Treatment technology of liquid phase at industrial waste landfill

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Abstract. The authors suggest the complex technology of their treatment on the example of the specific industrial waste landfill. The technology involves industrial liquid waste treatment by stages. The solution of petroleum oil wastes being pumped from the pond at the landfill is supplied to the primary purification in the conventional oil separator which is combined with the settling pond. Additional treatment of water from oil products and suspended solids is carried out by a flotation unit. After the flotation unit for post-treatment of water from heavy metals, it is fed through a channel of trapezoidal cross-section to a filter dam being made of sorbent. The channel has been constructed in the earth water course. The subsoil is heavy loam and clay. The channel has a filter barrier, the design of which is constructed in the form of 2 metal frames being covered with wire nettings. There is a waterproofing layer made of polyvinyl chloride film at the bottom of the channel under the frames. A packing of fibrous sorbent is placed between the wire nettings to finally purify liquid wastes from petroleum residue, which allows treating discharge in accordance with the requirements of maximum permissible concentrations for fish-husbandry water utilization.

1. Introduction
The negative impact of industrial waste landfills (hereinafter referred to as IWL) on the environment seems to be an extremely urgent problem, since the disposal of production and consumption wastes in itself is one of the most common modern methods of their handling. At present, the technologies being used to deposit industrial waste, unfortunately, do not exclude their subsequent harmful effects on various environment components (Table 1).

Table 1. The results of IWL impact on the environment (according to [1] with corrections).

| Environment components | Nature of the impact | Effects                                                                 |
|------------------------|---------------------|-------------------------------------------------------------------------|
| Atmosphere air         | Emissions of dust and gases (CH₄, CO₂, NOₓ, etc.) generated during IWL operation into the atmosphere.) | Dusting, pollution, gassing of the atmosphere, spontaneous combustion, spread of unpleasant smell of ammonia, hydrogen sulfide, sulfur dioxide and other volatile components |
2. Theoretical part and research objective

One of the significant factors of IWL negative impact on the environment is the formation and movement of seepage water - the liquid phase having been formed in the landfill body under the influence of atmospheric precipitation, removed water, biochemical processes of their decomposition. Seepage water is made of complex chemical composition, a very high content of toxic organic and inorganic substances, the presence of bacterial contamination. The amount of seepage water depends on climatic factors, waste moisture, utility infrastructure of the landfill, pre-treatment of wastes. Depending on climatic conditions and IWL capacity, the volume of seepage water can average between 2000 and 4000 m$^3$ per hectare per year [2-9]. At the same time, an important difference of seepage water from other types of wastewater is the uneven accumulation during the year due to seasonal fluctuations in the amount of atmospheric precipitation.

In many cases, the lack of reliable anti-seepage protection, collection system, purification and disposal of seepage water and liquid waste turns IWL into a long - term source of surface and groundwater contamination in the area of location. In this regard, reducing the negative impact of IWL on the hydrosphere is one of the major environmental problems of urban areas [10]. Unfortunately, IWL in the Kursk region is no exception. The existing system of handling industrial waste in the Russian Federation is based on landfill depositing and does not meet modern requirements. Landfills create a significant environmental and epidemiological danger, entail the destruction of natural landscape, soil, groundwater, atmospheric air pollution, etc. (see Table 1.).

| Environment | Impact |
|-------------|--------|
| Surface water | Discharge of wastewater and drainage water enriched with toxic elements and heavy metals into surface streams, Contamination of surface waters, deterioration of their hydrochemical and biological parameters |
| Ground water | Generation of leachate and flow of salts of heavy metals, biodegradable and persistent organic compounds into ground water, Deterioration of ecological condition of groundwater, changes in its chemical composition |
| Lands, soils | Construction of landfills, removal and destruction of the fertile layer of land, construction of roads and communications, Deformation of the earth's surface, destruction of topsoil, soil pollution |
| Landscape | Annexation of territories for IWL, Technogenic pollution of the landscape, restrictions on other uses of the territory |
| Earth depths | Formation of anthropogenic relief, possible formation of technogenic horizon of underground waters, Changes in the stress-strain state of rock mass, subsoil pollution, subsidence of the earth's surface, development of karst and landslide processes |
| Animal and vegetal life | Disturbance of topsoil and vegetation cover, reduction of fodder base, Reduction of vegetation communities, forced migration of animals, reduction of biological diversity of natural complexes |
At the same time, the current state of the Russian regions’ economy and their limited financial capacities necessitates the use of seepage water and liquid waste treatment methods, allowing to develop low-energy and low-labor-intensive technologies; to use available and cheap materials for purification, mainly, industrial waste having coagulating, sorption, ion exchange properties to reduce the environmental load of IWL on the hydrosphere, especially at the final stages of their life cycle [11-18].

