Applying of the Best Available Techniques in the Municipal Solid Waste Recycling

A V Zabelina¹, O I Sergienko²

¹Postgraduate student of the faculty of biotechnology, ITMO University, 49 Kronverksky Ave., lit. A, Saint Petersburg, 197101, Russian Federation
²Associate Professor of the faculty of biotechnology, candidate of technical Sciences, ITMO University, 49 Kronverksky Ave., lit. A, Saint Petersburg, 197101, Russian Federation

E-mail: zabelina@econw.ru, oisergienko@itmo.ru

Abstract. The article considers the experience of restructuring the activities of a municipal solid waste landfill into an enterprise for integrated waste recycling, taking into account the principles of circular economy. The introduction of the best available techniques for waste management allows to increase the quantity of raw material fractions that can be reused, and also helps to reduce the amount of waste sent to landfill. The results of the study allow to draw conclusions about the economic and environmental feasibility of using the best available techniques in municipal solid waste management. The article considers the activity of the Novyi Svet-ECO LLC in the Leningrad region. The waste management model developed for this company can be used for restructuring existing landfills for solid municipal and industrial waste disposal into more modern and efficient ecological and technological clusters and meets the principles of a circular economy.

1. Introduction

The problem of removing accumulated waste and the environmental consequences of this accumulation is global. Waste, as well as the needs of mankind for food and goods, will always be as long as there is a person on earth. Every year the volume of waste generated worldwide increases, and there is an urgent need to develop special measures and implement technologies that can help to reduce the amount of accumulated waste. This article presents a study of the restructuring the municipal solid waste (MSW) landfill into a multifunctional environmentally oriented technical park for waste recycling, organized according to the principles of the circular economy.

The relevance of the work is related to the need of extending the service life and to convert existing MSW landfills into multifunctional ecological and technological cluster (ecotechnocluster), the operation of which will not only minimize the amount of waste sent with a purpose of disposal, but also produce various types of raw materials and commercial products from MSW by processing and recycling them. The relevance of the research is also related to the search for solutions to reduce the amount of the company’s own waste and maximize the involvement of the generated waste in technological processes.

The degree of scientific development of the problem is not deep enough. In Russian science, as a rule, the problem of organizing production facilities for processing MSW as an alternative to landfills,
without taking into account the possibilities of operating landfills using low-waste or non-waste technologies. The need to implement an integrated approach to the management of MSW, taking into account the recycling of waste in addition to disposal, is considered in the works of A. S. Grinyuk and M. Yu. Sidorova [1], Yu. V. Nikulichev [2], N. I. Plyaskina and V. N. Kharitonova [3], K. A. Trushnikova [4], Y. I. Weisman and some other authors [5]. In foreign science, the subject of research is quite developed, we can note the articles of A. C. Bourtsalas, N. J. Themelis [6], G. Tchobanoglous and E. S. Vergara [7], devoted to the description of effective integrated approaches to the management of MSW. The monograph of P. Lacy, J. Rutquist [8] provides recommendations for organizing waste management activities in accordance with the principles of closed-loop economics and using of the best available techniques (BAT). However, it should be noted that the experience of MSW management presented in foreign studies of the last decade can be used as an example only if a model of MSW management is developed in accordance with the current Russian legislation and this model is implemented in local conditions.

The problem of the study is related to the fact that the main method of MSW removal in Russia is still the constructing of specially equipped landfills. At the same time, the most advanced, environmentally sound and cost-effective methods are considered to be the recycling of waste of various hazard classes, which allow obtaining raw materials for the production of new goods, products or energy. Some types of waste can be completely recycled, which allows you to organize the process of their disposal in a closed cycle. However, in Russia, such activities are not widely practiced yet.

2. Regulatory and legal justification for the MSW management

At the moment, the Russian Federation has a system of legal acts that define the main requirements for waste management. The key guiding document is Federal law No. 89-FZ of 24.06.1998, About Industrial and Consumption Waste [9], where the concept of MSW is defined. According to the Federal Classification Catalogue of Waste [10], there are forty-one types of solid municipal waste. Other types of waste (construction waste, industrial waste, etc.) are classified as other types.

