Domestic Solid Waste Landfills: Experimental Analysis of Leachate Stripping Technique

N E Chistyakov, A K Strelkov, S Y Teplykh
Water Supply and Wastewater Chair, Institute of Architecture and Civil Engineering, Samara State Technical University, 194, Molodogvardeyskaya St., Samara 443001, Russia
E-mail: chistyakov42@mail.ru

Abstract. The domestic solid waste (DSW) landfills activity is based on the natural processes of organic substances decomposition through their processing into other substances by micro-organisms. Such micro-organisms can only live in water or, in other words, they exist only in the aquatic environment, both in natural environment and under artificial conditions, e.g. in DSW landfill sites. This paper investigates the problem of DSW landfills leachate preparation for the reuse as irrigation water. Leachate is formed as an inescapable side-product of DSW landfills operation. Leachate is a result of precipitations and artificial irrigation contaminated by substances of microbiological decomposition and destruction of organic substances coming to landfill sites as domestic solid waste. The use of leachate as irrigation water will significantly change the DSW decomposition technology and the safety of landfill sites operations.

1. Introduction
Domestic solid waste landfills activity is based on natural processes of organic substances decomposition through their processing into other substances by micro-organisms [1-8]. These substances are either products that ensure optimum operation of other groups of micro-organisms, or end products such as carbon dioxide and water [9].

2. Relevance
Such micro-organisms can only live in water or, in other words, they exist only in the aquatic environment, both in natural environment and under artificial conditions, e.g. in domestic solid waste landfill sites [10]. It is these conditions that are created and maintained artificially to support the operation of DSW landfill sites [11]. It has been established that during DSW landfills operation, one cubic meter of domestic solid waste requires 6 liters of water to create conditions for undergoing biological processes [12]. However, there are studies showing that decomposition can be more intensive if the irrigation process is stimulated by using 10-15 liters of irrigation water. This is because the process of water flowing together with the products of organic substances decomposition (destruction) in the landfill body creates conditions for reacted or resulting substances outflow and removal from the reaction site. Therefore, favourable conditions for the continuation and acceleration of decomposition are created [13]. Thus, fuller saturation of the landfill body with water and the creation of conditions for water flow in the landfill body have a positive impact on biodeterioration.
Fuller saturation of the landfill body with water also creates conditions for acceleration of microbiological processes. At the same time, it results in greater accumulation of leachate, and consequently, in deterioration of the environmental situation in the landfill site area due to leachate accumulation [14].

3. Problem specification
Using leachate for irrigation purposes is a natural and reliable way out of this situation. It is known that the introduction of leachate and its recycling contributes to acceleration of the formation of landfill sites and to intensification of the processes of organic substances decomposition. It might lead later to the complete absence of formation, that is, to the reduction of the methanogenic phase to a minimum, which will significantly contribute to minimizing the impact on the environmental situation in the landfill site area.

4. Research Theory
The amount of leachate consists of the amount of precipitation, water supplied by the artificial irrigation and water generated by decomposition processes of organic substances occurring in the landfill site body [15,16].

The water flowing into in the landfill site body is used for evaporation, for partial deposit of water in the landfill site body, for maintaining humidity within the body. Some water is carried out by biogas. The last part of the water flows out of the landfill site body as leachate [17,18].

If leachate is used as irrigation water, with the maximum reduction of use (of substitution) for that part of clean water, the amount of leachate will gradually decrease because of the processes of water carry-over into the atmosphere (evaporation and biogas).

5. Practical significance
However, leachate contains volatile and heavily smelling components, such as volatile fatty acids and ammonia. It prevents usage of leachate as irrigation water. These components also prevent technicians from working with this fluid. In order to do it, staff must be protected by means of individual respiratory and body protection. This does not allow the technology to be applied because of its high cost [19,20].

Preliminary preparation of leachate may be a solution to this situation, i.e. its partial non-deep purification, which can eliminate risks preventing technicians from working with the liquid.

We believe that leachate preparation for further use may be carried out by a production technique based on leachate stripping with air flow. The stripping process has long been used for various production processes, including stripping liquids from a number of volatile compounds. Stripping is often used to improve water quality by adjusting concentrations of gases dissolved in it. Ammonia is one of these components.

In our case, it is ammonia that prevents the use of leachate, and makes it impossible for technicians to work with this fluid.

Although the stripping process has long been in use, specific technological parameters are different for different processes [21,22]. Previous studies show that leachate is not always uniform in its composition. Particular ingredients presence or absence in leachate depend on the time of year, on irrigation conditions, its intensity and regularity, and on other factors such as the landfill site age, climatic conditions, atmospheric precipitation, etc.

