MINISTRY OF EDUCATION AND SCIENCE OF UKRAINE
NATIONAL AVIATION UNIVERSITY
FACULTY OF ENVIRONMENTAL SAFETY,
ENGINEERING AND TECHNOLOGIES
DEPARTMENT OF ENVIRONMENTAL SCIENCE

APPROVED TO DEFENCE
Head of the Graduate Department
_____________ Tamara DUDAR
«_____» ____________ 2024

BACHELOR THESIS
(EXPLANATORY NOTE)

Theme: «Environmental and energy aspects disposal of organic waste»

Done by: seeker of EK-402 group, Vitaliy D. Melnychenko
(student, group, surname, name, patronymic)

Supervisor: Professor of the Environmental Science Department, PhD (Engineering Sciences), Associate Professor Lesia I. Pavliukh

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KYIV 2024

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ
НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ
ФАКУЛЬТЕТ ЕКОЛОГІЧНОЇ БЕЗПЕКИ,
ІНЖЕНЕРІЇ ТА ТЕХНОЛОГІЙ
КАФЕДРА ЕКОЛОГІЇ

ДОПУСТИТИ ДО ЗАХИСТУ
Завідувач випускової кафедри
_____________ Тамара ДУДАР
«_____» ____________ 2024 р.

КВАЛІФІКАЦІЙНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ «БАКАЛАВР»

Тема: «Еколого-енергетичні аспекти утилізації органічних відходів»

Виконавець: здобувач групи ЕК-402 Мельниченко Віталій Дмитрович

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КИЇВ 2024

NATIONAL AVIATION UNIVERSITY
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Department of Environmental Science
Specialty, Educational and Professional Program: specialty 101 “Ecology”, Educational and Professional Program: “Ecology and Environment Protection”
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APPROVED
Head of the Graduate Department
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«____» _________ 2024

BACHELOR THESIS ASSIGNMENT
Vitaly D. Melnychenko

1. Theme: «Environmental and energy aspects disposal of organic waste» approved by the Rector on April 03, 2024, № 504/ст.

2. Duration of work: from 20.05.2024 to 16.06.2024.

3. Output data of work: data on the state and conditions of the landfill, data from Google Earth.

4. Content of explanatory note: Analytical review of the literature on the topic of the diploma. Assessment of the hazardous impact of the solid household waste landfill on the environment. Calculations of the feasibility of installing methane collection equipment.

5. The list of mandatory graphic (illustrated) materials: tables, figures.

6. Schedule of thesis performance

№ з/п	Task	Term	Advisor's signature
1	Start of tasks	03.042024	
2	Collection of data on the landfill, methane extraction equipment.	03.04.2024-20.04.2024	
3	Data Analysis	21.04.2024-24.042024	
4	Making calculations	26.04.2024	
5	Completion of writing the first chapter of the work	30.04.2024	
6	Completion of writing the second section of the work	05.05.2024	
7	Completion of writing the third chapter of the work	15.05.2024	
8	Formulation of conclusions	20.05.2024	
9	Final design of the work	28.05.2024	
10	Work with norm control	02.06.2024	
11	Protection of qualification work	12.062024	

7. Date of task issue: «03» April 2024

Thesis supervisor: ________________ Lesya PAVLIUKH
(advisor's signature) (name, surname)

Task is taken to perform: ________________ Vitaliy MELNYCHENKO
(graduate's signature) (name, surname)

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

Факультет екологічної безпеки, інженерії та технологій

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(шифр, найменування)

ЗАТВЕРДЖУЮ
Завідувач кафедри
___________Тамара ДУДАР
«____» _________ 2024 р.

ЗАВДАННЯ
на виконання кваліфікаційної роботи
Мельниченка Віталія Дмитровича

1. Тема кваліфікаційної роботи «Еколого-енергетичні аспекти утилізації органічних відходів»
затверджена наказом ректора від «03» квітня 2024 р. №504/ст.

2. Термін виконання роботи: з 20.05.2024 р. по 16.06.2024 р.

3. Вихідні дані роботи: дані про стан та стан полігону, дані Google Earth.

4. Зміст пояснювальної записки: аналітичний огляд літератури за темою диплому. Оцінка небезпечного впливу полігону твердих побутових відходів на навколишнє середовище. Розрахунки доцільності встановлення обладнання для збирання метану.

5. Перелік обов’язкового графічного (ілюстративного) матеріалу: таблиці, рисунки.

6. Календарний план-графік

№ з/п	Завдання	Термін виконання	Підпис керівника
1	Початок завдань	03.042024	
2	Збір даних про полігон, обладнання для вилучення метану.	03.04.2024-20.04.2024	
3	Аналіз даних	21.04.2024-24.042024	
4	Виконання розрахунків	26.04.2024	
5	Завершення написання першого розділу роботи	30.04.2024	
6	Завершення написання другого розділу твору	05.05.2024	
7	Завершення написання третього розділу роботи	15.05.2024	
8	Формулювання висновків	20.05.2024	
9	Остаточне оформлення роботи	28.05.2024	
10	Робота з нормоконтролем	02.06.2024	
11	Захист кваліфікаційної роботи	12.062024	

7. Дата видачі завдання: «20» травня 2024 р.

Керівник кваліфікаційної роботи: ____________ (підпис керівника) Павлюх Л. І. (П.І.Б.)

Завдання прийняв до виконання: ____________ (підпис випускника) Мельниченко В. Д. (П.І.Б.)

ABSTRACT

Explanatory note to thesis «Environmental and energy aspects disposal of organic waste»: 49 pages, 2 figures, 5 tables, 35 references.

Aim of work – study of the impact on the environment of man-made threats of the Kyiv solid waste disposal site No. 5, and the proposal of engineering and technical solutions to minimize this problem.

Object of research is disposal of organic waste.

Subject of research is estimation of the volume of methane that can be extracted from a specific solid waste landfill.

Methods of research – analysis, synthesis, comparison, statistical and calculation methods.

The global problem of waste is one of the most significant environmental challenges of our time, which has a negative impact on both the environment and human health. In Ukraine, the situation with waste management is particularly acute due to the high level of waste production compared to developed countries, as well as due to excessive dependence on landfill. This highlights the need for improved technologies, stricter regulations and public education campaigns to improve waste management. Kyiv landfill No. 5 is a vivid example of existing problems, including the lack of proper sealing and the presence of combustible materials, which leads to the generation of methane and the threat of fires. This work examines a project whose goal is to improve the environmental situation and economic aspects of gas utilization and energy sustainability of methane obtained from landfills for energy production.

MUNICIPAL SOLID WASTE, DISPOSAL, LANDFILL, METHANE, ENVIRONMENTAL SAFETY

CONTENT

INTRODUCTION

Relevance of the work. In the modern world, the problem of disposal of organic waste is gaining more and more importance. Given the growing amount of waste and the need for environmentally friendly and energy-efficient solutions, the issue of proper handling of organic waste is becoming relevant for many countries, including Ukraine. This article is designed to consider various environmental and energy aspects of organic waste utilization, based on scientific data, technical capabilities and prospects for the development of the domestic industry. Special attention will be paid to the implementation of innovative technologies, such as anaerobic digestion and composting, as well as the development of policies and strategies that will contribute to the effective management of organic waste at the local and national levels. After all, the implementation of these technologies will not only reduce the amount of waste, but also allow obtaining additional sources of energy or natural fertilizers, which will have a favorable effect on agriculture and industry. We will also discuss world experience in this area, in particular successful examples from European and North American countries, which can serve as a model for Ukrainian enterprises and state bodies. These countries demonstrate how economic and environmental benefits can be harmoniously combined, turning the problem of waste into an opportunity for sustainable development. We will also try to assess what obstacles may arise on the way to the implementation of these innovations in the conditions of the Ukrainian economy and how they can be overcome thanks to cooperation between the government, scientific institutions and business.

