Наведено результати досліджень двостадійної технології очищення фільтратів звалищ твердих побутових відходів в аерованих лагунах та на міських каналізаційних очисних спорудах. Для другої стадії досліджено вплив кратності розбавлення фільтратів міськими каналізаційними стоками на ступінь та стабільність очищення

Ключові слова: фільтрат звалищ твердих побутових відходів, аерована лагуна, біологічне очищення, іммобілізація біоценозу

Приведены результаты исследований двухстадийной технологии очистки фильтратов свалок твердых бытовых отходов в аэрированных лагунах и на городских канализационных очистных сооружениях. Для второй стадии исследовано влияние кратности разбавления фильтратов городскими канализационными стоками на степень и стабильность очистки

Ключевые слова: фильтрат свалок твердых бытовых отходов, аэрированная лагуна, биологическая очистка, иммобилизация биоценоза

UDC 628.316:628.356

DOI: 10.15587/1729-4061.2018.122425

TWO-STAGE TREATMENT OF SOLID WASTE LEACHATES IN AERATED LAGOONS AND AT MUNICIPAL WASTEWATER TREATMENT PLANTS

M. Malovanyy
Doctor of Technical Sciences, Professor, Head of Department*
E-mail: mmal@lp.edu.ua

V. Zhuk
PhD, Associate Professor
Department of Hydraulics and Sanitary Engineering**
E-mail: zhuk_vm@ukr.net

V. Sliusar
PhD, Engineer*
E-mail: virashandrovych@ukr.net

A. Sereda
Postgraduate student*
E-mail: seredaa92@gmail.com

*Department of Ecology and Sustainable Environmental Management**
**Lviv Polytechnic National University
S. Bandery str., 12, Lviv, Ukraine, 79013

1. Introduction

The problem of treatment leachate of municipal solid waste (MSW) dumps and MSW landfills exists throughout the periods of design, operation and planned closure of these facilities. It should be noted that most of the MSW storage facilities in Ukraine are essentially dumps, not landfills. Unlike the MSW dumps, MSW landfills are engineering structures. They are equipped with a protective anti-filtering screen, leachate and biogas collection and disposal systems, a system of technical and biological remediation of garbage-filled land lots, a system of collection and removal of conditionally clean atmospheric water. In most cases, all these systems (or most of them) are absent at Ukrainian sites of MSW collection.

At the stage of designing up-to-date MSW landfills, an innovative technology of treatment of leachate collected by drainage systems is used. Productivity of this technology corresponds to the design productivity. During operation, priorities in choosing a leachate treatment system depend on the history of operation and the technical state of the leachate collection system. The problem consists in the choice of a leachate treatment system at the stage of closing the MSW dumps for which the often uncontrolled leakage of filtrates has led to their significant accumulation in storage ponds. The problem is especially acute for Ukraine, because of a large number of the MSW dumps that require their closure for a long time.

Efficiency of treatment of such leachates was studied using the Hrybovytsky (Lviv, Ukraine) MSW dump as an object of leachate study. Leachate of the Hrybovytsky MSW dump is formed in the garbage body as a result of infiltration of atmospheric precipitation, run out of groundwater at the sides of ravines and as a result of complex biochemical processes of decomposition of the organic part of the garbage.

The problem of depositing leachate of the Hrybovytsky MSW dump is complicated by the following factors:

– existence of large volumes of leachate (about 100,000 m^3) because of its accumulation in six storage ponds for a considerable period of time;

– necessity of to dispose of leachate in a relatively short time because of the acute need to free up the areas occupied by the leachate storage ponds. The ponds are located in the zone of leveling the land slope for the planned technical remediation of the land under the Hrybovytsky dump.

In solving the problem of eliminating the ecological danger caused by leachate of the Hrybovytsky dump, two stages should be distinguished:

1. Treatment of the accumulated leachate to enable realization of the project of remediation of the land occupied by the MSW dump.

2. Treatment of the leachate which will be formed in the body of the MSW dump for decades after land remediation

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as a result of biological processes of decomposition of the organic garbage component.

These stages fundamentally differ in terms of volumetric flow rate of the leachate that will come for treatment, physicochemical characteristics and the stage duration. It is ineffective to envisage the same technology for realization of both stages. The reasons for this are technological (impossibility to provide full loading of equipment and its efficient operation) and financial (significant over-expenditure) aspects. A similar situation is observed at other MSW dumps in Ukraine which require land remediation.

Therefore, development of an effective energy- and resource-saving technology for treatment of leachate of MSW dumps and landfills is an urgent task. As a result of introduction of such technology, the danger of environment pollution with leachate will be decreased and the conditions for remediation of the land occupied by MSW dumps will be created.

