Available online at www.CivileJournal.org

Civil Engineering Journal

(E-ISSN: 2476-3055; ISSN: 2676-6957)

Vol. 7, No. 06, June, 2021

Implementation of a Degassing System at the MSW Landfill

Anna Shkileva [1*]

[1] *Industrial University of Tyumen, Tyumen, Russia.*

Received 11 February 2021; Revised 28 April 2021; Accepted 06 May 2021; Published 01 June 2021

Abstract

Aitolo-Akarnania prefecture, western Greece, is an area with strong earthquakes and large active fault systems. The most, the second half of the 20th century was characterized for the world community by the aggravation of the environmental problem. Anthropogenic pollution of the environment with the growth of industrial and agricultural production, the growth of cities, the size of the population, the volume of their consumption clearly indicates that the world community is on the brink of an abyss. The destruction of forests, pollution of water bodies, degradation of soil, flora and fauna, the emergence of new diseases clearly shows that if urgent and drastic measures are not taken to save the environment, the life of future generations is problematic. In Russia, as in other countries of the world, the amount of solid household waste has been sharply increasing lately. Therefore, their processing and disposal is becoming an increasingly urgent problem that requires the adoption of complex solutions. At the same time, overcrowded and smoking landfills, as well as formed unauthorized landfills are the main sources of environmental pollution. Landfills of solid municipal waste not only cause an epidemiological hazard, but due to the anaerobic decomposition of organic waste, causing the formation of explosive biogas, become a powerful source of biological pollution. Biogas generated at MSW landfills in the process of decomposition has a toxic effect on living organisms, contributes to the outbreak of fires, and is a source of unpleasant odors. This problem must be solved by introducing a degassing system at municipal solid waste landfills already at the stage of their operation. The proposed degassing system at the MSW landfill is aimed at reducing the negative impact of biogas on the environment.

Keywords: Degassing; Landfill; Municipal Solid Waste; Biogas.

1. Introduction

A sharp increase in consumption throughout the world in recent decades has led to a significant increase in the formation of MSW, the bulk of which is currently taken to landfills [1]. Landfill burial leads to a variety of close and distant consequences, negative both for humans and for the entire environment as a whole, occurring immediately or after some time [2, 3]. Among these consequences, attention is drawn to the biochemical fermentation of MSW with the release of biogas into the atmosphere. As know, biogas consists of methane (up to 55%), carbon dioxide (up to 45%) and a number of other volatile substances. Biogas is explosive and fire hazardous, it has a depressing effect on plant development, can have a suffocating effect, and according to various estimates, it has 7-23 times more impact on global climate change than CO_2 [4].

The modern urban waste management system that has developed in Russia can be represented in the form of a block diagram (Figure 1). Waste is centrally collected and transported to large urban complexes, where it is further

* Corresponding author: shkileva.aa.tyuiu@gmail.com

http://dx.doi.org/10.28991/cej-2021-03091706

processed by one or more of the methods indicated in the block diagram. But the most voluminous on a global scale today is the method of burial at special landfills [5, 6].