The disposal of organic waste is of great importance both from an ecological and an economic point of view. It contributes to reducing the volume of waste disposal in landfills, which is a source of soil and water pollution. Landfills often release dangerous chemicals and toxins that can seep into groundwater, harming ecosystems and human health. In addition, organic waste is a potential source of renewable energy that can reduce dependence on fossil fuels. The use of biogas obtained by anaerobic decomposition allows to reduce greenhouse gas emissions and reduce the carbon footprint. This not only reduces the environmental burden, but also opens up new economic opportunities for the development of regions. Biogas production can create new jobs, stimulate the development of the local economy and ensure the energy independence of the regions. At the same time, proper management of organic waste contributes to the improvement of soil quality. Composting, for example, turns organic waste into valuable compost that enriches soils and helps reduce the need for chemical fertilizers. This creates better conditions for agriculture, increasing the fertility and moisture-retaining capacity of the soil. Also, the disposal of organic waste helps in the fight against climate change, creating conditions for the sustainable development of the community. Communities that implement effective waste management strategies not only reduce their environmental footprint, but also increase their ability to adapt to and mitigate the effects of climate change.

Modern municipal solid waste landfills (MSW) are specialized engineering facilities equipped with a protective anti-filtration screen, systems for the collection and utilization of infiltrates and biogas, a technical and biological remediation system, and a system for the collection and removal of conditionally clean atmospheric water. However, more than 80% of solid waste landfills operated today in Ukraine do not meet sanitary and technical standards, i.e. they are actually landfils and create a man-made burden on the environment [1].

The waste placed there undergoes complex physico-chemical and biochemical changes under the influence of atmospheric phenomena, specific conditions formed in the waste layer, as well as as a result of interaction between them. This leads to the formation of various toxic compounds, which, entering the environment, negatively affect its components [2].

The repercussions extend far beyond mere contamination. These landfills transform into havens for parasitic fauna and pathogenic microflora, posing a significant public health threat. Polluted leachate, a toxic stew of rainwater mixed with landfill contaminants, infiltrates underground and surface waters, rendering them unusable. Uncontrolled methane generation, a byproduct of decomposing waste, lurks as a silent threat, fueling spontaneous fires that can rage for weeks, spewing further pollutants into the atmosphere. These are just a few arrows in the quiver of environmental threats posed by these neglected landfills, demanding constant vigilance and mitigation efforts from overwhelmed authorities.

The reasons behind this bleak situation are multifaceted. Strained budgets often leave authorities struggling to secure funds for landfill reclamation or implementing advanced waste management technologies. The consequence? Continued reliance on these outdated and environmentally destructive practices. This necessitates a paradigm shift. Engineering solutions, robust monitoring programs, and a resolute commitment to environmental protection are indispensable tools to minimize the environmental footprint of these landfills.

Relevance of research. Significant reserves of biogas have accumulated in the massif of the Kyiv landfill No. 5. Due to the rather low density and good permeability of the garbage, part of the gas is released into the air. However, this landfill creates a significant negative impact on almost all components of the environment and is one of the biggest environmental problems in the region.

Therefore, research related to the calculation of the efficiency and productivity of innovative technologies, which should be laid at the design stages of modern solid waste landfills, are among the most relevant.

Given the dire circumstances, research into innovative technologies for today's landfills is of great importance. Implementation of these achievements at the stage of designing future landfills will allow Ukraine to free itself from the shackles of outdated practices. Calculating the efficiency and productivity of these new technologies is extremely important - it is an investment in a clean future.

This research paves the way for a paradigm shift in Ukrainian waste management, contributing to a future where landfills are no longer a threat to the environment, but become responsibly managed by necessity.

Aim of the work – study of the impact on the environment of man-made threats of the Kyiv solid waste disposal site No. 5, and the proposal of engineering and technical solutions to minimize this problem.

Objectives of the work:

1. Analysis of environmental issues associated with municipal solid waste landfills.
2. Calculation of the approximate volume of biogas yield of the Kyiv landfill
3. Rationale for installing a biogas plant at a solid waste landfill
4. Calculation of damaging factors in case of possible accidents.
5. Perform a feasibility study for the installation of a biogas plant at a landfill.

Object of research is disposal of organic waste.

Subject of research is estimation of the volume of methane that can be extracted from a specific solid waste landfill.

Methods of research – analysis, synthesis, comparison, statistical and calculation methods.

Personal contribution of the graduate: collection of data on MSW composition, landfill size and methane generation rate, development of a model to estimate the volume of methane that can be extracted from the landfill, consideration of a possible methane extraction system.

Publications:

1. Melnychenko V., Pavliukh L. "Green technologies" to strengthen the state's energy stability. *НОВІТНІ ДОСЯГНЕННЯ БІОТЕХНОЛОГІЇ.* VII Міжнародна науково-практична конференція «Новітні досягнення біотехнології»: 21–22 вересня 2023: тези доповідей Київ, 2023. С. 16-17.
2. Melnychenko V. STANDARDIZATION OF BIOGAS IN UKRAINE. *Environmental Safety of the State*: abstracts of XVII Pan-Ukrainian Scientific and Practical Conference of Young Scientists and Students, Kyiv, April 18, 2024. P. 41-42.
3. Melnychenko V., Pavliukh L. ECONOMIC AND ECOLOGICAL BENEFITS OF ORGANIC WASTE RESYCLING. Перші практичні дії та проблемні питання

реалізації Закону України «Про управління відходами»: збірка матеріалів Національного форуму «Поводження з відходами в Україні: законодавство, економіка, технології» (м. Івано-Франківськ, 21–23 листопада 2023 р.). С. 170-174.

CHAPTER 1
LANDFILLS OF SOLID DOMESTIC WASTE AS A DANGEROUS FACTOR OF TECHNOLOGICAL ENVIRONMENTAL POLLUTION

1.1. The concept of solid household waste

Human activity causes the formation of solid waste. Gaseous and liquid wastes are quickly absorbed by the natural environment, unlike them, solid wastes are assimilated for tens and hundreds of years. Solid waste storage sites occupy large areas. Every year in Ukraine, about 10 tons of waste are generated per inhabitant of the country, against 5 tons, as is the case in the countries of the European Union. The percentage of utilization and disposal of waste is practically zero. According to the statistical data, the amount of waste accumulation for the period 2010-2021 is shown in Table 1.1.

In total, the country accumulated about 13.5 billion tons of waste (as of 2021). The volume of solid waste generation in Ukraine is 6.5 times higher than in the USA and 3.2 times higher than in the EU countries. The problem of waste is mainly a problem of cities, the bigger the city, the more waste [1].