The main document containing requirements for the organization of MSW disposal is The Instructions for the Design, Operation and Reclamation of Landfills for Municipal Solid Waste [11], which was approved in 1996 and its currently outdated, since it does not take into account the main tasks and priorities of state policy in the field of environmental safety and waste management. An attempt to compensate for the gap in the current instructions was the adoption of the Decree of the Government of the Russian Federation No. 1589-R [12], which introduced a phased ban on the disposal of certain types of waste containing resource fractions. When recycling MSW, there is a problem with handling sorting residues, the amount of which, depending on the processing technology used, can be 65-85% by weight of the initial volume of MSW received for processing. As a rule, the remains of sorting are sent to the landfill, which makes the processing of MSW not effective due to the low percentage of resource fractions selected. The digest of The Information and Technical Reference 17-2016 Disposal of Industrial and Consumption Waste [13] recommends that organic and mineral part of the waste should be sent to composting, but this method is not considered among the best available techniques for recycling MSW, which is due to changes in law enforcement practice: in 2016, at the time of publication of this digest, MSW sorting residues were considered industrial waste generated in the enterprise's own technical process, and were classified as so called other type waste. Only in 2017, these residues were allocated to a separate subgroup of municipal solid waste.

2.1. Best available techniques for waste disposal

The Information and Technical Reference 17-2016 Disposal of Industrial and Consumption Waste highlights the technology of extracting secondary resources from waste that are subject to reuse and energy use. Automatic and manual sorting is highlighted. The most important aspect is the possibility of organizing the selection of organic waste fractions and so called ‘clean’ raw material flows (polymers, paper, cardboard, metal, glass, etc.). The second important aspect is the treatment of leachate, which is formed in large quantities due to the biological anaerobic decomposition of organic
waste fractions. In addition to the organization of an anti-filtration screen, it is proposed to install drainage systems designed to divert flood, rain, sewage and process water generated during the operation of the landfill. At the same time, the question of how to dispose of landfill leachate waste remains open. In the absence of local treatment facilities in the landfill infrastructure, it is proposed to send the collected leachate for neutralization to a specialized organization. However, due to the large amount of leachate formation, this method is not economically feasible. The Information and Technical Reference 17-2016 also notes the need to set up degassing stations in order to select the gaseous fraction formed from the decomposition of waste. At the same time, the technology of burning landfill gas for the purpose of subsequent generation of electricity and heat is indicated in the digest as promising.

2.2. Best available techniques for waste recycling
The digest of The Information and Technical Reference 15-2016 Waste Recycling (Except Waste Incineration) [14] is linked to The Information and Technical Reference 17-2016 Disposal of Industrial and Consumption Waste. Both manuals include recommendations for the implementation of MSW treatment and subsequent utilization of those waste elements that contain a renewable resource. The basis of MSW processing is the principle of sorting into homogeneous groups based on the material of origin of the product or packaging that has lost its consumer properties (polymers, glass, textiles, rubber, paper, cardboard, non-ferrous metal, ferrous metal). Solid fuel production from waste is indicated as a promising technology. The resulting solid RDF fuel must meet the characteristics of The National Standard 33516-2015 Solid Fuel from Municipal Waste. Technical Characteristics and Classes [15]. Based on the BAT, Noviy Svet-ECO LLC’s MSW disposal activities were reorganized.

3. Implementation of the best available techniques at the MSW landfill
The object of research - Noviy Svet-ECO LLC operates a solid waste landfill. The main activity is the disposal of municipal solid waste (about 90% of the total volume of incoming waste) [16]. This type of activity is carried out on the basis of a license for the right to manage waste, which is valid indefinitely. In November 2019, after the license was re-issued in connection with the organization of new production areas, a MSW sorting and recycling line, a composting and leachate treatment site were launched at the Noviy Svet-ECO landfill, in accordance with the recommendations of using the BAT. The introduction of new production areas allowed to solve the problem of reducing the amount of production of the company's own waste, intended for safe removal by involving it in economic turnover.