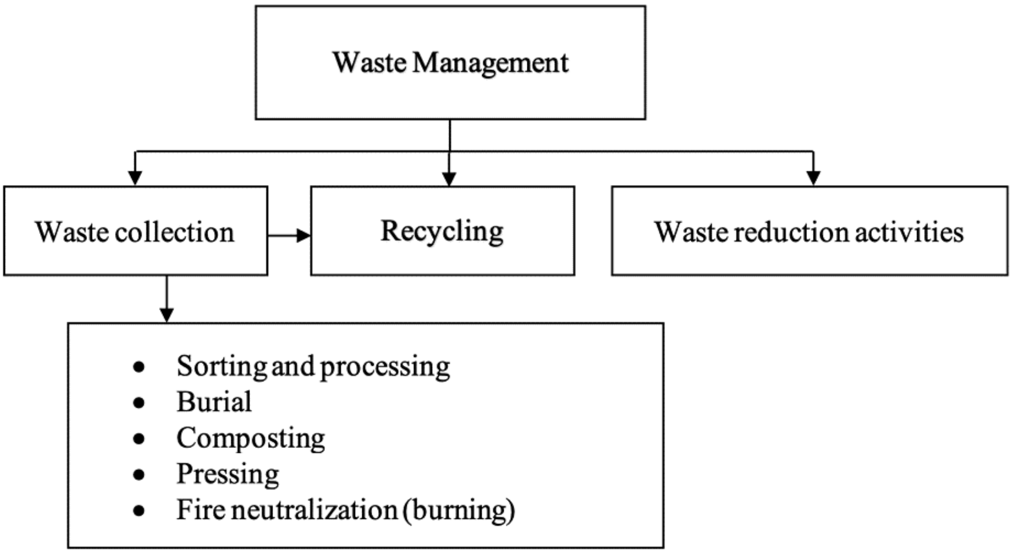

Figure 1. A flowchart of a municipal waste management system

A landfill is a natural or artificial earth quarry, reaching an area of several hectares with a depth of 10-20 m, located above dense waterproof layers of earth and having a multilayer protective screen made of artificial and natural materials [7]. Drainage pipes are laid along the entire perimeter of the landfill to bring the generated wastewater and landfill gas (biogas) to the surface. The landfill is equipped with a special fire extinguishing system. Drainage water must undergo special treatment, and the resulting biogas must be neutralized or disposed of in some way [5].

The problem of landfill gas utilization in Russia is very acute for one simple reason: we practically do not have equipped landfills described above, but we have unequipped landfills, often not isolated from aquifers, without drainage wastewater and biogas, sufficient compaction and fire extinguishing systems [8, 9]. One of these is the Velizhansky MSW landfill which was put into operation in August 2010. The occupied area is 30 hectares, and the design capacity is 333,545 m^3/year, 230 thousand tons/year.

Landfill gas (biogas) is formed as a result of the fermentation of organic constituents in waste in the landfill body during biochemical decomposition [10]. Along with gaseous decomposition products, gaseous constituents of depositions (for example, greenhouse gases) and water vapor (in a saturated state) are also formed [11]. The resulting gases and vapors form a wet gas mixture of variable composition [12]. The main components of this mixture are methane CH_4 and carbon dioxide CO_2 [13]. Due to its main constituents, as well as the presence of other hazardous components [14], the emission of landfill gas can have a harmful effect on the environment in the form of [15]:

- Danger of explosion, burning, smoke;
- Landfill reclamation obstacles;
- Spreading of a certain odor;
- Release of toxic or hazardous constituents;
- Harmful influence on the climate.

Proceeding from this, gases must be collected and managed (treated) [16]. To date, there is no biogas removal system at the landfill. Fires resulting from the ignition of methane are extinguished by filling the landfill surface with inert soil and sprinkling the waste with water. In the first case, there is a loss of the volume [17] of maps that could be used for filling with waste, in the second - excessive moisture, leading to an acceleration of the fermentation processes (an increase in the yield of methane) and the formation of excess filtrate.

2. Materials and Methods

In order to determine the risks of changes in the volumes of biogas yield as a result of changes in the composition of the imported waste, calculations of the daily emission of components were carried out for different proportions of the content of active organic matter (Figure 2).