Table 1.1

Dynamics of waste generation on the territory of Ukraine

Year	Generated	Disposed of	Incinerated	Disposed of in specially designated places or objects	Total accumulated waste for utilization, in specially designated places or objects
2010	425,914.2	145,710.7	1,058.6	336,952.2	13,267,455.0
2011	447,641.2	153,687.4	1,054.5	277,106.8	14,422,372.1
2012	450,726.8	143,453.5	1,215.9	289,627.4	14,910,104.7
2013	448,117.6	147,177.9	918.7	288,121.1	15,167,368.9
2014	355,000.4	109,280.1	944.7	203,698.0	12,205,388.8
2015	312,267.6	92,463.7	1,134.7	152,295.0	12,505,915.8
2016	295,870.1	84,630.3	1,106.1	157,379.3	12,393,923.1
2017	366,054.0	100,056.3	1,064.3	169,801.6	12,442,168.6
2018	371,849.1	112,314.3	1,249.7	170,272.2	12,794,214.8

2019	389,722.3	119,192.1	1,321.4	176,206.8	13,117,133.4
2020	331,912.1	99,837.5	878.1	157,222.5	13,071,177.9
2021	357,149.8	112,415.0	987.2	162,742.6	13,428,925.4

According to the Law of Ukraine "On Waste Management " - "household waste" is waste generated in households, as well as waste from small enterprises and institutions, which are similar in composition to household waste. This applies, in particular, to waste from cooking, packaging, paper, textiles, furniture, electrical and electronic equipment, as well as construction waste.

Solid waste - the remains of substances, materials, objects, products, goods, products that cannot be used for their intended purpose in the future. So it can be said that components of raw materials that are not used in the production of products, or substances and energy that arise during technological processes and cannot be disposed of in this production, are called waste [6].

Secondary material resources (SRM) - a collection of all types of waste that can be used as the main or auxiliary raw materials for the production of new products. Real VMR are those resources for which effective methods and technological schemes for processing have been created. Potential VMR are those resources that are not real [8].

According to forecasts of the Institute of Environmental Economics and Sustainable Development of the National Academy of Sciences of Ukraine, the rate of MSW generation per unit of population is up to.

In 2020, it should increase to 347 kg/year, and in 2030 - to the level of 395 kg/year [20].

The dynamics of solid waste generation in the EU can be very clearly traced, depending on the country's industrial development, population density and its standard of living. The industrialized and wealthier West of Europe generates much more household waste than the countries of the East. According to the latest Eurostat data, compared to Ukraine in terms of population, Spain generates 440 kg of MSW/person (Ukraine – 280,5 kg/person). Ukraine's territorial neighbors, Poland and Romania, generate 364 kg/person and 301 kg/person, respectively.

In Ukraine, the densely populated regions of the east and south, as well as the city of Kyiv, generate the largest amount of MSW. At the same time, only 3/4 of the country's population is covered by solid waste removal services. Note that the official statistical data of the Ministry of Regions are largely approximate. Due to the fact that there is practically no practice of weighing solid household waste in Ukraine, accounting is usually carried out in units of volume (cubic meters). Recalculation in units of mass (t) is carried out based on the density of MSW, which is about 0.2-0.3 t/m3 [12].

Table 1.2

Amount of waste generation in different European countries, kg/person

Country	Waste Generation (kg/person)
Austria	827
Denmark	787
Luxembourg	720
Cyprus	640
Ireland	609
Germany	617
Italy	485
Greece	473
Spain	440
France	506
EU Average	513
Czech Republic	436
Slovakia	412
Hungary	381
Slovenia	378

Poland	364
Estonia	373
Romania	301
Ukraine	280.5

In statistical reporting, there are sometimes numerical inconsistencies, when, for example, the volume of MSW transported or buried in a certain region slightly exceeds the volume generated. Most likely, this is related to the receipt of data from various sources - from ZHEKs, carriers, landfills and other participants. Small errors in the local calculations of each of the enterprises lead to similar inconsistencies on the scale of the region. It can also be caused by the assignment of other types of waste to solid waste, for example, the disposal of industrial waste at solid waste landfills [6].

1.2. Problems of anthropogenic land pollution by landfills solid household waste

One of the most acute environmental problems of today, which requires an urgent solution, is the generation and accumulation of a large amount of solid household waste (MSW) (Table 1.3). Removal of household waste to landfills means transferring unnecessary and sanitary hazardous substances from one place to another: from the city to the city.

Finding free land near large cities becomes a significant problem [25].

Abroad, more and more countries are abandoning such an outdated way of solving the problem. In the leading European countries (Denmark, Sweden, Belgium, the Netherlands, Germany, Austria, etc.), less than 20% of solid household waste is landfilled, and the remaining 45-60% is processed as recycled material, 25-35% of waste is incinerated. In the plans of these countries, in 5-7 years, to completely stop burying solid household waste in landfills.

In the private sector, due to the lack of a proper solid household waste collection system, thousands of spontaneous landfills are formed that cannot be accurately accounted for.

It should also be noted that the number of landfills in Ukraine significantly exceeds the number of landfills [24].

When solid household waste is placed in landfills and landfills, the negative impact on the natural environment consists in the disturbance of landscapes, pollution of soils, air basins, surface and underground waters, which leads to the degradation of natural ecosystems, changes in living conditions and the state of health of people [12-14].

Table 1.3

Management of household and similar waste

Year	Waste Collected (thousand tons)	Waste Disposed (thousand tons)	Including Landfill Disposal (thousand tons)	Incinerated for Energy Recovery (thousand tons)	Incinerated Without Energy Recovery (thousand tons)	Utilized (thousand tons)	Including Composting (thousand tons)	Per Capita (kg)
2011	10356.5	7030.0	4321.5	154.0	98.5	74.5	...	226.6
2012	13878.0	9362.7	5175.1	149.9	78.6	57.4	...	304.3
2013	14501.0	9504.4	5178.5	147.6	2.9	9.4	...	318.7
2014	10748.0	5893.8	3397.9	149.0	3.8	3.8	...	250.0
2015	11491.8	6233.0	4194.3	254.3	2.1	4.0	...	268.5
2016	11562.6	6089.5	4208.1	257.3	2.0	6.5	...	271.0
2017	11271.2	6469.0	4417.5	244.4	1.2	16.5	8.2	265.3
2018	12135.4	7234.1	4874.2	261.7	1.4	18.0	9.5	278.1
2019	12778.2	7712.3	5142.8	273.5	1.3	20.7	10.2	294.2
2020	11223.1	6649.2	4409.5	235.2	1.5	13.0	7.8	258.5

Practice has shown that landfills of solid household waste emit harmful gases into the air, and many harmful substances into the water and soil (from heavy metals to hydrocarbons). Materials that can still be reused are lost forever. Landfills often self-ignite, and poisonous smoke spreads from them over a long distance, polluting nearby areas [21].

Solid waste has a negative effect on all components of the multi-story structure of landscapes, but a particular danger is associated with the penetration of pollutants into the soil - a geochemical barrier in which dangerous pollutants accumulate.

The state of the soil cover near the objects of man-made influence makes it possible to assess the degree of pollution and identify the most dangerous areas, because it is through the soil that the translocation of polluting elements into plants and groundwater and their subsequent migration through the trophic chain into the human body is possible [6].

In Ukraine, there are officially 5,455 landfills and landfills with a total area of more than 8.5 thousand hectares. Such data is provided by the Ministry of Regional Development, Construction and Housing and Communal Services of Ukraine. The number of landfills on the territory of Ukraine is shown in the table below (Table 1.4).

Table 1.4

The number of landfills by region

Region	Number of landfills	Region	Number of landfills
Vinnytsia	741	Kirovohrad	457
Poltava	675	Zaporizhzhia	441
Chernihiv	659	Ivano-Frankivsk	377
Odessa	608	Dnipropetrovsk	361
Zhytomyr	589	Kharkiv	352
Kyiv	576	Donetsk	347
Khmelnytskyi	534	Luhansk	325
Rivne	522	Zakarpattia	297
Sumy	489	Lviv	272
Ternopil	482	Kherson	262
Cherkasy	475	Mykolaiv	251
Volyn	462	Chernivtsi	234

The analysis of groundwater pollution at the sites of solid waste landfills shows that the content of polluting components in groundwater can significantly (by tens and hundreds of times) exceed the MPC; filtration inhomogeneity and fissures of the underlying rocks cause uneven movement of polluting components in groundwater and their long-term preservation in the aquifer [21].