We are convinced that the development of leachate stripping parameters should be done separately for different specific conditions through laboratory experimental research or through practical implementation of this process on production facilities with composition and design similar to local conditions of a particular landfill site.

We have started to develop leachate stripping parameters by working on a laboratory installation using leachate from "Preobrazhenka" landfill site.
This laboratory installation is a cubitainer with 200 x 200 mm plan size (excluding walls thickness). Its height is 1100 mm. At the top of the model, the side walls have holes to connect the fluid supply piping and its flow in the case of a dynamic experiment. There is an air supply pipe at the bottom of one of the sidewalls (50 mm from the bottom) and there is discharge piping at the same height of the opposite wall. There is an aerator with dispersible air spraying connected with the intake pipeline inside the cubitainer. Aerator is designed for water aeration in the aquarium. It is made of porous polyethylene, not subjected to buildup of mechanical particles, and not subjected to corrosion. The performance of the aerator is chosen by calculating the capacity required to provide the required intensity of saturation. The intensity of aeration is taken from the literary data for ammonia stripping. That is 60 m3/m3 per hour in the study of the process in Ukraine (Kharkov) as well as in France and in the United States.

6. Experimental research and its results
The experiment was conducted under laboratory conditions, at room temperature about 22°C. The leachate temperature was 18-20°C. Air flow discharge was taken as indicated by a gas-flow rate device installed on the air supply line from the compressor to the installation.

Leachate chemical composition was investigated by laboratory methods in a hydro-chemical laboratory according to the following parameters:
- Nitrogen-ammonium (NH₄⁺),
- Volatile fatty acids (according to Krapivin),
- COD,
- BOD₅.

Samples to determine these indicators were selected as follows: the original sample was selected before the installation was launched, the second sample was picked up after 1 hour of aeration, the third sample was taken in four hours after the start of the aeration and the last sample – in eight hours from the beginning of the aeration.

In the original sample, the ingredients were concentrated in the following way:
- VFA (volatile fatty acids according to Krapivin) - absence,
- COD – 2251.2 mg/l,
- Nitrogen ammonium (ion ammonium) – 470 mg/l,
- BOD₅ – 370.3 mg/l.

Bubble aeration in the model was firstly installed according to the external qualities of the process, its uniformity, the absence of spikes, and so on. The air-flow measure was then carried out. It was 63.3 m3/m3 per hour. In the first few minutes of aeration there was foam forming on the surface of the liquid with a layer of up to 20-25 cm. After 20 minutes, the formation of the foam ceased. The foam completely disappeared gradually, within 30-40 minutes.

After the first hour of bubble aeration, a sample of the examined fluid was selected. It visually different from the original sample by its organoleptic parameters. First of all, there was no smell, the sample was of a lighter colour.

The chemical analysis showed a significant change in the composition of the pollution:
- VFA (according to Krapivin) - absence,
- COD – 1337.6 mg/l,
- Nitrogen ammonium (ion ammonium) – 275.0 mg/l,
- BOD₅ – 208.0 mg/l.

Bubble aeration in the next three hours was conducted with an intensity of 57.795 m3/m³ per hour. After four hours of bubble aeration, the second sample of the examined fluid was selected. The results of the tests there were as follows:
- VFA (according to Krapivin) - absence,
- COD – 1337.6 mg/l,
- Nitrogen ammonium (ion ammonium) – 255 mg/l,
BOD₅ – 224 mg/l.
The analysis shows that there were no significant changes in concentrations at this stage of the experiment.

After another four hours, that is, eight hours from the beginning of the process, another sample was taken. The results of the tests there were as follows:
- VFA (according to Krapivin) - absence,
- COD – 1335.0 mg/l,
- Nitrogen ammonium (ion ammonium) – 250 mg/l,
- BOD₅ – 208 mg/l.

After eight hours of bubble aeration the stripping process was terminated.

7. Conclusion
1. The process of domestic solid waste landfills leachate stripping by bubble aeration with an intensity of about 60 m³/m³ per hour, yields very good results and allows the use leachate for irrigating the landfill site. The leachate can be used without further purification as it loses an unpleasant and intense smell preventing technicians from working with it.
2. According to the main important parameters, DSW landfill leachate stripping carried out during the first hour is almost complete. The reduction of nitrogen ammonium concentrations to human sensitivity level allows technicians and other staff members to work with the leachate, as the intensity of the smell is reduced to human sensitivity level.
3. The reduction of the main components during the first hour of bubble aeration is as follows:
   - nitrogen ammonium: from 470 mg/l to 275 mg/l, that is 41.5%;
   - COD: from 2251.2 mg/l to 1337.6 mg/l, that is 40.6%;
   - BOD₅ – from 370.3 mg/l to 208 mg/l, that is 43.8%. Further reduction in the concentrations of the ingredients is negligible or, therefore, does not occur at all. It means that leachate stripping is efficient when performed within one hour, further stripping is useless.