Large IWL is located at the distance of 15 km west of Kursk. To the north and west of the landfill are lands intended for agriculture. There are also fields, ravines, forest belts in the surrounding area. The IWL under study is located in the Oktyabrsksy district of the Kursk region, 1.3 km south-east of the village of Starkovo. In addition to continuously generated seepage water, there were placed liquid petroleum oil wastes and waste water in special pits. The thickness of petroleum products’ layer in the pits is 1.0 m; total volume of wastewater is 7905 m³; petroleum products and liquid coolant – 2091 m³ [19]. The qualitative composition of liquid waste is presented in the Table 2.

| Sample number | Cl   | Fe   | Mn   | Cu   | Zn   | Pb   | Cr   | Ni   | Cd   | Hg  |
|---------------|------|------|------|------|------|------|------|------|------|-----|
| 990 (discharge water) | 298  | 11.9 | 1.25 | 0.23 | 1.79 | 0.27 | 1.06 | 0.09 | 0.03 | 0.22 |

3. Results of experimental research
Detailed analysis of the location of IWL under study, qualitative and quantitative compositions of liquid waste and leachate, physical modeling of liquid phase treatment processes at IWL made it possible to develop the following procedure of their treatment.

The pumped solution of petroleum oil wastes from the pond is fed to the primary purification in the traditional oil separator which is combined with the settling pond. Later, final treatment from oil products and suspended solids is carried out by flotation unit INSTEB-1/3.5 (Figure1).

In order to be additionally treated from heavy metals after the flotation unit, water is fed through a channel of trapezoidal cross-section to a filter dam being made of sorbent “Sorbex”. The channel adjoins the dam from the downstream side. Its bottom width is 0.8 m. It has been made in the earth water course, subsoil is heavy loam and clay, the ratio of slopes – m=1, the channel depth – 3 m, the slope is equal to 0.00033. The depth of the channel is set as follows: for the head (upper) reach of the channel extending up to the dam made of sorbent - 3 m; for the tail reach of the channel extending to dam №2 – 0.7 m. The surface of the earth water course, and also channel slopes shall be leveled, compacted and well tamped in order to avoid erosion.

There is a filter barrier in the channel at a distance of 6 meters from the dam slope (it is 3 m wide at the bottom of the channel). It has been designed by VNIIGiM (All-Russian Hydraulic Engineering and
Melioration Research Institute). The design of the filter barrier is made in the form of 2 metal (or plastic) frames which are fixed in the channel slope. The frames are covered with Rabitz type steel-wire fabric. The distance between the frames is 2.1 m. The bottom of the channel under the frames is insulated with PVC film. Between the frames there is a packing made of fibrous sorbent (flax shive, etc.). Its thickness is 2 m. The function of this filtering packing is the post – treatment of liquid waste from oil residues up to 0.7 mg/l (see Fig. 2).

The design of the dam is adopted in compliance to the requirements of SNiP 2.06.03-85 “Meliorative systems and constructions” – pile dike made of sorbent “Sorbex”. Upstream slope is consolidated with gravel. There is a protective layer of compacted clay (0.5 m thickness) on the crest of the dam.

Hydraulic analysis of the dam has been conducted by the method of A. A. Uginchus, based on the modification and solution of the system of seepage equations of Academician P. N. Pavlovsky. The dam has been calculated in relation to the quantity of seepage discharge rate passing through the dam at a water depth in the channel before the dam H=2 m, the known permeability coefficient of the material composing the dam (granular sapropel - 130 m/day). The calculation contains head losses during seepage through the dam, the position of depression curve, the height of effluent seepage at the levee land side and water depth in the channel below the dam.

According to the calculations, the time of water removal from the pit at the design seepage conditions equals to 2.7 months.

The amount of sorbent is determined based on the conditions of heavy metals absorption being contained in liquid waste and bringing their concentration in the leachate to minimal permissible concentrations [20].

The total amount of pollutants entering the sorbent during the filtration cycle is determined by the formula:

\[
C_{sp} = \Sigma \left( C_{ei} - MPC_i \right) M \times 10^{-3} \text{kg}
\]

where \( C_{ei} \) - concentration of \( i \) substance (fishery category of water use, mg/l); \( M \) – total volume of wastewater, \( \text{m}^3 \).

Absorption capacity of granular sorbent (“Sorbex”) 190-200 mg-equivalent/100 g; volume weight 0.7-0.8 tons/\( \text{m}^3 \).

The required amount of sorbent for laying in the dam without compaction:

\[
G_c = \frac{G}{S} = 17.31 \text{tons}
\]

Volume of dam \( (V_d) \) made of sorbent “Sorbex”:

\[
V_d = \frac{17.31}{0.7} = 24.72 \text{m}^3
\]

Thus, it is necessary to construct one dam to absorb the total amount of pollutants (Fig. 1).