The danger of solid waste landfills for human life is also caused by the presence and development of pathogenic microorganisms in them, namely: causative agents of hepatitis, tuberculosis, dysentery, ascariasis, respiratory, allergic and other diseases. The leachate, which accumulates in significant quantities at solid waste landfills, contains more than ten compounds harmful to humans [16].

The most accurate indicator of the level of organization and civilization of a country is its attitude to the problem of garbage. The highest achievement in this problem is the creation of specialized enterprises for processing and reuse of household and other urban waste [11].

Today, there are more than 400 such enterprises operating in Europe, which provide heat and electricity to more than 25 million residents at the expense of solid household waste. Some countries of the world (for example, in the USA, Israel) create large special landfills-reactors where biogas is collected and used.) Active work is now being observed to create waste processing enterprises equipped with sorting lines with manual sorting of household waste. A separate system for collecting individual components of solid waste ensures the production of relatively clean secondary resources and reduces the amount of exported waste. This is an extremely time-consuming, unproductive and sanitary ин pollute the air, water and soil with harmful substances. The release of methane and other toxic gases leads to atmospheric pollution, while the infiltration of rainwater through landfills causes contamination of ground water and water bodies.

The method of burying waste in landfills is outdated and does not meet modern environmental standards. In developed countries, this method is gradually being replaced by more sustainable practices such as recycling, composting and energy recovery. In Ukraine, unfortunately, such methods are just beginning to gain popularity, and their implementation requires serious investments and legislative initiatives.

In view of the above-mentioned problems, Ukraine should urgently switch to sustainable waste management practices. This involves increasing the level of recycling, implementing a separate garbage collection system, developing infrastructure for organic waste composting, and implementing waste-to-energy technologies. Such measures not only reduce the negative impact on the environment, but also contribute to economic growth and the creation of new jobs.

CHAPTER 2

CHARACTERISTICS OF THE MAIN TECHNOLOGICAL HAZARDS OF LANDFILL №5

2.1. Characteristics of landfill site No. 5 of the village of Pidhirtsi burial ground solid household waste

Due to the presence of gas at the landfill, fires can occur with emissions of dangerous particles into the air. Also, after precipitation under the influence of moisture, leachate is formed from garbage - a harmful liquid.

The water-bearing layer of this territory of the Poltava-Kharkiv deposits is 9-40 meters deep, the distance from reservoirs and drains is 500 m, the distance from water intakes (artesian well of the landfill) is 40 m.

The soil conditions are sandy loam, clay, sand and loam.

Kyiv solid waste landfill No. 5 is located within the development of Neogene and Quaternary formations.

Within the Neogene formations, deposits are represented by light gray, fine-grained quartz sands, sometimes iron-bearing. The thickness of the sediments is uneven and varies from 1 to 30 m. The depth of the roof of the rocks varies from 5-8 m in the beams to 40 m in the watersheds [4].

Miocene-Pliocene sediments are represented by a layer of striated and red-brown clays. These rocks are distributed locally and confined to high watersheds. The depth of their occurrence is from several to 25 m. The deposits are represented by variegated and unevenly colored clays: from greenish-gray to brownish-red in color, with traces of fertilization. Their capacity varies from 0.5 to 18 m.

Quaternary rocks represented by various genetic types: swamp, alluvial, lacustrine-alluvial, alluvial-deluvial, eluvial, eolian-deluvial, lacustrine - hydroglacial and glacial. The age of the sediments is from the Lower Quaternary to modern [7].

Lower Quaternary formations are represented by gray clays, dense, silty and heavy loams and represent a local water resistance. Their thickness is 1-3 m and rarely reaches 5 m. Lower Quaternary clays are widespread locally, because they were formed in disconnected declines to the Quaternary surface. These deposits are located within the watersheds on Miocene-Pliocene rocks. They open at depths of 10-25 m.

Undissected Middle-Upper Quaternary formations are represented by eluvial loams, eolian-glacial loess loams, lacustrine-glacial sandy loams, loams, fluvioglacial sands and moraine loams. They are widespread within watersheds and their slopes. The thickness of the deposits varies from a few meters to 25 m, with an average of 10-15 m. They lie on Lower Quaternary or Miocene-Pliocene clays, and in the case of their absence on Poltava sands. Overlapping with modern soil.

Upper Quaternary alluvial deposits are confined to the first and second floodplain terraces of the Dnipro River. They are represented by quartz, multi-grained sands with lenses of sandy loams, loams, and clays. They reach 15-18 m in strength. They are spread to the east of the territory of the solid waste landfill in the Dnipro River valley. From the surface, the Upper Quaternary sediments overlap with modern alluvial, eluvial, eolian formations or directly reach the day surface.

Upper Quaternary-modern eolian formations are represented by fine-grained quartz sands. They form disconnected mounds within the spread of the first and second floodplain terraces of the Dnipro River in the east. The thickness of aeolian sands is 1-5 m.

Modern formations are represented by alluvial and alluvial-deluvial sands, sandy loams, loams, swamp silts and peats, as well as modern soil. Alluvial and alluvial-deluvial sediments are developed along the valleys of modern watercourses and the bottoms of large streams in the form of strips with a width of 50-100 to 1 km. Their capacity reaches 15-20 m, and the average is 8-10 m.

Marsh sediments are developed in the form of isometric or elongated areas along the floodplains of modern watercourses. The thickness of silts and peats is 1-3 m. Modern soil consists of alluvial formations, humus loams and sandy loams, which are almost universally distributed. Their power is 0.3-1.0 m [9].

Kyiv landfill No. 5 of solid household waste is located near the village of Pidhirtsi, Obukhiv district, Kyiv region. The enterprise "KYIVSPETSTRANS" is engaged in the collection and disposal of waste. The land plot with a total area of 65.2 hectares is located 25 km from the city limits of Kyiv and 18.6 km from the city of Obukhiv. The nearest settlements in the area of the solid household waste landfill: p. Podhirtsi (3 km to the east), village Krenichi (1.5 km to the west).

The landfill site No. 5 is located in a geodynamically stressed area, where tectonic movements amount to +1-2 mm per year, and the relief height difference is more than 50 m. The growth rate of individual ravines in this area is on average 1-3 m/year. On the slopes of the ravines, small landslides, collapses and soil collapses develop, which contribute to the expansion of the ravine. The density of the ravine-beam network in this area is very high and is 0.9 km/km^2. Landslides - separation of earth masses and their movement down the slope under the influence of gravity. The displaced mass is called a sliding body, and the surface on which the sliding body detaches and moves down is called a sliding surface or a sliding surface [10].

Landslides in this area are confined to the steep right side of the Dnipro valley. They develop mainly on variegated clays of the Neogene. Due to the high hypsometric position of variegated clays, the conditions for the formation of landslides are equally favorable both on the banks of rivers and in ravines. Landslides and landslides at the landfill site are associated with overwetting of the slopes' soils by atmospheric precipitation, with soil erosion and waterlogging. Suphozia - washing out of dusty particles in loose rocks by underground waters, which causes the sedimentation of the stratum that lies above, with the formation of depressions, small sufosis holes and saucers on the surface. Suphosia is most widely developed in loess and loess-like soils [19].