2. Literature review and problem statement

An overview of the most promising technologies recommended in Ukraine [1] and widely tested abroad was made to select an optimal strategy for minimizing environmental hazard of the Hrybovytsky MSW dump.

Wide application of leachate treatment by the technology of reverse osmosis [2] to treat leachates of MSW landfills collected by drainage systems is observed worldwide. This technology ensures a high degree of treatment. The treated leachate can be disposed in the surface water basins and the resulting concentrate (about 10–20 %) is returned to the body of the dump. Disadvantage of this technology is significant capital costs for setting in operation of the unit and operating costs to ensure its functioning. Hence application of this method is promising for treatment of constant leachate flows from the dump body. Use of this technology to treat large leachate volumes accumulated in storage ponds is unprofitable and inefficient.

As early as the 1990s, there was information on the prospects of electric-plasma treatment of leachate [3, 4]. The technology was characterized as attractive both for the cost of implementation and for the quality of treatment. However, because of its technological complexity, this technology has not yet found a broad industrial application.

The technologies of evaporation and drying as well as chemical binding of leachates require evaporation of large amounts of water. As they require significant energy costs, these technologies are unacceptable for processing large volumes of leachates accumulated in storage ponds of the MSW dumps.

Anaerobic treatment of leachates is a promising technology [5] as the treatment process is accompanied by an additional biogas production. Authors of work [6] have shown a promising use of successive anaerobic (UASB reactor) and aerobic (aerated lagoon) stages of leachate treatment. It was established that the total degree of treatment in such a system from ammonia nitrogen after the aerobic stage can reach 99.6 % and the degree of reduction of COD is 66–94 % (57–87 % after anaerobic stage and 35–70 % after an aerated lagoon). However, a significant disadvantage of the anaerobic process of leachate treatment is sensitivity to changes in temperature and pH as well as to various toxic substances contained in leachates [7, 8]. Under the conditions of an alternating chemical composition of leachate which differs for different storage ponds of the Hrybovytsky MSW dump, industrial realization of this technology is problematic in its realization.

Authors of [9] suggest a comparative assessment of various methods for implementation of anaerobic and aerobic technologies of leachate treatment (UASB technology, ASBR technology, MBBR technology, MBR technology, aerated lagoon). According to this analysis, the largest (95 %) removal of COD from dump leachates was achieved in aerated lagoons.

Application of sorption technologies using natural sorbents or sorbents prepared from vegetable raw materials can be promising for treatment of leachates from heavy metals [10].

In our opinion, based on the above analysis, the treatment technology in an aerobic medium under the conditions of aerated lagoons [11–15] is the most promising for treatment of the Hrybovytsky dump leachate. Analysis of the known information on its industrial application abroad suggests that this technology can be effectively applied at the first (preliminary) stage of treatment of the Hrybovytsky dump leachates. After preliminary treatment, the leachates can be sent to municipal wastewater treatment plants (WWTP) for additional purification. Before sending to the WWTP, it is expedient to dilute the filtrates with municipal sewage at a ratio which would ensure stable operation of the city WWTP.

Authors of [11, 12] point out the prospects of application of aerobic methods in treatment of MSW landfill leachates. Microbial communities present in sewage treatment systems are well adapted to the destruction of complex organic compounds in a wide range of waste flows. Aerobic biocenosis can be activated in the systems for treating MSW landfill leachates, and treatment with its help has a number of advantages over the anaerobic systems. These advantages include low cost of construction of sewage treatment plants, flexibility of their operation, ability to quickly change treatment modes, easy start-up of the units, ease of maintenance and convenience for automation. One of the most technically simple methods of aerobic treatment of the MSW landfill leachates is establishing the aerated lagoons equipped with mechanical, pneumatic or jet aerators. Treatment proceeds by chemical and biological oxidation. For implementation of the method of aerated lagoon on an industrial scale, it is necessary to previously establish the necessary time of the leachate staying in the lagoon and the intensity of aeration in an experimental way [12].

Work [13] shows the results of successful use of an aerated lagoon for treatment of leachates of the Bryn Posteg (Wales) MSW landfill launched in 1982. From July 1983 until January 1986, the 1,000 m^3 volume aeration lagoon treated about 26,000 m^3 leachates which averaged 900 m^3/month or 30 m^3/day. Maximum daily influx of leachate was 150 m^3. The bottom and walls of the lagoon were covered with a waterproof polyethylene membrane. The lagoon was equipped with two floating surface aerators of 11 kW each. The period of leachate treatment in the aerated lagoon was, as a rule, not less than 10 days, the process was carried out almost in a completely automatic mode [13]. Sewage treated in the aerated lagoon was re-pumped by an automated sewage pumping station (SPS) in a 3-km long pressure pipeline into the sewer collector and then arrived at small rural Llanidloes WWTP. After joint treatment with household wastewater, the backwater was discharged into the Severn Poway's River of a fishery type of water usage in which salmon is bred.