As part of the restructuring of production, technological processes were organized for sorting solid waste in order to select raw fractions, production of fuel chips, ferrous and non-ferrous metal scrap, solid RDF fuel from waste and technogenic soil produced by open field composting. In addition, the company's specialists developed a method for recycling leachate by changing its aggregate state (lithification) [17, 18]. Previously, the filtrate of the landfill of hazardous class IV, formed in the amount of 3,800 tons / year, was not subject to disposal and was sent for neutralization to a specialized organization.

Thus, the final commercial products obtained at the enterprise as a result of the introduction of the BAT for the utilization of MSW with pre-treatment are: fuel chips, secondary black scrap metal, secondary aluminum can, scrap electronic waste, glass scrap, paper and cardboard waste paper, secondary polymers of various types, alternative solid fuel Topal-1, inert insulating material produced by the method of lithification and technogenic soil obtained as a result of composting. All types of products received the necessary conclusions, duly issued technical specifications and catalogue lists are registered.
4. Environmental and economic assessment of the effectiveness of implementing the best available technologies in waste management

Based on the results of production control, it was concluded that the introduction of the best available technologies at the MSW landfill allowed to use more solid municipal and other waste for recycling and less for disposal, thereby reducing the technogenic impact of the MSW landfill on air, soil, surface and underground water and other components of the environment.

According to the accounting data of Noviy Svet-ECO LLC, the amount of MSW accepted for disposal in 2019 was 456,082.96 tons; the amount of MSW processed for utilization of resource fractions in 2019 was 37,543.45 tons. Thus, as a percentage in 2019, 92.39% of MSW from the total amount of waste received was sent for disposal, and 7.61% for processing with subsequent recycling. A relatively low percentage of the amount of waste sent for recycling is due to the lack of a license during 2019 that allows the processing and disposal of MSW on the line and sections located in the production area of the landfill.

In 2020, the planned amount of disposed waste will be 72.73% of the total amount received, and 27.27% of the waste will be sent for processing and recycling. The expected environmental effect in 2020 is an increase in the volume of MSW processing with utilization of resource components by 19.66% compared to the previous year.

At this stage, the authors calculated the economic effect of the introduction of composting and lithification sites, since the work of these two divisions is most consistent with the principles of the circular economy of the enterprise and meets the goals of implementing the best available techniques.

The costs of organizing a composting site and operating it for one year are shown in table 1.

| # | Type of costs                                      | Cost amount, RUB. |
|---|--------------------------------------------------|-------------------|
| 1 | The purchase of the mixer                         | 2 700 000         |
|   | Total: capital expenditures                      | 2 700 000         |
| 2 | Fuel costs for special equipment (per year)       | 297 000           |
| 3 | Payment for the work of personnel serving the site (per year) | 1 080 000 |
| 4 | Other costs (10% of the total cost of items 2-3)  | 137 700           |
|   | Total: operating costs                           | 1 514 700         |

When dispose the remains of MSW sorting, the educator of this type of waste pays a fee for the negative impact on the environment to the budget. The fee for the disposal of the remains of MSW after sorting (or so called ‘tails’) in the absence of a recycling site for 2020 will approximately amount to 5,256,825 rubles including 3,812,667 rubles for ‘tails’ of hazard class IV and 1,444,1578 rubles for waste ‘tails’ of class V, respectively). If this type of waste is fully recycled, the fee will be equal to 0 rubles.

We calculate the annual economic benefit of the new technology implementation as the difference between the amount of annual savings and the share of capital expenditures for the launch of the composting site related to this year:

\[ A_{eb} = S - C_{op} - R \cdot C, \]
where S is the sum amount of annual savings due to fee reduction of payment for placement of the remains of sorting MSW, RUB / year;

C – capital expenditures for composting equipment, RUB.

R – the standard rate of return on capital investments, we assume R=0.15;

C_{op.} – the cost to operate the equipment for composting, RUB/year.

\[ A_{eb} = 5\,256\,825 - 1\,514\,700 - 0.15 \times 2,700,000 = 3,337,125 \text{ RUB/year.} \]

Thus, the annual economic effect for the first year of operation of the composting site will amount to 3,337,125 rubles, while the costs of organizing the site will be taken into account when forming the tariff for receiving MSW for disposal and processing, provided that these costs are justified in the production program sent to the authorized territorial tariff regulation body.