Refinement of the technique parameters of the stripping will be carried on to establish more precise parameters for the process.

References
[1] Strelkov A K, Teplykh S Y and Gorshkalev P A 2014 Economic activity influence on surface run-off quality Water Del. & Sanit. Eng. 8 pp 21–5
[2] Galperin E M, Gostev A B, Strelkov A K and Plekhanov A G 2007 On reliability of sewerage network Water & Ecol. Prob. & Sol. 2(31) pp 50–7
[3] Shuvalov M V, Strelkov A K, Tarakanov D I and Shuvalov R M 2008 Introducing a programme of activities for the development of sewerage network in Samara region Water Del. & Sanit. Eng. 3-1 pp 13–7
[4] Shuvalov M V, Strelkov A K, Tarakanov D I and Shuvalov I S 2014 On the question of calculation of productivity of surface wastewater treatment plants (by way of discussion) Water Del. & Sanit. Eng. 8 pp 51–5
[5] Galitskov S Y, Kichigin V I, Strelkov A K and Tsypin A V 2008 Automatic management of local waste-water disposal plants Water Del. & Sanit. Eng. 8 pp 61–4
[6] Strelkov A K 1999 Improvement of water management of a large industrial center with account of environmental factors (with Samara region as an example) Doctoral thesis in Engineering Science (Samara State University of Architecture and Civil Engineering) p 294
[7] Strelkov A K, Teplykh S Y, Gorshkalev P A, Nosova E G and Sargsyan A M 2014 Peculiarities of discharge disposal regulation into centralized sewage system Sc. Surv. 2 pp 131–7
[8] Shuvalov M V, Strelkov A K and Shuvalov R M 2010 Recommendations for the design of public sewer systems in small built-up areas Ind. & Civ. Eng. 8 pp 22–4
[9] Strelkov A K and Teplykh S Y 2013 Environment protection and ecology of the hydrosphere (Samara) p 487
[10] Chertes K L, Strelkov A K, Bykov D E, Sedogin M P and Tarakanov D I 2001 Waste-water sludge as insulation materials for domestic solid waste and its utilization Water Del. & Sanit. Eng. 6 pp 36–8

[11] Fyodorov P M 2005 Monitoring of the geoenvironmental system “domestic solid waste landfill site”, with St Petersburg as an example (St.-Petersburg) p 131

[12] Glushankova I S 2004 Filtration water of domestic solid waste landfills purification at various stages of its life cycle (Perm) p 331

[13] Stalinskiy D V, Epstein S I, Musikina Z S and Varnavskaya I V 2009 Waste water treatment plants for domestic solid waste landfills waste water purification (RU Patent 2361823 20)

[14] Chistyakov N E, Strelkov A K and Zanina Z V 2014 Product water of domestic solid waste landfills usage Traditions and innovations in architecture and civil engineering 71th All-Russia Scientific Practical Technical Conf. Proc (Samara) pp 747–8

[15] Chistyakov N E and Strelkov A K 2015 On the recycling of product water of domestic solid waste landfills Sc. Surv. 15 pp 95–101

[16] Tarakanov D I 2002 Technology for the treatment of oil soils and waste water sludges for use as insulating materials in domestic solid waste landfill sites (Samara: Samara State Academy of Architecture and Civil Engineering) p 182

[17] Chistyakov N E, Strelkov A K and Zanina Z V 2014 Preparing product water of domestic solid waste landfills for usage as irrigation water Traditions and innovations in architecture and civil engineering 71th All-Russia Scientific Practical Technical Conf Proc (Samara) pp 748–9

[18] Chistyakov N E, Strelkov A K, Lobanov V Y and Zanina Z V 2014 Preparing product water of domestic solid waste landfills for further usage Water Del. & Sanit. Eng. 8 pp 45–9

[19] Kofman V Y 2013 Product water of domestic solid waste landfills purification Survey of foreign literature Water Del. & Sanit. Eng. 3 pp 46–56

[20] Strelkov A K, Egorova Yu A and Bykova P G 2014 Choosing the most effective reagents for water purification Water Del. & Sanit. Eng. 8 pp 5–9

[21] Starovoitov M K and Yudaev I G 2009 Complex installation for biochemical treatment and wastewater after-purification (RU Patent 2409524 1)

[22] Chistyakov N E and Poluyan V I 2016 Seasonal changes in the quality of domestic solid waste landfills product water Traditions and innovations in architecture and civil engineering 73th All-Russia Scientific Practical Technical Conf Proc (Samara) pp 238–41