As a typical example of use of aerated lagoons for treatment of "old" leachates, treatment station of the Bell House, England, MSW landfill put into operation in 1995 may be mentioned. The results of systematic study of parameters of this station during the period from May 1999 to December 2000 are given in [14]. The treatment process proceeded in four consecutively connected aeration lagoons with a total volume of 254 m^3. The leachate was aerated for 4–6 hours a day with the help of blowers and aeration pipes laid on the lagoon bottom. The leachate flow to the treatment station varied in a very wide range of 1.0 m^3 to 22.1 m^3/day or about 11 m^3/day on average. Accordingly, the time of hydraulic holding of leachate in the complex of four lagoons varied from 254 days to 11.5 days or 23 days on average. The average leachate temperature during the study period corresponded to the air temperature and was 13.5 °C while the average temperature of the "raw" leachate before its feeding to the lagoon No. 1 was markedly higher: 16.7 °C [14]. The value of the leachate COD at the entrance to the lagoon system during the observation period varied in the range from 800 to 3,400 mg O_2/dm^3. The total effect of treatment for COD expressed as a percentage of its input value was 75.5 %. The average concentration of ammonium nitrogen in the leachates of the Bell House MSW landfill obtained during the study period was 965 mg/dm^3, the total effect of removing ammonium nitrogen was 99.0 %. For 30 months, the average value of BOD_5 for the leachates at the entrance was 3,700 mg O_2/dm^3 while it was 18 mg O_2/dm^3 for the purified leachate that is, the average effect of filtrate treatment for BOD_5 was 99.5 %. The COD of leachates at the entrance to the aerobic lagoon averaged 5,500 mg O_2/dm^3 with maximum values in the summer months up to 15–20 g O_2/dm^3. Average value of COD at the exit of 153 mg O_2/dm^3 was obtained. That is, the effect of treatment for COD exceeded 97 %. The average content of ammonium nitrogen in the entering leachate was 130 mg/dm^3 during the study period, in the range of 400–500 mg/dm^3 in the summer months and the maximum value was 600 mg/dm^3. The leachate temperature in the aerated lagoon varied from 0–7 °C in winter to 5–15 °C in spring and autumn and to 15–22 °C in summer. The lagoon even froze and thickness of ice was several inches but a high quality of the leachate treatment was obtained already in 2–3 weeks after melting of ice. In general, authors of [14] stated that the aerated lagoon worked effectively even at low leachate temperatures. Humidity of the sediment resulting from treatment varied in the range of 96.5 to 97.35 %.

The experience of using biological methods for leachate treatment in cold climatic conditions of Norway is described in [15]. Informative is the statistics that as of 1995, 35 out of 365 Norwegian MSW landfills simply dropped "crude", not treated leachate, into sewage networks and less than 10 MSW landfills used biological treatment systems. Work [15] describes in detail the study of operation of the Esval Treatment Park biological treatment station which takes leachate from the Esval MSW landfill of 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 height of the precipitation layer is 800 mm. The Esval Treatment Park treatment plant put in operation in 1993 includes 4 stages of biological leachate treatment:

1) anaerobic treatment in a 400 m^3 tank;
2) treatment in a 4,000 m^3 aerated lagoon;
3) treatment on two parallel artificial filter wetlands with an area of 400 m^2 each;
4) treatment in an artificial filter wetlands with a free surface area of 2,000 m^2.

The volumetric flow rate of the leachate coming for treatment varied from 30 to 300 m^3/day at an average value of 120 m^3/day. Thus, the average hydraulic retention time of leachate in the aerated lagoon was 33 days. The leachate was saturated with air with the help of three floating aspiration propeller aerating mixers of AIRE-O2 type of 2.6 kW each [15]. The average COD of the "raw" leachate was 1,260 mg O_2/dm^3. This indicator decreased to an average of 1,180 mg O_2/dm^3 after the anaerobic stage and up to 380 mg O_2/m^3 after the aerated lagoon.

From the analysis of the results of field studies, it can be concluded that treatment of leachate in an aerated lagoon (or in sequentially connected lagoons) is a simple, low-cost and sufficiently effective method of preliminary leachate treatment. The achieved degree of leachate treatment [13–15] is acceptable for further treatment at municipal wastewater treatment plants.