Next, the annual economic effect of the introduction of a new leachate decontamination area was calculated in the same way as the difference between the amount of annual savings and the share of capital costs for starting the lithification section. Information about the costs of setting up a production site and for the first year of operation is presented in Table 2.

| #  | Type of costs                                           | Cost amount, RUB. |
|----|--------------------------------------------------------|-------------------|
| 1  | Manufacture of equipment for lithification, including installation and commissioning | 4,343,684         |
| 2  | Construction of a concrete-covered platform            | 49,000            |
|    | **Total: capital expenditures**                        | **4,392,684**     |
| 3  | Engineering support (power grid) for a year            | 1,734,000         |
| 4  | Payment for operators and handymen who serve the site in 2 shifts, year | 540,000           |
| 5  | Other costs (10% of the total cost of items 3-4)       | 227,400           |
|    | **Total: operating costs**                             | **2,501,400**     |

Other costs in tables 1 and 2 refer to the costs of emergency repairs or other unforeseen expenses that may occur during the operation of the sites. Let's consider two options for calculating the annual economic effect, depending on the presence or absence of a contract with a licensed organization for the neutralization of leachate.

Option 1: in the absence of local treatment facilities at the MSW landfill, we calculate the cost of transferring filtrate waste for neutralization to a specialized company, if the average annual volume of filtrate formation is 3,800 tons, and the minimum cost of neutralization of this type of waste is 3,000 rubles per ton:

\[ 3,800\,\text{tons} \times 3,000\,\text{rubles/ton} = 11,400,000\,\text{rubles.} \]

Calculate the annual economic benefit:

\[ A_{eb} = 11,400,000 - 2,501,400 - 0.15 \times 4,392,684 = 8,239,697\,\text{rubles.} \]

Thus, the economic benefit in the first year of operation of the lithification section will amount to 8,239,697 rubles.

Option 2: calculate the annual economic effect if the leachate educator does not have a contract with a licensed organization for neutralization. In this case, the entire filtrate will be considered...
disposed, since the opposite is not proven, and the fee for negative impact for this type of waste will be calculated with an over-limit coefficient \( k = 5 \) [40]. The fee for placing 1 ton of filtrate in 2020 will be 1,433.16 rubles per ton [41], then:

\[
3 \times 3800 \times 1433.16 \times 5 = 27230040 \text{ rubles.}
\]

Thus, in the second version of the calculation, the economic benefit will be:

\[
A_{eb} = 27230040 - 2501400 - 0.15 \times 4392684 = 24069737.40 \text{ rubles.}
\]

The payback period \( P \) will be:

\[
P = \frac{C}{S - C_{op.}}
\]

Substituting it, the payback period \( P = 0.72 \text{ years for the composting section and 0.49 years for the lithification site.} \)

Comparison of data on costs and the amount of annual savings allows us to conclude that after the organization of new production sites in 2020, the fee for negative environmental impact in terms of waste disposal will be reduced by 5,262,102.14 rubles and will amount to only 2,204.83 rubles, provided that all the residues of MSW sorting and landfill filtrate generated in 2020 are being recycled.

In 2020, 1/5 of the waste coming to the enterprise will be fully recycled. Thus, the ecological and economic effect is obvious. In the context of the global problem of waste accumulation, it is necessary to increase production capacity to increase the amount of recycled MSW.

5. Conclusions
The article considers the conversion of an enterprise from an operator for MSW disposal (landfill) to an operator for the recycling of MSW, followed by the disposal of an inert fraction (ecotechnocluster). The data obtained in the course of the study allow us to confirm the hypothesis that it is necessary to convert existing MSW landfills into technoclusters that work for the effective production and use of secondary raw materials. The design of new waste disposal facilities should take into account the organization of sorting stations and disposal sites for specific types of waste in their infrastructure.

The proposed methods of processing and recycling MSW can be considered as a priority in terms of using the best available techniques not only for this enterprise, but also for organizing the activities of other enterprises related to the management of MSW.