The most dangerous places in terms of suffusion processes in the foundation of a solid waste landfill are drainage structures. Sufosis removal of the soil from under the anti-filtration screen leads to a violation of its integrity and leachate release through the drainage system. According to the landscape-geochemical zoning, the Kyiv solid waste landfill is located in a zone with the ability to self-clean and accumulate [22].

These landscapes are developed on loess and crystalline rocks. Within them, the downward and upward migration of chemical elements, as well as the areal washing of heavy metals with the soil layer and unloading of groundwater in the lowered part of the relief (river valleys, bottoms of ravines) are clearly visible. These processes contribute to the cleaning of landscapes from man-made pollution. At the same time, landscapes of this class are subjected to significant ecological and geochemical loads due to pollution by heavy metals and toxic substances entering the environment with waste.

2.2. Problems of ecological and man-made safety of the landfill

Solid household waste landfill No. 5 was opened in 1986. Its purpose is to dispose of solid waste from the city of Kyiv and the Kyiv region. Landfill No. 5 in the village of Pidhirtsi is the largest in Ukraine. Since 1986, garbage has been brought here from Kyiv and nearby settlements. (Fig. 2.1.).

Fig. 2.1. Spatial location of the waste body of landfill No. 5 on the GoogleEarth satellite image.

For a long time, waste disposal at the landfill was carried out without observing technological and sanitary standards, which led to the emergence of a number of man-made problems that pose a danger to the environment and human health.

Fire hazards.

The household waste landfill is a special object, it is a place where a large volume of combustible materials is concentrated: paper, polyethylene, plastic (the latter emits a large amount of carcinogens when burned, which are especially dangerous for human life) [33].

Fire occurs for several reasons:

• burning garbage is brought;

• arson (frequent occurrence).

There is still a possibility of lightning striking the landfill, but the main reason is considered to be the so-called spontaneous ignition of landfills. Landfill gas - methane - is formed over time from the organic component of garbage (food waste, paper, leaves and branches). Each landfill is a huge bioreactor, in the bowels of which, as a result of the anaerobic decomposition of waste of organic origin, this biogas is formed. Biogas generation occurs not only during the operation of landfills, but also for ten years after their closure [31]. The uncontrolled spread of landfill gas into the environment causes negative effects of both local and global nature, namely:

— occurrence of fires due to spontaneous release of landfill gas;

— saturation of the pore space of the soil environment with biogas, which causes asphyxiation of the root system of plants;

— gas contamination of buildings and underground communications

— poisoning of people and animals;

— strengthening of the greenhouse effect due to the emission of biogas.

The most vulnerable part of the landfill is the slopes of the landfill, they are easier to set on fire and extremely difficult to extinguish, and slopes often reach 10-15 meters in height [32].

Biogas utilization system at the landfill.

At the Kyiv landfill No. 5, reclamation work is ongoing, a large part of which is devoted to the degassing process. Degassing consists in the removal of harmful gases produced during the decomposition of waste. Degassing methods used at the landfill include active and passive systems such as gas wells, ventilation systems, and special gas collectors. The effectiveness of these measures is extremely important for the protection of the environment, as it reduces the concentration of methane and other dangerous gases, contributing to the reduction of greenhouse gas emissions and the improvement of air quality. Reclamation of the landfill after successful degassing opens up prospects for its further use, for example, for the creation of recreational areas or other socially useful objects, which will contribute to the ecological and social development of the region. Therefore, the multilateral approach to degassing and reclamation of the Kyiv landfill No. 5 demonstrates positive prospects for ensuring environmental safety and sustainable development.

2.3 Conclusion to Chapter 2

Polygon No. 5 is located in the Kyiv region, Ukraine, near the village of Pidhirtsi. This landfill has been operating since 1986 and has become the object of numerous environmental and technical problems that require an immediate solution. Polygon No. 5 contains a large amount of combustible materials such as plastic, paper and other waste, which are easily ignited, especially when combined with methane produced by the decomposition of organic matter. This set of factors significantly increases the risk of fire. such incidents can be caused not only by human activity, such as arson, but also by natural factors such as heat and spontaneous combustion. The consequences of such fires can be devastating, they threaten local infrastructure, human health and lead to significant damage to the air with toxic substances and smoke, which can spread over significant distances

The problem of gases generated in landfills includes a wide range of environmental challenges. Methane, which is one of the main components of these gases, not only contributes to the parity effect. but it also has dangerous properties. Uncontrolled migration of methane can lead to explosions, leaks and other catastrophic events. In addition, moisture accumulation in the soil can destroy vegetation, reducing soil fertility and destroying natural flora. The contact of methane with groundwater can lead to its pollution, which endangers the quality of drinking water for local communities. All these aspects are modified after the end of monitoring and control of gas emissions at landfill No. 5. The presence of methane gas at the landfill is a serious environmental problem. Methane, being one of the most aggressive greenhouse gases, can spread uncontrollably, covering a significant area of landfills. Uncontrolled migration of methane can lead to a whole range of low-level negative consequences, from the subsequent desires that create high employment, to the death of plants due to lack of oxygen and poisoning of the soil. In addition, inhalation of methane is dangerous for public health, causing poisoning headaches, dizziness and other cepilous symptoms. Ultimately, it also greatly worsens the wig effect, creating the conditions for global warming that leads to climate change.

Putrefying waste in landfills creates a harmful leachate of a weak substance, which contains dangerous chemicals and microorganisms that can cause diseases in humans and animals. This leachate penetrates deep into the soil, contaminating the groundwater, which can be a source of drinking water for the local population. Groundwater pollution is stereotypically widespread, turning into a global problem. In addition, releasing this destructive cocktail into the surface field pollutes the development of the lake and lake system, which can lead to mass kills of fish and other aquatic flora and fauna. These are risks not only for human health, but also for a whole range of ecosystems that depend on these water resources.

CHAPTER 3
FEASIBILITY OF INSTALLATION OF A BIOGAS PLANT ON THE BASE OF CALCULATION METHODS OF RESEARCH

3.1. Calculation of the approximate volume of biogas of the Kyiv landfill No. 5 solid waste

A solid waste landfill is a kind of biochemical reactor, in the bowels of which, under certain conditions, the processes of anaerobic decomposition of components of organic origin develop, as a result of which biogas is generated. The creation of landfill gas (methane fermentation) occurs at temperatures from 10°C to 50°C. At the same time, the humidity accompanying gas formation processes can vary from 8% to 90% (the optimal humidity of waste for gas generation is 40-50%). A necessary condition for the formation of biogas is the absence of oxygen in the massif of the landfill [5].

The composition of biogas determines a number of its specific properties. First of all, it is flammable. The average calorific value of biogas combustion is 5530 kcal/mZ. In certain concentrations, biogas is toxic. Specific indicators of its toxicity are determined by the presence of trace elements, such as hydrogen sulfide (H2S). As a rule, landfill gas is characterized by a sharp, unpleasant smell. Approximate composition of biogas: methane - 40-60%, carbon dioxide - 30-45%, nitrogen, hydrogen sulfide, oxygen, hydrogen and other gases - 5-10%. The calorific value of biogas is 18-25 MJ/m^3. Explosiveness limits of a mixture of biogas with air are 5-15% [15].

The mixture of biogas with air is explosive. The threshold of explosive concentrations of methane in the air varies between 5-18%. Biogas is also one of the so-called greenhouse gases, which gives it a category of global importance and makes landfill gas the object of close attention of the world community [28].