3. The aim and objectives of the study

This study objective was to establish features of implementation of the technology of two-stage treatment of the MSW dump leachates. The first stage is preliminary treatment in aerated lagoons and the second stage is the additional treatment at WWTP.

To achieve this objective, the following tasks had to be solved:

– determine the nature of variation of concentration of dissolved oxygen and pH in the process of biological aerobic treatment of leachates of the Lviv MSW dump from pollutants;

– determine in a dynamic mode the effect of time of holding in the reactor and temperature on kinetics of biological aerobic treatment of the Lviv MSW dump leachates;

– investigate in a static mode the effect of ratio of dilution of leachate with municipal sewage on kinetics of treatment of leachate at municipal WWTP;

– investigate in a dynamic mode stability of observance of treatment indicators in time in the process of treatment of leachates at municipal WWTP.

4. Materials and methods used in the study

4. 1. Simulation of preliminary treatment of leachates of MSW dumps in an aerated lagoon

Aerobic treatment studies were carried out under laboratory conditions with the help of the unit (Fig. 1) which simulated conditions of the aerated lagoon, according to the following procedure [16]. A flask was filled with the filtrate of the Hrybovytsky MSW dump taken from the storage pond in an amount of 4 liters. Air was blown to the lower part of the flask with the help of laboratory aerator at a flow of $4.2 \cdot 10^{-5}$ m^3/s. Initial parameters of the leachate: concentration of dissolved oxygen (C_{DO}): 1.87 mg/dm^3; pH: 8.64; concentration of ammonium ions: 900 mg/dm^3; chemical consumption of oxygen: 11,000 mg O_2/dm^3.

Concentration of dissolved oxygen was measured by a portable oxygen sensor *sens*Ion6™, Canada, concentration of ammonium nitrogen was determined photometrically by the procedure of [17]. To determine chemical oxygen demand, a known method was used [18], pH was determined potentiometrically using a portable pH/ISE/mB/°C meter of *sens*Ion™2 brand, Canada.

Fig. 1. Scheme of the experimental unit used in the study of aerobic treatment of leachate

The leachate was aerated in a continuous mode. The studies of leachate treatment in the static mode were conducted at a constant temperature of 20 °C. At the stage of the static mode, the maximum degree of leachate treatment was set which can be achieved in the process of aerobic biological oxidation under experimental conditions [16]. After a certain period of time, samples were taken and the above parameters were determined.

The studies in the dynamic mode were conducted at variable parameters depending on the purpose of a particular study series. In the course of studies in the dynamic mode, a definite portion of leachate was poured from the flask at certain intervals of time and replaced with the same portion of fresh leachate. The dynamic mode simulated treatment in situ conditions when fresh leachate is constantly fed into the aerated lagoon and the treated leachate is taken to the next stage of preliminary treatment. Each series of dynamic studies included adding of fresh leachate, taking off treated leachate, sampling and analysis of samples until constant values were achieved during three days and then the next mode was studied. Determination of dependence of the treatment efficiency on temperature is important for realizing the dynamic stage of treatment in real conditions. Therefore, the treatment modes were tested under thermostatically controlled conditions (13 °C, 20 °C and 30 °C).

The microscope of the MIN-8 model (St. Petersburg, Russia) was used for biocenosis studies. Specimens taken from the leachate treatment system after 15 days of treatment in the aerobic mode were photographed at ×900 magnification.

4. 2. Simulation of treatment of leachate from the MSW dump at the municipal WWTP

The study of the stage of additional treatment of the Hrybovytsky MSW dump leachate was carried out at an experimental pilot unit (Fig. 2) which was mounted at the Lviv wastewater treatment plant. The unit included a 1.2 m internal diameter aeration model reactor 1 made of polyethylene with a tubular aerator 2 installed at its bottom. Air was supplied from the existing compressor station. Concentration of dissolved oxygen was set the same as in the actual facility and controlled by a portable electronic oxygen meter. The air flow was regulated using the valve 3 on the supply pipeline. Leachate in an amount of 1 m^3 was taken from the storage pond No. 5 of the Hrybovytsky MSW dump and delivered to the Lviv WWTP were the experimental unit was located.