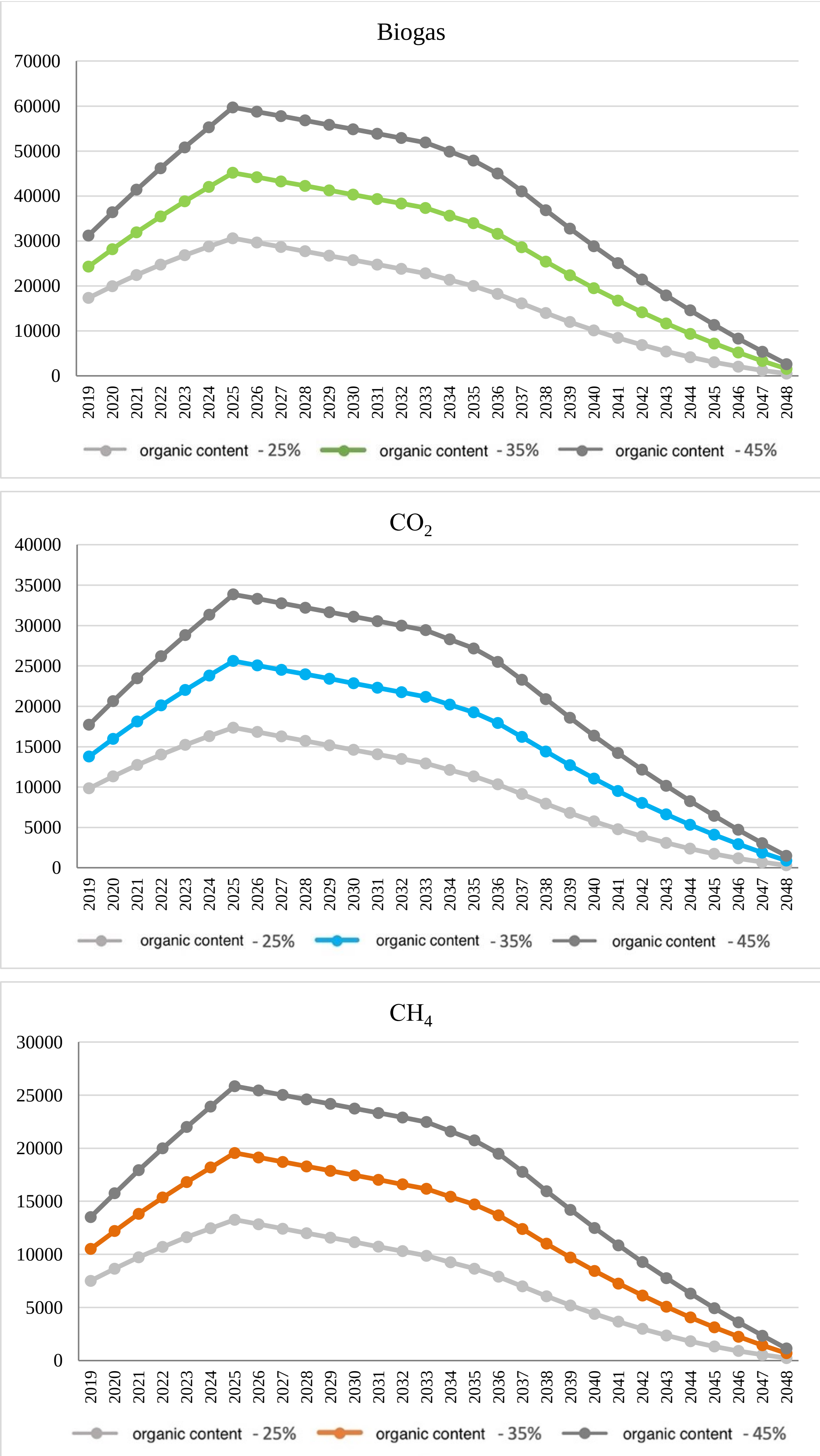

Figure 2. Predictive assessment of the yield of biogas components with different organic content

The maximum biogas yield in the most probable range of the content of the organic part of the waste (25-45%) will vary:

- Biogas in general - from 30,626 to 59,718 m^3/day;
- Methane - from 13,260 to 25,856 m^3/day;
- Carbon dioxide - from 17,366 to 33,861 m^3/day.

It is believed that the need for an active degassing system providing for the installation of gas-gathering wells (drains) and a technological system for biogas management (treatment) arises when more than 500 m^3/h methane is released [18]. Calculations showed that for the conditions of the Velizhansky MSW landfill, taking into account volume fluctuations due to changes in air temperature and morphological composition of waste, the following maximum values of biogas yield should be taken:

- Biogas in general - 1882 m^3/h (±606 m^3/h);
- Methane – 815 m^3/day (±262 m^3/day);
- Carbon dioxide – 1067 m^3/day (±344 m^3/day).

3. Results and Discussion

Thus, the results of the calculations confirm the need to implement a degassing system that allows the disposal of landfill gas at the stage of landfill operation [19]. The landfill gas management system is as follows. All horizontal drains are tied into a single gas-collecting header, which diverts the total gas volume to the management (treatment) system. Ensuring the disposal of landfill gas envisages collect and burn it in a high-temperature flare.

The gas treatment scheme includes:

- Removal of mechanical impurities on coarse and fine filter units;
- Removal of droplet moisture on the separator of the first separation stage (upstream of the compressor station);
- Increase in gas pressure by means of gas blowers installed at the compressor station;
- Biogas combustion in a flare.

With the help of a gas blower, which simultaneously creates both the vacuum ensuring the supply of gas from the landfill and the required yield pressure necessary for further supply through the pipeline systems, the gas is delivered to the gas combustion plant located in the eastern part of the landfill. Landfill gas that has passed the combustion process in a gas combustion plant loses unpleasant odors and is completely neutralized [20].