To reduce the ingress of biogas from the MSW landfill into the atmosphere DBN V.2.4-2- 2005 "Solid Household Waste Landfills. The main provisions of the design" [3] makes mandatory the implementation of measures regarding the degassing of PTPV, aimed at the maximum collection and utilization of biogas due to forced pumping of it from the body of PTPV and further utilization as fuel for engine-generators in order to obtain thermal and electrical energy. The collection of landfill (landfill) biogas also allows to reduce the amount of dangerous toxic, including carcinogenic, organic compounds (aromatic hydrocarbons, formaldehyde, dioxins, etc.) entering the atmospheric air from the surface of the landfill [30].

Although the determination of the effectiveness of such a project requires additional research to obtain objective data on site, there are several methods that allow estimating the estimated amount of gas released from the body of the landfill (clause 3.76 DBN B.2.4-2-2005) [3].

Forecasting the amount of biogas released is made taking into account the composition and properties of MSW, the capacity and term of operation of the MSW landfill, the scheme and maximum height of MSW storage, the hydrogeological conditions of the MSW storage area, the pH of the water extract from MSW.

It is recommended to calculate the expected amount of biogas released during anaerobic decomposition of solid waste according to the formula (3.1), item 3.76/ [3]:

$$V_{r.b} = P_{sdw} \times C_{l.o} \times (1 - Z) \times Kr, \quad (3.1)$$

$$V_{r.b} = 17100000000 \times 0.5(1\text{-}0.5) \times 0.45 = 1923750000 \text{ m}^3$$

where $V_{r.b}$ is the estimated amount of biogas, m3;

Psdw - total mass of solid waste stored at the landfill, kg;

$C_{l.o}$ - the content of easily decomposable organic matter in 1 ton of waste ($C_{l.o}$= = 0.4-0.7);

Z - ash content of organic matter (Z = 0.2-0.3);

Kr is the maximum possible degree of anaerobic decomposition of organic matter during the calculation period (K_r = 0.4-0.5).

Taking into account unforeseen circumstances, the specific volume of biogas that can be collected from 1 ton of solid household waste during the entire period of operation of the biogas collection system is determined by the formula:

$$V'_{r.b} = V_{r.b} \times K_c \times K, \quad (3.2)$$

where V'r.b is the volume of biogas that can be collected from 1 ton of solid waste, m^3;

K_c - coefficient of efficiency of the biogas collection system ($K_c = 0.5$);

K- coefficient of correction for unforeseen circumstances (K = 0.65-0.70).

At the same time, the following values should be taken into account:

- weight amount of biogas obtained during anaerobic decomposition of 1 g of biogas from 1 g of decomposed ashless solid waste material;

- volume mass of biogas - 1 kg/m^3;

- calorific value of biogas 5000 $kcal/m^3$ (~21 MJ/m^3).

In this way, we introduce an additional coefficient β in the dimension of 0.806×10^{-5}:

$$V'r.b=1923750000 \times 0.5 \times 0.7 \times 0.806\times10^{-5}$$

$$V'r.b= 5426 \text{ from 1 t of solid waste, } m^3$$

Since this calculation according to the DBN of the expected amount of biogas released during the anaerobic decomposition of one ton of solid waste does not take into account the duration of biogas formation in the body of the solid waste landfill, to determine the amount of biogas formed at the landfill, the empirical dependence of methane formation on the number of solid waste storage, which is widely is used in the calculation model of the Environmental Protection Agency (USA):

$$Q = L0 \times R \times \left(e^{-k\times c} - e^{-k\times t}\right), \quad (3.3)$$

$$Q = 5426 \times 450000(e^{-1/6 \times 0} - e^{-1/62\times 38})$$

$$Q \sim 1118850000 \ m^3/year = 1118850000/365/24 = 127722 \ m^3/hour$$

where:

Q - the amount of methane produced during the year, m^3/year;

L0 - methane formation potential, m3/ton of solid waste

R - the average amount of solid waste transported to the landfill, t/year;

k- constant amount of methane formation, 1/year;

c - time since the landfill was closed, years;

t - time since the opening of the landfill, years.

According to the calculation according to the formula (3.3), the amount of biomethane generated at landfill No. 5 is approximately 131849 m^3/hour.

After the MSW landfill is closed, the organic part of MSW continues to decompose, producing biogas. The basic raw data that were used for the calculation:

• The beginning of the importation of solid waste - 1986.

• Imported in 2023 – 450,000 tons of solid waste.

• Accumulated amount of solid waste (2023 data) – 17.1 million tons of solid waste.

• The average depth of the landfill is 60 m.

• The expected term for landfill reclamation is 2024.

Based on the results of calculations based on the given data of the landfill and the amount of possible utilized biogas, the installed capacity of the generating equipment using the biogas from the degassing of the landfill was calculated.

Analyzing the calculated data, it can be concluded that a project for the construction of a complex for the collection and utilization of landfill gas with a total installed capacity of 5000 kW (productivity in 2026) to 5800 kW (productivity in 2028) can be guaranteed to be implemented at this landfill site. The modular execution of generator units allows to increase the produced power in proportion to the number and power of individual units. In the future, depending on the depletion of the biogas flow from the body of the solid waste landfill, part of the generating modules can be dismantled and installed at other solid waste landfills.

3.2. Biogas utilization equipment and impact calculation factors in case of possible accidents

For the collection and disposal of landfill gas, it is most appropriate to use a cogeneration plant.

Cogeneration is a highly efficient use of the primary energy source - in this project, biogas, for obtaining two forms of useful energy - heat and electricity [33].

The main advantage of a cogenerator over conventional thermal power plants is that energy conversion takes place here with great efficiency. In other words, the cogeneration system allows the use of heat that is normally lost. At the same time, the need for energy is reduced by the amount of thermal and electrical energy produced, which contributes to the reduction of production waste. Installations based on gas (gas piston) engines are characterized by the greatest efficiency, reliability and versatility. This is caused, first of all, by modern requirements for the ecological cleanliness of the environment, as well as the reduction of operating costs for organic fuel and the availability of its use. Gas engines are used to work as part of generator sets designed for continuous and periodic operation (removing peak loads) with combined production of electricity and heat.

It is advisable to use the cogeneration plant in a container version (Fig. 3.1.). Biogas collected from a solid waste landfill,

will be used as fuel for gas-piston engines that transmit mechanical energy to electric generators of cogeneration plants.

Fig. 3.1. Cogeneration plant in container design

It was established that the most effective from the point of view of operation is the installation of four CHPs with a total installed electric power of 55 MW (10x500 kW). The capacities of CGU engines operating on methane and biogas are practically the same.

The thermal power provided by the cooling jackets of engines running on methane and biogas is not the same, and is 525 and 560 kW, respectively. The heat can be used for hot water supply and heating of the production facilities of the solid waste landfill. Excess heat in the summer will be dissipated into the environment with the help of emergency coolers located on the roof of the container.

If the tightness of the technological systems of the proposed gas cogeneration plant is damaged, there is a possibility of an explosion and fire. In order to determine the affected zone and establish the expediency of using this installation, a number of calculations were carried out in this work.

Energy indicators of explosiveness of gas cogeneration plants are the following criteria:

- Total energy potential of the installation - (E), characterized by the sum of energies of adiabatic expansion of the vapor-gas phase, complete combustion of existing and newly formed vapors from the liquid due to internal and external energy during emergency opening of the equipment, kJ.

- The total mass of combustible vapors of an explosive vapor-gas cloud (m) is reduced to a single specific energy of combustion, kg.

- The relative energy potential of the explosion hazard (Oв) of the technological unit.