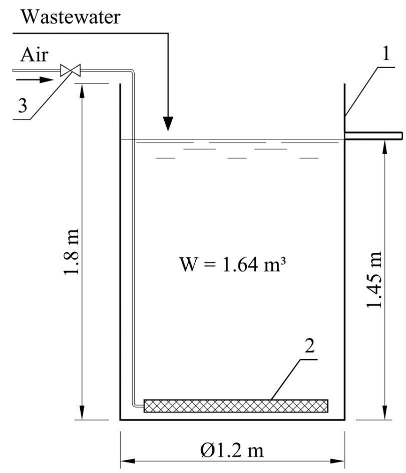

Fig. 2. Schematic view of the experimental unit for the study of additional treatment of the Hrybovytsky MSW dump leachate at the Lviv WWTP: model aeration reactor (1); tubular aerator (2); valve (3)

To start the unit, a mixture of sewage with activated sludge was delivered to the study site. This mixture was poured into the experimental aeration unit and a calculated amount of leachate was added to obtain mixtures corresponding to the following dilution degrees: 10; 500; 1,000; 1,250; 1,500. A mixture of sewage with activated sludge was added to the reactor until a total volume of 1.64 m^3 was obtained. After that, samples were taken for chemical analysis and the unit was switched on. Each cycle of static studies lasted for 6 hours. At the end of the air supply, a sample of the mixture of leachate with sewage and activated sludge in a volume of 1.5 dm^3 was taken for chemical analysis.

Treatment of the mixture of sewage with leachate was studied in a dynamic mode in the experimental aeration unit (Fig. 2) under constant aeration conditions. Two model primary setting tanks equipped with circulation pumps and control valves were connected by a pipeline system to the unit reactor. The primary model setting tank No. 1 was intended for the mixture of sewage with leachate, and the primary model setting tank No. 2 contained sewage without leachate. During eight day hours, the mixture of sewage and leachate was evenly added to the aeration unit from the tank No. 1. After 8 hours of feed of the sewage and leachate mixture, the process of the aeration tank operation was simulated for 16 hours without addition of leachate. The treated sewage from the experimental aeration unit was fed into the model secondary setting tank. Supply of sewage from the primary setting tanks was switched between the No. 1 and No. 2 tanks with the help of ball valves. Thus, operation of WWTP was simulated in real conditions: in the daytime when besides the municipal sewage, leachate was fed to them for additional treatment and at other times, when the sewage inflow was reduced and only municipal sewage was treated.

It should be noted that the above-described studies were carried out using the Hrybovytsky MSW dump leachate without any preliminary treatment. In the case of the implementation of the stage of additional treatment of leachate, indicators of the second stage of treatment should be significantly improved.

5. Composition of the Lviv MSW dump leachate

The average chemical composition of the Lviv MSW dump leachate is presented in Table 1. It should be noted that similar composition of leachate (with slight differences depending on local conditions) is characteristic for all Ukrainian MSW dumps.

Table 1

The average chemical composition of the Hrybovytsky MSW dump leachate

No.	Indicator name	Unit	Concentrations for the samples taken over different periods, mg/l				
			29.01.17	28.02.17	13.04.17	24.05.17	MPC
1	NH_4 (for N)	mg/dm^3	548.1	847.5	932.7	1,130.8	2
2	BOD_5	mg/dm^3	3,760	3,348	3,456	1,415	15
3	Suspended matter	mg/dm^3	3,011	2,587	2,019	2,845	-
4	Iron	mg/dm^3	10.7	14.3	14.3	13.1	0.3
5	Cadmium	mg/dm^3	0.005	0.041	0.038	0.047	0.001
6	Cobalt	mg/dm^3	0.028	0.140	0.184	0.227	0.1
7	Manganese	mg/dm^3	0.015	0.024	0.038	0.042	0.1
8	Nickel	mg/dm^3	0.09	0.12	0.13	0.13	0.1
9	Led	mg/dm^3	0.12	0.11	0.12	0.14	0.03
10	Strontium	mg/dm^3	0.022	0.034	0.036	0.048	7
11	Solid residual	mg/dm^3	15,245	14,875	14,322	13,483	-
12	Chlorides	mg/dm^3	3,900	4,368	5,213	4,715	350
13	COD	mg/dm^3	6,500	9,678	10,010	8,856	80

Note: MPC=maximum permissible concentrations

According to the presented data, almost all leachate ingredients exceeded the MPC. But the most dangerous (in the case of sending leachate to municipal wastewater treatment plants) was the content of ammonium nitrogen, BOD_5 and COD. The described studies were directed precisely to treatment from these contaminants.

Table 1 also indicates how leachate composition varied depending on the sampling time. Apparently, this was because of non-stationarity of the biodegradation processes, the varying degree of leachate dilution with atmospheric precipitations in the storage ponds, external temperature, variability of filtration flow parameters, etc.

