average temperature of the infiltrates during the study corresponded to the air temperature and was 13.5 °C, while the

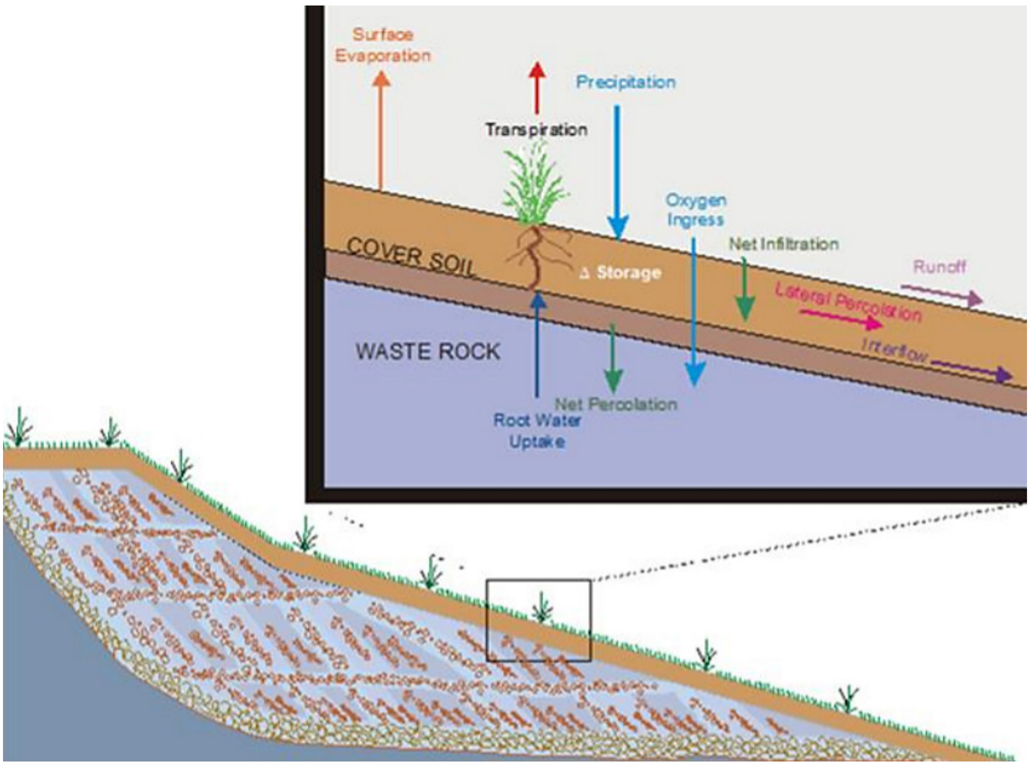

Figure 2. Conceptual scheme of a waste-dump coverage and its hydrogeology

average temperature of the "raw" infiltrate before feeding to Lagoon No. 1 was noticeably higher − 16.7 °C (Hossain, 2018).

The value of HSC infiltrates at the entrance to the lagoon system during the observation period varied in the range from 800 to 3400 mg of O_2/dm^3; the average value of HSC was 1740 mg of O_2/dm^3. After the first Lagoon, an average HSC of 620 mg of O_2/dm^3 was obtained; after 2-4 lagoons, 510, 492, and 426 mg of O_2/dm^3 were obtained, respectively (Idris, 2004). Thus, the total effect of HSC purification, expressed as a percentage of its input value, was: after the first lagoon − 64.4%, after two stages − 70.7%, after three − 71.7%, after all four stages − 75.5%.

The average concentration of ammonium nitrogen in the Bell House Polygon infiltrates obtained during the study period was 965.2 mg/dm^3. After lagoon No. 1, the average concentration of ammonium nitrogen was 185.1 mg/dm^3, and at the exit of lagoons No. 2−No. 4 − 25.5; 4.0 and 9.3 mg/dm^3, respectively (Jerie, 2016). Thus, the total effect of the ammonium nitrogen removal after each of the four lagoons was 80.8%, 97.4%, 99.6% and 99.0%, respectively.