Calculations:

The mass of methane contained in the casing and technical gas collectors in the cogeneration plant according to the technical characteristics [30]:

V (gas) = 2 m^3;

1 m^3 (gas) = 2 kg;

Gtheoretical (gas) = 2 kg;

Gpractical (gas) = 2·0.85 = 1.7 kg.

We find the total energy potential of the explosion hazard (E) of the cogeneration plant [42-43]:

$$E = \Sigma G \cdot q, \quad (3.4)$$

where: G is the mass of methane in the casing and technical gas collectors, qi is the specific heat of gas combustion, kJ/kg; q = 49800 (kJ); E = 1.7·46300;

E = 78,710 (kJ/kg).

We find the total mass of combustible gases of an explosive vapor-gas cloud (m), reduced to a single specific energy of combustion, which is equal to 46000 kJ/kg (3.5):

$$m = E/4.6 \cdot 104 \text{ (kg)}, \quad (3.5)$$

m = 78 710/46000;

m = 1.711 (kg).

We find the relative energy potential of the explosion hazard (Qв) of the cogeneration plant using the formula (3.6):

$$Q_B = (1/16.534) \cdot 3\sqrt{E}, \quad (3.6)$$

$$Q_B = (1 / 16.534) \cdot 3\sqrt{78\ 710};$$

$$Q_c = 2.592.$$

According to the values of the relative energy potential (Q_B) and the reduced mass of methane (m), the gas cogeneration plant belongs to the III class of explosion hazard.

The calculation of the impact zones of the impact factors of explosions is carried out by calculating the TNT equivalent of an explosion of a steam-gas environment.

The TNT equivalent of a steam-gas explosion (WT), which is determined by the conditions of the adequacy of the nature and degree of destruction in the case of explosions of vapor clouds and concentrated BP, is calculated by the formula (3.7):

$$W_r = \frac{0{,}4q'}{0{,}9q_T} \times z \times m, \quad (3.7)$$

where: W_T - TNT equivalent, kg; 0.9 - the share of trinitrotoluene (TNT) explosion energy spent on the formation of a shock wave; 0.4 - the share of the energy of the explosion of the vapor-gas medium, which is spent directly on the formation of the shock wave; q' - specific heat of combustion of steam-gas medium, kJ/kg; qT - specific TNT explosion energy, kJ/kg. For the calculation of TNT equivalents, the heat of detonation of TNT is taken as 4520 kJ/kg. z is the fraction of the reduced mass of the steam involved in the explosion, m is the reduced mass of PGS, kg (based on the calculation of the energy potential).

For unorganized vapor clouds in an open space with a large mass of combustible substances, the proportion of substance participation in the explosion z can be taken as 0.1.

$$W_r = \frac{0{,}4 \times 78710}{0{,}9 \times 4520} \times 0{,}1 \times 1{,}711$$

$$W_T = 1{,}324 \text{ kg}.$$

The radii of the destruction zones are determined by the formula (3.2.5):

$$R = K \times R_0, \quad (3.8)$$

where: at *m* < 5000 kg

$$R_0 = \frac{\sqrt[3]{W_T}}{\left[1+\left(\frac{3180}{W_T}\right)^2\right]^{1/6}};$$

$$R_0 = \frac{\sqrt[3]{1,324}}{\left[1+\left(\frac{3180}{1,324}\right)^2\right]^{1/6}};$$

R_0 = 0,09 м.

Then calculation of the radius of the lesion (3.9):

$$R_n = K_n \times R_0, \quad (3.9)$$

• the radius of the zone of complete destruction of buildings and mortal danger to people:

$R_1 = K_1 \cdot R_0 = 3.8 \cdot 0.09 = 0.342$ m – the radius of the zone with excess pressure in the expected epicenter of the explosion $\Delta P \geq 100$ kPa;

• the radius of the zone of severe destruction of building structures, collapse of brick walls and mortal danger to people:

$R_2 = K_2 \cdot R_0 = 5.6 \cdot 0.09 = 0.504$ m – the radius of the zone beyond which the excess pressure at the front of the expected shock wave is 100 kPa<ΔP<70 kPa;

• the radius of the zone of medium destruction of building structures and mortal danger for people in the open area:

$R_3 = K_3 \cdot R_0 = 9.6 \cdot 0.09 = 0.864$ m - the radius of the zone outside which the excess pressure at the front of the expected shock wave is 70 kPa<ΔP<28 kPa;

• the radius of the zone of weak destruction (destruction of window openings, easily removable roofs) and severe injury to people in an open area:

$R_4 = K_4 \cdot R_0 = 28 \cdot 0.09 = 2.52$ m - the radius of the zone outside which the excess pressure at the front of the expected shock wave is 28 kPa<ΔP<14 kPa;

• the radius of the zone of partial destruction of the glazing, which is safe for people in the open area:

$R_5 = K_5 \cdot R_0 = 56 \cdot 0.09 = 5.04$ m - the radius of the zone outside which the excess pressure at the front of the expected shock wave is 14 kPa<ΔP<2 kPa.

According to the calculations, it can be seen that the radii of the destruction zones will be so small that only the equipment of the installation itself will fall into the affected zone. Thus, it can be concluded that this installation model is quite safe in terms of explosion and fire hazards.

3.3. Technical and economic efficiency of the proposed solution

It is planned to sell electricity from landfill biogas at the "green" tariff of 401.85 kopecks/kWh. (according to the Laws of Ukraine: "On Electric Power" dated 10/16/1997 No. 575/97-BP as amended, "On Amendments to Certain Laws of Ukraine Regarding Ensuring Competitive Conditions for the Production of Electricity from Alternative Energy Sources" dated June 4, 2015 No. 514-USh), Resolutions of the NCREKU dated 29.12.2017 No. 1617 "On the establishment of "green" tariffs for electric energy for business entities and a surcharge to "green" tariffs for compliance with the level of use of Ukrainian-made equipment", and it is advisable to use thermal energy in the future for local needs, for example, in the technological process of waste sorting, high-temperature destruction of hazardous waste, for heating outbuildings of a solid waste landfill.

The results of the preliminary calculation of the efficiency of the installation of the KGU with the disposal of landfill gas of landfill No. 5TPV [20] are shown in Table 3.1. using the data given in the technical passport of the equipment to be used and the main characteristics of the biogas installation [30]. At the same time, the NBU exchange rate for 05/15/2024 was used (1 US dollar = 39.70 UAH).

When calculating the amount of electricity produced per year, the product of 90% of the recommended installed capacity of the KGU (5000 kW) and the number of hours worked per year was calculated [18]:

$$4500 \times 24 \times 365 = 39420000 \text{ kWh/year};$$

The cost of electricity produced according to the "green" tariff for a year is calculated by multiplying the quantitative value of the "green" tariff (401.85 kopecks/kWh) and the amount of electricity produced per year (39420000 kWh/year):

$$401.85 \times 39420000 = 15840927000 = 158409270 \text{ UAH/year};$$

The amount of total capital costs consists of capital costs for equipment and capital costs for construction and is:

$$260441520 + 321560080 = \text{UAH } 582001600;$$

In this way, a simple payback period will be calculated by the ratio of total capital costs to the cost of electricity produced under the "green" tariff for a year:

$$158409270 \div 582001600 = 0.27 \approx 3.8 \text{ years}.$$

Table 3.1

The results of the preliminary calculation of the installation efficiency of an electric power plant with disposal of landfill gas of a solid waste landfill

Name values	**Value**	**Dimensionality**
weekend data		
Intensity collection biogas	127722	m^3/hour
Recommended installed power of KSU	5000	kW(e)
Operational expenses for the year		
Capital expenses for KSU equipment	260441520	UAH
Capital construction costs and additional materials	582001600	UAH
Technical and economic Indexes efficiency implementation of the measure		
Number electricity that produced in a year	39420	MWh/ year
Cost of electricity produced under the "green" tariff per year	158409270	hryvnias/ year

Total capital costs	582001600	UAH
Simple term payback	3.8	year

The calculations did not take into account environmental payments (for environmental pollution with waste), investment costs for creating a greenhouse economy and potential income from its operation [23]. The production of electricity with the utilization of heat makes it possible to improve the economic indicators of the project in comparison with the production of only electricity.