The combustion system consists of 2 main elements at high temperature flare and a container with the main equipment and elements that require protection from weather conditions. Biogas is supplied to the container. An indicative thermometer, indicative manometer, and temperature and pressure sensors are installed on the gas line inside the container, from which a signal is sent to the monitoring and control system. The landfill gas then enters a stainless-steel filter used to prepare the gas for compression. Excess moisture is discharged from the filter into a condensate collection tank located outside.

Following the filter, an electric valve is installed on the gas line, which cuts off the gas blower. The gas blower provides minimum inlet vacuum and outlet overpressure to feed the high-temperature flare. The blower capacity can be varied by means of frequency control (an inverter is included in the scope of delivery). Following the gas blowers at the outlet from the container, an indicative thermometer, an indicative pressure gauge, and temperature and pressure sensors are installed on the gas line.

The container houses the control system in the control compartment which ensures stable gas combustion, warns of errors, and turns off the system in case of an accident. The control system is supplemented with an optional EWON module (for remote monitoring and control) and a gas analysis system (for monitoring four gases). The container is heated and protects the equipment from precipitation and low temperatures. A flow sensor is installed outside the container the signal from which also comes to the control system. After that, the gas goes directly to the high-temperature flare for combustion. The gas combustion system is fully automated and starts/stops automatically. The high-temperature flash cycle starts as soon as an external start command is issued.

Combustion occurs at temperatures of at least 850 °C and with a holding time of 0.3 sec. This ensures complete combustion of methane, which complies with Russian and international norms and standards. This allows achieving complete combustion and significantly reducing harmful emissions and the formation of unpleasant odors [21].

The technical characteristics of the equipment used in the project are presented below (Figure 3).

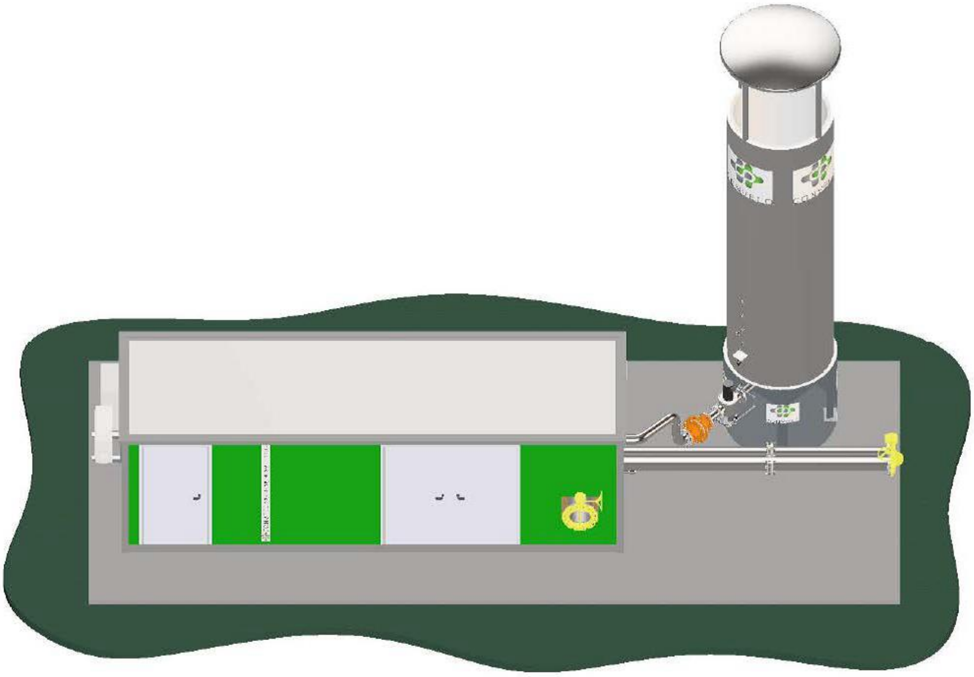

Figure 3. Scheme of a block-container flare unit

To ensure reliable operation of the compressor unit, the compressor units are mounted in a block container. The block-container is a room for placing compressor equipment and automation systems in the corresponding compartments, ensuring a certain microclimate in them, reducing the sound pressure level.

The block container mounted air extraction from the upper zone through the baffle, providing a single breathability. Exhaust ventilation is switched on automatically from gas analyzers upon reaching 10% LEL (lower concentration limit of distribution) for methane. Air intake is from the upper zone. Exhaust ventilation can be switched on manually from a button located outside the front door to the BCU room for preliminary ventilation. The fans are located inside the container block. An emergency ventilation system is used to remove gases and smoke from the block container after the automatic powder fire extinguishing installation. The main parameters of the biogas combustion system are presented in Table 1.