Considering that the volume of Lagoon No. 1 was 80 m^3 [69], and the average time of hydraulic retention of infiltrates in it is 7.3 days, the corresponding effects of cleaning infiltrates according to HSC (64.4%) and ammonium nitrogen (80.8%) are very high due to the relatively small volume of the structure and, accordingly, low operating costs.

The experience of using biological methods for cleaning infiltrates under the cold climatic conditions of Norway is described in the work (Kaza, 2018). Statistics are informative that as of 1995, out of 365 Norwegian solid waste landfills, 35 simply dumped "raw", untreated infiltrate into sewer networks, and less than 10 landfills used biological treatment systems. (Kaza, 2018) describes in detail the operation of the esval treatment park biological infiltrate treatment plant, which receives infiltrates from the Esval MSW landfill with a total area of 5 hectares, located 50 km northeast of Oslo. The average January temperature in this area is –7 °C, the average annual depth of the precipitation layer is 800 mm. The landfill has been receiving both domestic and industrial solid waste and sediments from septic tanks since 1972.

In (Maqbool, 2011), the results of determining the qualitative composition of infiltrates in the period from June to December 1993 were presented (the number of definitions is 10 PCs.). The average HSC value of the" raw " infiltrate was 1260 mg O_2/dm^3, after the anaerobic stage this indicator decreased on average to 1180 mg O_2/dm^3, and after the aerated lagoon − to 380 mg O_2/dm^3. Thus, the average effect of HSC infiltrate purification in the aerated lagoon alone was 67.8 %. At the exit of artificial urine of the 2nd degree, HSC averaged 140 mg of O_2/dm^3. The overall effect of 4 − stage HSC cleaning is 88.9%.