3.4 Conclusion to Chapter

In today's conditions of active development of environmentally friendly power technologies, recycling and the use of renewable resources is gaining more and more importance. One of the promising directions is the installation of biogas plants at landfills for generating electricity and heat. In this context, the possibility of installing a biogas plant at landfill No. 5 in Kyiv is considered, as it can potentially provide numerous economic and environmental benefits.

One of the main parameters that determines the feasibility of installing a biogas plant is the presence of methane, which is formed as a result of the decomposition of organic waste. According to calculations, the annual production of methane at landfill No. 5 is approximately 131,849 cubic meters per hour. Such a significant amount of gas can be effectively used for energy generation, which makes the project economically and energetically profitable

Based on the methane potential analysis, it is recommended to install a cogeneration plant with a total capacity of 5,000 kW with the possibility of expansion to 5,800 kW. Such an installation will allow efficient use of the collected methane for the production of both electricity and heat. It is the combination of two types of energy that makes cogeneration plants particularly efficient.

According to the calculations, the proposed biogas plant is classified as an object with a low level of explosion hazard. This is due to the limited amount of gas stored at the facility. Thus, the project meets modern safety standards and excludes the risk of major accidents.

The assessment of the economic feasibility of the project showed that the generated electricity will be sold using the "green tariff". project effectiveness.

In general, the installation of a blue gas plant at landfill No. 5 is a technically feasible and economically justified project. Considering the great potential of available methane and the presence of profitable tariffs for "green electricity", the project looks promising from the point of view of long-term investments.

In addition to economic benefits, the implementation of the project will contribute to reducing the negative impact on the environment by reducing greenhouse gas emissions Use of methane. that would otherwise have been released into the atmosphere, will allow for a cleaner environment and promote the development of renewable energy sources.

CONCLUSIONS

1. One of the most acute environmental problems of today, which requires an urgent solution, is the generation and accumulation of a large amount of solid household waste and the problem of its further management. The sources and composition of household waste are diverse, ranging from organic matter and plastics to metals and glass, each presenting unique challenges in terms of disposal and recycling. The impacts of waste accumulation on the environment are profound and multifaceted, contributing to pollution, habitat destruction, and adverse effects on wildlife and human health. Effective waste management faces numerous challenges, such as inadequate infrastructure, insufficient public awareness, and the financial and logistical difficulties of implementing large-scale recycling programs. However, sustainable waste management solutions, including reducing waste generation, enhancing recycling efforts, and adopting waste-to-energy technologies, offer promising avenues for mitigating these issues. Policy recommendations for improved waste management emphasize the need for stringent regulations, comprehensive waste management strategies, and international cooperation to address the global nature of this problem. In conclusion, tackling the issue of household waste requires a multifaceted approach that incorporates technological Innovation, public participation, and robust policy Frameworks to ensure a cleaner, healthier environment for future generations.

2. The staggering magnitude of the waste crisis in Ukraine underscores a significant environmental and policy challenge. With a total of approximately 12.5 billion tons of waste, Ukraine's volume of solid waste generation is notably 6.5 times higher than that of the United States and 3.2 times higher than that of European Union countries. This discrepancy highlights not only the inefficiencies and systemic issues within Ukraine's waste management infrastructure but also the broader environmental implications such as increased pollution, land degradation, and potential health risks to the population. Addressing this crisis necessitates comprehensive policy recommendations that include the

adoption of advanced waste management technologies, stringent regulatory frameworks, and robust public awareness campaigns. By integrating these strategies, Ukraine can aim to align its waste management practices with international standards, ultimately mitigating the adverse environmental impacts and fostering a more sustainable future.

3. In our country, the primary method of waste disposal, with a staggering 80% reliance, involves burying waste at solid waste landfills. This practice, while common domestically, is increasingly being abandoned by numerous nations abroad in favor of more sustainable solutions. Leading European countries such as Denmark, Sweden, Belgium, the Netherlands, Germany, and Austria exemplify this shift by landfilling less than 20% of their solid household waste. Instead, they have adopted more advanced waste management strategies, with 45-60% of waste being processed into recycled material and 25-35% subjected to incineration. This stark contrast between domestic and European waste disposal methods highlights the need for our country to reconsider and modernize its waste management practices, potentially drawing on the successful models employed by these European counterparts.

4. The operation of the Kyiv solid waste landfill No. 5 is marked by significant environmental problems, primarily due to the practice of only partial compaction of the surface layers of waste. During the entire period of operation, this landfill allowed the penetration of atmospheric precipitation and surface runoff into the body of the landfill. These inadequate sealing measures have resulted in the landfill becoming easily accessible to stormwater and other forms of surface water, which in turn has led to significant saturation of the landfill with infiltration waters, also known as leachate. As these leachates seep through the waste, they become contaminated with a variety of harmful substances. Such pollution poses a serious risk to the quality of groundwater and the surrounding ecosystem. These factors highlight the critical need for comprehensive compaction techniques and enhanced waste management protocols to effectively mitigate these adverse environmental impacts. But in recent years, reclamation work has begun at the landfill, which should solve these problems, but garbage is still taken there due to the lack of other options.

5. Kyiv Landfill No. 5 serves as a significant repository for a vast array of household waste, comprising a substantial volume of combustible materials such as paper, polyethylene, and plastic. Notably, the incineration of plastic poses grave health risks due to the emission of carcinogenic substances, which carry heightened dangers for human life. An essential byproduct of this landfill is methane gas, which originates from the decomposition of organic waste materials including food remnants, paper, and plant debris. The formation of methane within the landfill presents a considerable hazard, as its uncontrolled dispersion can lead to spontaneous combustion, thereby exacerbating the threat of fires. This interplay of chemical and biological processes highlights the pressing need for effective management strategies to mitigate the inherent risks associated with Kyiv Landfill No. 5, emphasizing the importance of regulatory oversight and innovative waste handling approaches. By addressing these concerns, the potential for environmental and public health preservation is significantly enhanced.

6. It is guaranteed to implement the construction project of a landfill gas collection and utilization complex with a total installed capacity of 5,000 kW (productivity in 2025) to 5,800 kW (productivity in 2027) at landfill No. 5 of solid household waste. The modular execution of generator sets allows to increase the produced power in proportion to the number and power of individual units.

7. In terms of operation, it is proposed to install ten cogeneration units (model PG620B1, manufacturer FG Wilson (Great Britain), PERKINS engine) with a total capacity of 5 MW (10x500 kW).

8. According to the calculations, it can be seen that the radii of the destruction zones during the plant accident will be so small that only the equipment of the plant itself will fall into the affected area. Thus, it can be concluded that this installation model is quite safe in terms of explosion and fire hazards.

9. The system can pay for itself in just 3.8 years, significantly boosting the project's economic viability. Optimized resource use leads to increased energy efficiency and cost savings, underscoring the importance of maximizing return on investment and improving

profitability. This assessment highlights the strategic advantage and sets a benchmark for future energy projects.

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