Reducing the amount of disposed waste causes a reduction in the fee for the negative impact, increases the service life of the landfill due to a slower depletion of capacity. The search, development and implementation of new and existing best available techniques should be carried out continuously. When choosing a technology for handling a specific type of municipal solid waste, priority should be given to the technology of waste recycling, rather than disposal. The model for organizing waste management activities using the best available techniques implemented at Noviy Svet-ECO LLC can be used to restructuring existing MSW landfills in Russia or to design new facilities for this purpose.

6. References
[1] Grinyuk A S and Sidorova M Yu 2019 Development of the Project of a Unified System for Processing, Utilization and Disposal of Ballast of Solid Municipal Waste on the Example of Reconstruction of the Solid Municipal Waste Landfill "Gusinoborodsky" Collection of materials of the XV International exhibition and scientific Congress "Intereexpo GEO-Siberia-2019" 175-178
[2] Nikulichev Yu V 2017 Waste Management Experience of the European Union Analyte. review Moscow: RAS UNION Center for scientific information. research. globe. and regional p 55
[3] Plyaskina N I and Kharitonova V N 2016 Management in the sphere of solid municipal waste management: current state ECO All-Russian economic journal vol 12 5-19
[4] Trushnikova K A 2016 Global trends in the organization of solid municipal waste disposal services URL: https://cyberleninka.ru/article/n/mirovye-trendy-v-organizatsii-uslug-pou-utilizatsii-tverdyh-kommunalnyh-othodov (accessed 2020-05-27)
[5] Waste management Polygon technologies for solid waste disposal Reclamation and post-
operational maintenance of the landfill 2012 ed Y I Weisman (Perm: Publishing house of Perm nat. research polytech. University) p 244

[6] Bourtsalas A C and Themelis N G 2019 Recovery of Materials and Energy from Urban Wastes: A Volume in the Encyclopedia of Sustainability Science and Technology (London: Springer) p 545

[7] Vergara S E and Tchobanoglous G 2016 Municipal Solid Waste and the Environment: A Global Perspective [Electronic resource] URL:https://pdfs.semanticscholar.org/e805/fd55026b05e9a97933430dba148a130113ab.pdf?_ga=2.121481036.594251301.1591383356-1166776043.1591383356 (accessed 2020-05-27)

[8] Lacy P and Rutqvist J 2015 Waste to Wealth: The Circular Economy Advantage (London: Palgrave Macmillan) p 216

[9] Federal law No. 89-FZ of June 24, 1998 About production and consumption waste [Electronic resource]: Access from the system "Consultant Plus"

[10] Order of the Federal service for supervision of nature management dated may 22, 2017 No. 242 «On approval of the Federal classification catalog of waste» [Electronic resource]: Access from the system "Consultant Plus"

[11] The Instructions for the Design, Operation and Reclamation of Landfills for Municipal Solid Waste 1996 (Moscow: Minstroy) p 39

[12] Decree of the Government of the Russian Federation No. 1589-R of 25.07.2017 The list of types of industrial and consumption waste that include useful components, the disposal of which is prohibited [Electronic resource]: Access from the system "Consultant Plus"

[13] The Information and Technical Reference 17-2016 Disposal of Industrial and Consumption Waste (Moscow: BAT Bereau) p 195

[14] The Information and Technical Reference 15-2016 Waste Recycling (Except Waste Incineration) (Moscow: BAT Bereau) p 198

[15] The National Standard 33516-2015 Solid Fuel from Municipal Waste. Technical Characteristics and Classes (Moscow: Standardinform) p 19

[16] Data of statistical reporting under the form 2-TP (waste) for the years 2001-2019 (Noviy Svet: Noviy Svet) p 349

[17] Zabelina A and Tereshonok O 2020 Experience in implementing the best available technologies for waste disposal (Internauka vol 19 (148)) ed A Enikeev (Moscow: Internauka) pp 129-142

[18] Lialina O A, Penner Y A, Senchenko V A, Solovev D B 2020 Visualization of the Cargo Orientation in Space under Movement by a Tower Crane in Low Visibility Conditions IOP Conf. Ser.: Mater. Sci. Eng. 753 Paper № 032065 [Online]. Available: https://doi.org/10.1088/1757-899X/753/3/032065