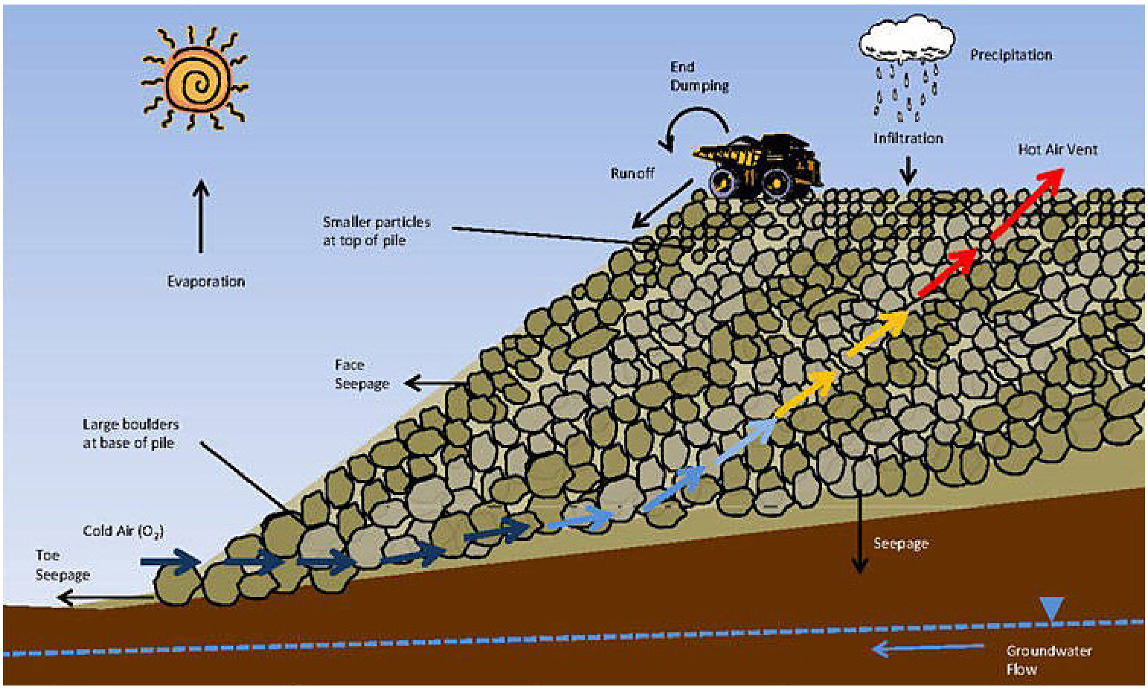

Figure 3. Waste dump scheme

Biological oxygen consumption for 7 days (BSC7) decreased from 300 mg of O_2/dm^3 in the incoming infiltrate to 260 mg of O_2/dm^3 after the anaerobic stage, 48 mg of O_2/dm^3 after the aerated lagoon, and 25 mg of O_2/dm^3 at the outlet of the treatment plant (Moqbel, 2009). Consequently, the average effect of BSC7 infiltrate purification in the aerated lagoon alone was 81.5%. The overall reduction in BSC7 as a result of 4-stage cleaning is 91.7%.

The sediment in the aerated lagoon was separated in its quiet starting part. It was planned that the sediment from the lagoon would be removed periodically, once every 5–10 years, provided that a certain maximum permissible level was reached.

From the analysis of the results of previous field studies, it can be concluded that cleaning infiltrates in an aerated lagoon (or lagoons connected in series) is a simple, low-cost and fairly effective method of pre-cleaning infiltrates. At all three considered treatment plants, using biological treatment under aerobic conditions, the values of the main indicators of organic contamination in infiltrates (HSK, BSK5, ammonium nitrogen) were achieved below the corresponding limit norms (GN) for discharge into the city sewer system of Moscow.

The analysis shows the prospects of using the method of aerobic pretreatment of infiltrates of the Moscow solid waste landfill. At the same time, for the successful implementation of this method of preliminary cleaning, it is necessary to develop an appropriate scientifically based technological scheme for cleaning, taking into account the characteristics of the composition of infiltrates of the Moscow solid waste landfill, as well as the value of the design volume consumption of infiltrate that will be received for cleaning.

Laboratory data indicate that the infiltrate that accumulates at the foot of the landfill is an aqueous solution of a complex chemical composition. The composition of the infiltrate mainly determines the ecological state of surface and underground water in the landfill impact zone. The color of the infiltrate is dark brown, it has a sharp unpleasant smell, a large amount (6-8 mg / dm^3) of suspended solids, and an extremely high content of organic substances (BSK5 – 7840 mgO^2/dm^3), nitrates (10583 mg/dm^3), chlorine (5000–8000 mg/dm^3). The infiltrate is also characterized by a high concentration of many heavy metals: lead (55 MPC), cadmium (38 MPC), manganese (3 MPC), chromium (2.4 MPC) and others. Its extremely unsatisfactory sanitary and microbiological state is also characteristic (LCP index-2.4·105 CFU/dm^3, E – coli index-2.4·105 CFU/dm^3, coli – phages-1.6·104 buo/dm^3 (Ripetskii, 2018).

Within the framework of the agreement No. 16 d/w/1188 "conducting research on the impact of the urban solid waste landfill on soil pollution, air basin, surface and underground water, vegetation cover, etc. around the urban solid waste landfill and in the adjacent territories", which was carried out by the National University "Moscow Polytechnic" in 2018, the physical and chemical