6. The study results

Below is a summary of the results of a complex of studies, both those performed earlier [16] and those supplemented later with new data. The purpose of additional studies for the stage of preliminary treatment of leachate in aerated lagoons was to establish the type of microbiological culture enabling biological treatment of leachate, and the effect of temperature on efficiency of biological treatment of leachate in an aerated lagoon. For the stage of additional treatment of leachate at sewage treatment facilities, influence of leachate on stability of operation of these facilities and on the value of the sludge index for biocenose of wastewater treatment plant was investigated.

6. 1. The study of the static mode of preliminary treatment of leachate in an aerated lagoon

Fig. 3, 4 show interpretation of the data obtained in the studies of aerobic biological treatment in the static mode [16] in the experimental unit shown in Fig. 1. Results of microbiological analysis of biocenosis inactivated in the conditions of an aerated lagoon are presented in Fig. 5

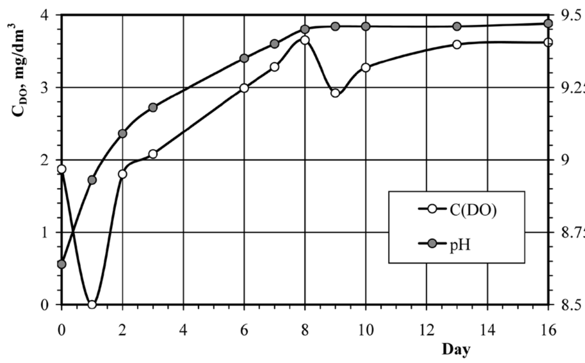

Fig. 3. Kinetics of changes in concentration of dissolved oxygen and pH in the static mode of biological treatment of the Hrybovytsky MSW dump leachate in aerobic conditions

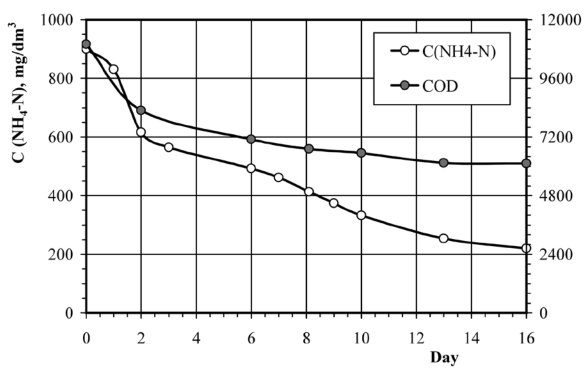

Fig. 4. Kinetics of aerobic biological treatment of leachate from ammonium ions and organic contaminants in the static mode

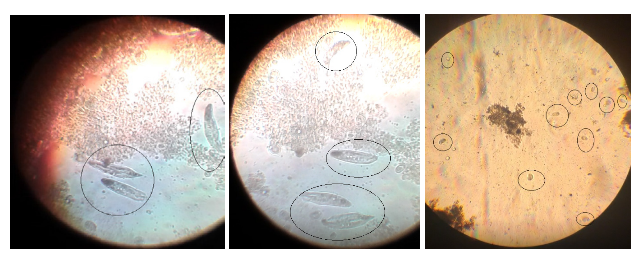

Fig. 5. Microorganisms detected in leachate after 16 days of aeration

6. 2. Investigation of a dynamic mode of preliminary treatment of leachate in a model aerated lagoon

The results of study of aerobic biological treatment in a dynamic mode in the experimental unit are shown in Table 2 [16].

Table 2

The results obtained in the study of aerobic biological treatment of leachate in a dynamic mode in the experimental unit [16]

Quantity of leachate pour off/refill, ml/day	Time of keeping in reactor, days	C (NH_4–N), mg/dm³	pH	C (DO), mg/dm³	COD, mg/dm³
250	16	583.09	9.38	3.90	5,534.7
350	11.5	585.47	9.42	3.87	5,536.4
400	10	584.19	9.37	3.91	5,535.2
500	8	615.81	9.21	3.95	5,487.1

Influence of the process temperature on kinetics of biological aerobic treatment of the Lviv MSW dump leachate in a dynamic mode was studied on the experimental unit (Fig. 1) according to the procedure described above. The flask-reactor was placed in thermostatic conditions where constant study temperature (13 °C, 20 °C, 30 °C) was maintained throughout the study period. As a criterion of influence of temperature on treatment dynamics, the change of relative concentration of ammonium nitrogen (N) in the filtrate was taken which was determined by formula

$$N = \frac{C(NH_4 - N)_{\text{fin}}}{C(NH_4 - N)_{\text{in}}}, \quad (1)$$

where $C(NH_4–N)_{in}$ and $C(NH_4–N)_{fin}$ are respectively initial and final concentrations of ammonium nitrogen in the leachate that is treated. Dependence of the change of relative concentration of ammonium nitrogen in leachate on the process temperature is presented in Fig. 6.