There has been adopted an individual absorber of surface waters. The maximum intensity of water withdrawal is no more than 10 lpd, the water layer above the filter well is no less than 0.1 m. The well is loaded with activated carbon of AG -3.5 grade.

4. Proposals and results of experimental research

The results of physical simulation of treatment processes of industrial waste liquid phase under laboratory conditions are summarized in the scheme (Figure 2).
The technology under consideration involves the recycling of waste flax shive and sorbent “Sorbex”, which is carried out in a stationary mixer. As a result of oil wastes and coolant waste, bottom sediment and oil-contaminated pit’s soils utilization, the resulting product can be used in road construction at the production facilities of “Kurskavtodor” as an additive or an integral part for the preparation of asphalt concrete mixtures; in the construction of sites for the storage of equipment, roads in the territory of IWL; for refilling of IWL pits by layer-by-layer stacking with further compaction by a roller, and also as a waterproofing layer for recultivation of the landfill.

Figure 2. Change in pollution load by treatment stages.

5. Conclusion
The proposed integrated solution of liquid waste and seepage water treatment in compliance with the requirements of maximum permissible concentrations can also be effectively applied at solid waste landfills of the Kursk region, as well as at other similar facilities.
References

[1] Gonopolsky A M 2008 Multi-stage treatment technology of leachate of solid waste landfill *Water: chemistry and ecology* 2 25–30

[2] Vaisman Ya I, Petrov V Yu, Sereda T G 2009 Factors that influence the volume of generated leachate of burial (deposition) of solid waste (Saint Petersburg: Piter) p 176

[3] Pivovarov D B, Khakimov F I 2008 Study of the ecological situation in the solid waste landfill area (Moscow: Eksmo) p 162

[4] Matrosov A S 2008 *Waste management* (Moscow: Vyshayay shkola) p 228

[5] Raznoschik V V,Abramov N V 2008 *Environmental protection in the disposal of municipal solid waste to landfills* (Moscow: Eksmo) p 240

[6] Adlan M N,Palaniandy P, Aziz H A 2011 Optimization of coagulation and dissolved air flotation (DAF) treatment of semi-aerobic landfill leachate using response surface methodology (RSM) *Desalination* 277 1–3

[7] Fedorov L G 2009 *Garbage* (Moscow: RKHTU) p 175

[8] Shcherbina E V 2007 *Environmental safety of solid waste landfills* (Moscow: Phenix) p 136

[9] Renou S, Givaudan J G, Poulain S, et al. 2008 Landfill leachate treatment: review and opportunity *Journal of Hazardous Materials* 150 468–493

[10] Povarov A A 2009 Treatment technology of drainage landfill water *Solid household waste* 4 26–27

[11] Khaustov V V, Ustiugov D L 2017 Formation of drainage waters of Tyrnyauz deposit in ecological aspect *IOP Conf. Ser.: Earth and Environmental Sci.* 87 042006

[12] Khaustov V V 2015 On treatment of technogenic solutions of mining company by natural sorbents *Proceedings of Southwest State University Issue: Engineering and technology* 3 102–111

[13] Khaustov V V, Dubyaga A P 2012 On the influence of Tyrnyauz deposit development on the aquatic ecosystem of the river Baksan (biochemical aspects) *Proceedings of South-West state University Issue: Technique and technology* 2 part 2 pp 228–235

[14] Khimchenko S V, Blank T A, Belikov K N, et al. 2017 New effective sorbents for purification of aqueous media from technogenic contaminants *Functional Materials* 24(4) 706–714

[15] Sirotkina E E, Novoselova L Yu 2005 Materials for Adsorption Purification of Water from Petroleum and Oil Products *Chemistry for Sustainable Development* 13 359–375

[16] Ignatiev D A, Mitin E A 2015 Improvement of the existing technological process of purification of waste waters of galvanic production from heavy metals, impurities and waste *Volga scientific Bulletin* 12-1 (52) 5–9

[17] Timofeev K L, Lebed B A, Akulich L F 2012 Sorptive technology of extracting nonferrous metals from mine waters *Proceedings of the universities* 6 7–10

[18] Somyn V A, Poletaeva M A, Komarova L F 2008 The Establishment of water circulation systems with sewage treatment from ions of heavy metals *Polzunovskii Bulletin* 3 205–209

[19] Khaustov V V 2013 About the impact on groundwater within one of the industrial and residential agglomerations of Kursk *Proceedings of Southwest State University* 5(50) 236–242

[20] Martynova M A, Khaustov V V, Chasovnikova E V 1991 Use of natural sorbents for purification of industrial effluents *Bulletin of LSU* 1 27–33