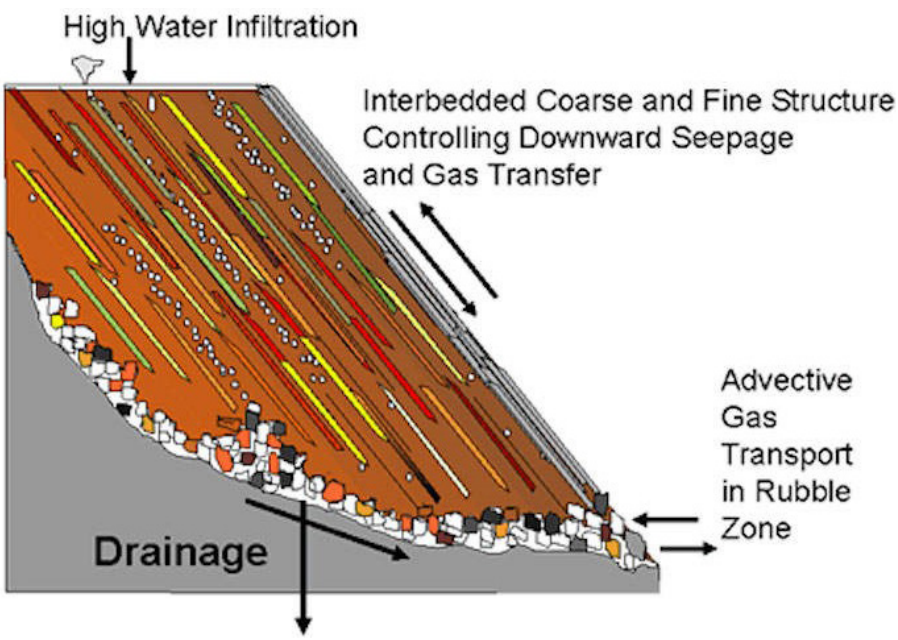

Figure 4. Water infiltration system and drainage

Table 1. Concentration of pollutants in infiltrates of the Moscow solid waste landfill

№	Indicator	Content, kg/m^3		
		Pond storage #1	Pond storage #2	Pond storage #3
1.	Dry residue	21	17	14.8
2.	Magnesium	4	4.6	6.2
3.	Chlorides	12	11.6	8.8
4.	Phosphates	213	84	62
5.	Ammonium nitrogen	565.5	275	240
6.	Nitrate nitrogen	2.6	2.5	2.3
7.	Petroleum products	171	119.7	133.3
8.	BSK5	419.3	315	233
9.	HSK	300	279	293
10.	Phenols	7330	5130	5940
Heavy metals				
11.	Iron	3.5	3.5	3.5
12.	Lead	3.7	2.6	2.8
13.	Nickel	1.7	1.3	1.4
14.	Chrome	13.6	6.6	9.4
15.	Cadmium	32	23	25

composition of the infiltrate was studied. For this purpose, the infiltrate samples were taken from existing storage ponds No. 1–3 at that time. Analysis of the results of chemical analysis of infiltrates indicated that the infiltrates contain phenols, petroleum products, heavy metals, chlorides, phosphates, etc. in the concentrations significantly higher than the maximum permissible for water bodies (Table 1).

Oxidation of organic substances on CBS is carried out due to the vital activity of aerobic organisms, which form accumulations in the form of plates (activated sludge). Compared to the natural biotope, aeration tanks have a relatively lower diversity of species of organisms due to the high concentration of pollutants in wastewater (Ripetskiy, 2018). The fauna of activated sludge, provided that there are no violations of the technological regime of purification, is characterized by mass development. The predominant group is ciliates, especially circular ones, and one of the reasons for this is the closed cycle of activated sludge along with peritrichs attached to it (Gurevich, 2018). The species diversity of the AM biocenosis is specific and depends on the quality of runoff and the operating mode of the OS (Dyachkova, 2020).

Activated sludge (AM) is a biocenosis of mineralizing organisms that can SORB organic substances of wastewater on their surface and oxidize them in the presence of oxygen. Activated sludge is a complex ecological system, the organisms of which are located at different trophic levels. The population of activated sludge microorganisms depends on the composition of wastewater and the conditions of aerobic oxidation (Urakov, 2020).

Various physical and chemical conditions are formed in different types of wastewater treatment plants, as a result of which different groups of organisms develop in them (Portnova, 2020).