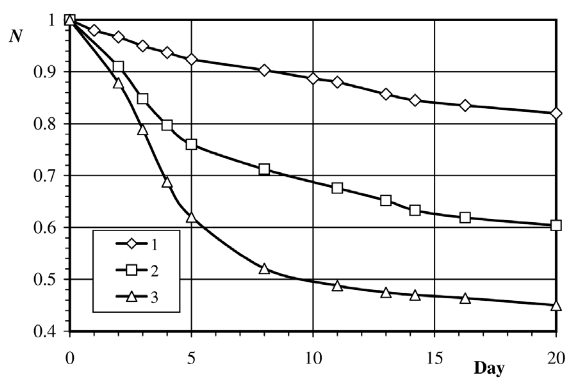

Fig. 6. Kinetics of the change of relative concentration of ammonium nitrogen in leachate vs. process temperature: 13 °C (1), 20 °C (2) and 30 °C (3)

6. 3. Study of the static mode of leachate treatment at the municipal WWTP

The values of input concentrations of ammonium nitrogen ions and the values of COD for various ratios of leachate dilution with municipal wastewater M (10; 500; 1,000; 1,250; 1,500) were established. Dependence of the effect of treatment of the sewage/leachate mixture from ammonium ions and the dynamics of reduction of contamination by COD on these ratios of dilution was investigated.

The treatment effects $E_{NH_4^+}$ and E_{COD} were determined by dependences (2) and (3):

$$E_{NH_4^+} = \frac{C(NH_4 - N)_{in} - (NH_4 - N)_{fin}}{C(NH_4 - N)_{in}} \cdot 100\,\%, \quad (2)$$

$$E_{COD} = \frac{(COD)_{in} - (COD)_{fin}}{(COD)_{in}} \cdot 100\,\%, \quad (3)$$

where $(COD)_{in}$ and $(COD)_{fin}$ are initial and final values of COD, respectively.

The dependence of the effects $E_{NH_4^+}$ and E_{COD} on the ratio of dilution found in the analysis of the studies of treatment of leachate in the static mode carried out at the municipal WWTP are shown in Fig. 7.

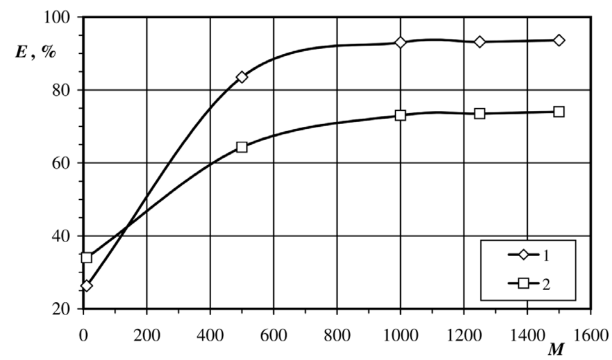

Fig. 7. Dependence of the effects of treatment of leachate and municipal sewage mixture from ammonium ions (1) and COD (2) on the ratios of leachate dilution ratio *M*

6. 4. Investigation of the dynamic mode of treatment of leachate at municipal WWTP

Stability of maintaining the treatment indicators in time in the process of leachate treatment at municipal WWTP in the dynamic mode was judged by variation of the sludge index and stability of the values of the effects of treatment from pollutants. The dynamics of setting of activated sludge in the process of long-term continuous treatment of a mixture of leachate and municipal sewage was investigated. Ratio of leachate dilution with municipal sewage M=500 was taken.

7. Discussion of the study results

7. 1. Analysis of the results of study of the stage of preliminary treatment of leachate in the aerated lagoon

Analysis of the results obtained in the studies of aerobic biological treatment in the static mode carried out on the experimental unit [16] shows that during the 16-day cycle, it was possible to achieve almost a 2-fold reduction in COD and more than a 3-fold decrease in concentration of ammonium ions. This is the maximum possible degree of treatment for the studied conditions. However, it is not feasible to set an objective of treatment to these maximum levels in real conditions because of significant material and energy costs involves. That is why it has become necessary to carry out the following studies of preliminary treatment of leachates in the aerated lagoon in a dynamic mode.

During the entire cycle of studies, the solution pH asymptotically increased from 8.64 to 9.47.

The microbiological analysis (Fig. 5) has shown that the leachate that was treated contained a wide spectrum of microbiological aerobic culture which differs from the culture of the activated sludge present at the municipal WWTP. Composition of this culture and the laws of its development require additional studies. Probably, the extrema of concentration of dissolved oxygen in the leachate (the 1st and the 9th day) are associated with the periods of inactivation of this biocenose.