Table 1. Parameters of the biogas combustion system

Flare unit brand	UFU-01.UHL.02.Z
Nominal capacity, m^3 / h	1900
Maximum productivity, m^3 / h	2200
Performance adjustment, %	20 - 100
Flare height, m	15
Internal diameter, mm.	2190
Outer diameter, mm.	2420
Installation weight, t	15
Block compressor installation	2VGS-32 / 0.88-1.18 PCh U1
Compressor	1 worker + 1 standby
Compressor power consumption, kw	37
Rotation frequency of the main rotor of the compressor, rpm	3000
Suction pressure, mbar	-100
Discharge pressure, mbar	60
Overall dimensions of the block container, mm:	
Length	9000
Width	3000
Height	3800
Dry installation weight, t	15

4. Conclusions

The flare unit is designed for a maximum capacity of 1900 m^3/h. The ventilation system starts to operate in normal operation conditions for a short period of time (for example, 5 minutes every hour) when a biogas leak is detected. Thus, the construction of a landfill gas utilization complex will minimize its negative local and global impact, as well as significantly improve the environmental situation in the region, while guaranteeing:

- Reduction of methane emissions to zero level, thanks to the controlled combustion process;
- Absence of emissions of hydrogen sulfide, mercaptans and other odorous gases that are harmful to human health;
- Improving the socio-economic status of the territory;
- Reducing the risk of explosions and fires in the territory [22, 23].

As mentioned above, landfill gas is a powerful factor in the negative impact of landfills on the environment. At the same time, according to the EPA, from one million tons of waste, the amount of gas is generated, sufficient to generate 0.78 MW of electricity, which is more than enough to clean the leachate of the landfill of these wastes.

5. Declarations

5.1. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

5.2. Funding

The author received no financial support for the research, authorship, and/or publication of this article.

5.3. Conflicts of Interest

The author declare no conflict of interest.

6. References

[1] Rehman, Abdur, Kashif Ali Khan, Tayyaba Hamid, Hassan Nasir, Izhar Ahmad, and Muhammad Alam. “Effective Utilization of Municipal Solid Waste as Substitute for Natural Resources in Cement Industry.” Civil Engineering Journal 6, no. 2 (February 1, 2020): 238–257. doi:10.28991/cej-2020-03091467.

[2] Sharma, Bhupendra K., and Munish K. Chandel. “Life Cycle Cost Analysis of Municipal Solid Waste Management Scenarios for Mumbai, India.” Waste Management 124 (April 2021): 293–302. doi:10.1016/j.wasman.2021.02.002.

[3] Paladino, O., and M. Massabò. “Health Risk Assessment as an Approach to Manage an Old Landfill and to Propose Integrated Solid Waste Treatment: A Case Study in Italy.” Waste Management 68 (October 2017): 344–354. doi:10.1016/j.wasman.2017.07.021.

[4] Smaga, G.A., G.A. Basha, O.A. Savateeva and S.P. Kaplina “Possibilities of using landfill gas in Russian cities” Moscow: "Solid household waste" Issue 2 (2010): 36–38.

[5] Malakhov, V.M., A.G. Gritsenko and S.V. Druzhinin “Urban waste in Russia: state, problems, solutions” Novosibirsk: GPNTB SO RAN (2012): 126 p.

[6] Sadh, Pardeep Kumar, Surekha Duhan, and Joginder Singh Duhan. “Agro-Industrial Wastes and Their Utilization Using Solid State Fermentation: a Review.” Bioresources and Bioprocessing 5, no. 1 (January 2, 2018): 1-15. doi:10.1186/s40643-017-0187-z.

[7] Pecorini, Isabella, Eleonora Peruzzi, Elena Albini, Serena Doni, Cristina Macci, Grazia Masciandaro, and Renato Iannelli. “Evaluation of MSW Compost and Digestate Mixtures for a Circular Economy Application.” Sustainability 12, no. 7 (April 10, 2020): 3042. doi:10.3390/su12073042.

[8] Sadchikov, A.V. “Use of Combined Fermentation Technology to Improve the Efficiency of the Energy Complex of the MSW Landfil.” Edited by E.V. Shamsutdinov, Yu.V. Vankov, and V.V. Sergeev. E3S Web of Conferences 124 (2019): 05027. doi:10.1051/e3sconf/201912405027.