In addition to the physiological groups in the bacterial composition of activated sludge, ecological groups are distinguished; each unites the microorganisms that exist in a certain temperature range and at certain concentrations of dissolved oxygen. Active silt develops microorganisms of all three temperature groups, i.e. psychrophilic, mesophilic and thermophilic, but facultative psychrophils and mesophiles dominate. Under the conditions of sufficient oxygen concentration, aerobes predominate in the active sludge, but facultative anaerobes are also common along with them. Obligate anaerobes are also found in the active sludge, the existence of which is possible in microzones with low oxygen content or complete absence thereof. Such microzones can occur inside activated sludge flakes as their size and density increase. Changes in the temperature and oxygen regimes in the aeration tank lead to the changes in the relations between organisms of different ecological groups (Urakov, 2020).

Since only the biont organisms adapted to cyclic changes in saprobic conditions (which is associated with the recirculation of activated sludge) can develop intensively in the aeration tank, the ecosystem of the structure will be characterized by an almost complete absence of organisms with an autotrophic type of nutrition. In addition, the development of photosynthetic algae will be hindered by the lack of light in the activated sludge thickness due to the high concentration of the latter.

In the pH range of 4–9, activated sludge flakes carry a negative charge; they have a developed surface and a high adsorption capacity. The mechanism of flake formation is related to the development of bacterial colonies. The bulk of extracellular polymers consists of polysaccharides and proteins. In the process of wastewater treatment, the intensive accumulation of polymers by bacteria occurs in the phase of endogenous respiration: first, cells oxidize spare substances, then cellular lipids, carbohydrates, and proteins. In mixed cultures, flakes are formed more intensively. The structure of silt flakes changes with the mass development of filamentous bacteria and some fungi in the active silt. Flakes increase in size and become loose. This phenomenon is called "activated sludge swelling". Swelling occurs with an excess of carbohydrates in wastewater or a lack of biogenic elements with insufficient aeration. Swollen silt is removed from secondary settling tanks, impairing the quality of treated water. Swollen silt also has useful properties. The active surface of such silt is larger than that of ordinary silt and it better removes organic pollutants from wastewater. Moreover, the need for nitrogen and phosphorus in filamentous bacteria is significantly lower than in ordinary bacteria, so it is advantageous to use such silt for wastewater treatment with an insufficient amount of biogenic elements (Bespalova, 2018).

Organic or ash-free substance of activated sludge consists of proteins, fats, carbohydrates (from oxygen, nitrogen, hydrogen, carbon). The ratio of these elements depends on the composition of the treated wastewater and the technological mode of treatment. For the silt of urban treatment plants, the ash content is 25–30%. Compared to cellular matter, the contents of iron and silicon in silt increase. After hard water purification, the sludge mass contains insoluble calcium phosphate, which increases the mass density and ash content of the activated sludge.

CONCLUSIONS

For static studies, a mixture of wastewater and activated sludge was delivered to the research site. The infiltrate in the amount of 1 m^3 was taken from the storage pond No. 5 of the solid waste landfill and delivered to Kos at the location of the experimental installation. A mixture of wastewater and activated sludge was poured into the experimental aeration plant and the calculated amount of infiltrate was added to obtain the mixtures corresponding to such dilution multiplicities: 10; 500; 1000; 1250; 1500. A mixture of wastewater and activated sludge was added to the reactor until a total volume of 1.64 m^3 was obtained. After that, the samples were taken for chemical analysis and the unit was turned on. Each cycle of studies in static mode lasted 6 hours. At the end of the air supply, a sample of the infiltrate mixture with wastewater and activated sludge with a volume of 1.5 dm^3 was taken for a chemical analysis.

The article described the characteristics of the landfill, the infiltrate of which was used for research, and the study of environmental hazards in the zone of influence of which was the purpose of monitoring studies. The general characteristics of the materials used in the research, i.e. infiltrate and activated sludge of CBS, were given. The method of monitoring studies was described in detail, involving the method of sampling and the algorithm for visualizing data for monitoring hydrosphere pollution in the landfill impact zone.

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