Investigation of leachate treatment in the aerated lagoon showed that the optimum time of keeping the leachate in the reactor is 10 days. In this case, 35 % treatment of leachate from ammonium ions and 50 % reduction of COD was achieved. As the data given in Table 2 show, in the case of reducing the time of filtrate staying in the reactor to 8 days, efficiency of treatment from ammonium ions decreased to 31 % although the degree of purification for COD remained practically the same. Therefore, ultimately, the optimum time of the leachate staying in the reactor should be determined on the basis of a technoeconomic study of the leachate treatment technology as a whole.

As can be seen from Fig. 6, kinetics of variation of relative concentration of ammonium nitrogen in the leachate largely depends on the temperature of the process of biological aerobic treatment. Therefore, to implement the two-stage technology of the dump leachate treatment in aerated lagoons and at municipal WWTP, it is necessary to adjust the modes of implementation of individual processes depending on the ambient temperature. With the decrease in the ambient temperature, it is necessary either to increase the time of leachate staying in the aerated lagoon or increase the ratio of leachate dilution with municipal sewage.

7. 2. Analysis of the results obtained in the study of the stage of additional leachate treatment at municipal WWTP

Static studies have established that of all studied dilution ratios, concentration of ammonium nitrogen in the mixture exceeded the limit norm for discharge into the sewage system only in the case of leachate dilution ratio of M=10. Therefore, this ratio of dilution is unacceptable for the use in actual treatment processes.

As can be seen from Fig. 7, the maximum value of effect of treatment from both ammonium ions and COD is achieved at the value of the ratio of dilution of leachate with municipal sewage M=1,000. It should be noted that in the case of additional treatment of the previously treated leachate in the aerated lagoon, this dilution ratio will be even smaller. Therefore, multiplicity of dilution of leachate with municipal sewage in excess of M=1,000 is inappropriate in practice.

The studies of the stage of leachate treatment at municipal WWTP carried out in a dynamic mode have established that since the fourth day of study, the activated sludge settled more slowly and became homogeneous which gives grounds for concluding its partial suppression. However, the value of the sludge index until the end of the study did not exceed the limit permissible for operation of municipal wastewater treatment plants, i. e. 130 cm^3/g. Probably, a longer time is necessary for a full adaptation of the activated sludge biocenosis at the municipal WWTP. Besides, efficiency and stability of the process of additional treatment at municipal WWTP will improve significantly in the case of realization of the stage of previous leachate treatment in conditions of aerated lagoons.

In the process of realization of a dynamic mode of additional treatment, stability of the values of the effects of treatment from ammonium nitrogen and for COD was also observed. This indicates the possibility of efficient additional treatment of the MSW dump leachates at municipal wastewater treatment plants.

Thus, as a result of the studies, optimal parameters of fulfillment of all stages of the proposed technology were established. This will make it possible to predict fulfillment of industrial processes of the dump leachate treatment. However, every MSW dump is characterized by its own composition of leachate. Therefore, the study results require adaptation for each individual dump. The presented results are the beginning of a systematic study in this scientific field. In the future, it is necessary to establish dependence of the technology implementation parameters on the type of leachate and the features of its additional treatment at treatment facilities of various types. It is also important to study the ways of intensifying the treatment processes.

8. Conclusions

1. For the static mode of studies of preliminary leachate treatment in an aerated lagoon, the pH of the solution monotonously increased from 8.64 to 9.47 throughout the study cycle. For the concentration of dissolved oxygen in the leachate, extrema (on the first and the ninth days) were observed which may be connected with the periods of inactivation of biocenosis which provides biological treatment of the leachate under aerobic conditions.

2. In the biological aerobic treatment of the Hrybovytsky MSW leachate from pollutants in a dynamic mode, the optimal time of leachate staying in the reactor was 10 days. The change in the relative concentration of ammonium nitrogen in the leachate largely depends on the process temperature, so for implementation of a two-stage technology of treatment of the MSW dump leachates in aerated lagoons and at municipal WWTP, it is necessary to adjust the modes of realization of individual processes depending on the ambient temperature.

3. For treatment of leachate at municipal WWTP in a static mode at the values of the ratio of leachate dilution with municipal sewage M=1,000, the maximum effect of treatment from both ammonium ions and the COD was achieved.

4. For treatment of leachates at municipal WWTP in a dynamic mode, stability of indicators of treatment in time has been achieved. The value of the sludge index did not exceed the limit value acceptable for operation of municipal WWTP until the end of the study.

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