[9] Afonin, K V, T S Zhilina, A A Zagorskaya, M N Pavlova, and A N Shchekin. “The Use of Municipal Solid Waste as Secondary Energy Resources on the Example of the Housing Complex Novopatrushevo, Tyumen.” IOP Conference Series: Materials Science and Engineering 972 (November 22, 2020): 012025. doi:10.1088/1757-899x/972/1/012025.

[10] Memon, Muhammad Jaffar, and Abdul Rehman Memon. “Wheat Straw Optimization via Its Efficient Pretreatment for Improved Biogas Production.” Civil Engineering Journal 6, no. 6 (June 1, 2020): 1056–1063. doi:10.28991/cej-2020-03091528.

[11] Astretsov, V.M., S.E. Zaitsev and A.B. Lifshits "Landfills for municipal solid waste in the near Moscow region." Clean City 4 (1998): 37–43.

[12] Angelidaki, Irini, Laura Treu, Panagiotis Tsapekos, Gang Luo, Stefano Campanaro, Henrik Wenzel, and Panagiotis G. Kougias. "Biogas Upgrading and Utilization: Current Status and Perspectives." Biotechnology Advances 36, no. 2 (March 2018): 452–466. doi:10.1016/j.biotechadv.2018.01.011.

[13] Sidorenko, O. V., A. A. Shkileva, and E. S. Smirnova. "Comparison of Carbon Dioxide Removal Methods from Ground Waters." International Journal of Engineering and Advanced Technology 8, no. 4 (2019): 1411-1414.

[14] Shkileva, A. A., P. I. Vasenin, M. I. Kutuzova, and A. A. Gabudina. "Assessment of the crisis status of the construction organization." International Journal of Civil Engineering and Technology 9, no. 9 (2018): 658-665.

[15] Awe, Olumide Wesley, Yaqian Zhao, Ange Nzihou, Doan Pham Minh, and Nathalie Lyczko. "A Review of Biogas Utilisation, Purification and Upgrading Technologies." Waste and Biomass Valorization 8, no. 2 (January 9, 2017): 267–283. doi:10.1007/s12649-016-9826-4.

[16] "Landfills for municipal solid waste. Design, operation and reclamation: SP 320.1325800.2017" (approved by the Ministry of Housing and Utilities of the Russian Federation on 17.11.17: effective from 18.05.18) Moscow: Standardinform (May 18, 2018): 12 p.

[17] Aleksandrova, N N, A A Shkileva, and V V Popov. "Comparison of Reconstruction Options for Water Supply Network of Small Village." IOP Conference Series: Materials Science and Engineering 753 (March 7, 2020): 042056. doi:10.1088/1757-899x/753/4/042056.

[18] Skvorčinskienė, R., N. Striūgas, K. Zakarauskas, and R. Paulauskas. "Combustion of Waste Gas in a Low-Swirl Burner under Syngas and Oxygen Enrichment." Fuel 298 (August 2021): 120730. doi:10.1016/j.fuel.2021.120730.

[19] Maksimova, Svetlana, Anna Shkileva, and Ekaterina Verevkina. "Life Cycle Cost and Energy Conservation for Water System Pumping Station Reconstruction." Edited by A. Zheltenkov and A. Mottaeva. E3S Web of Conferences 164 (2020): 01002. doi:10.1051/e3sconf/202016401002.

[20] "Instructions for the design, operation and reclamation of solid waste landfills" (approved by the Ministry of Construction of the Russian Federation on 2.11.96: effective from 5.02.97) Moscow: Stroyizdat (1996): 39 p.

[21] "Sanitary protection zones and sanitary classification of enterprises, structures, and other objects: SanPiN 2.2.1/2.1.1.1200-03" (approved by the Ministry of Justice of the Russian Federation on 29.04.03: effective from 15.03.08.) Moscow: Federal Center for State Sanitary and Epidemiological Supervision of the Ministry of Health of Russia (2001): 51 p.

[22] Konokovich, V.M. and N.A. Lysukho "Analysis of methods for utilizing biogas from MSW landfills" Sakharov Readings 2019: Environmental Problems of the XXI Century. Minsk (2019): 47–50.

[23] Stompel, S.I. and V.A. Bukov "Technologies for collecting and deactivating biogas and leachate from solid waste landfills. Experience of PG Safe Technologies" Ecological equilibrium: anthropogenic changes in the geographic envelope of the earth, nature protection. Saint-Peterburg (2013): 27–39.