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STRATEGY OF EXHAUST MUNICIPAL WASTE LANDFILL RECULTIVATION

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Abstract

Purpose and objectives of the work. *This scientific paper is devoted to waste treatment issues. The aim of this scientific investigation ison the basis of prototype analysis to develop a modern waste management technology, which includes proposals for further exploitation the territory of exhaust Stadnytske landfill.* ***Methods of research:*** *the statistical and theoretical methods, analysis, comparison.* ***Research results.*** *Neutralization the negative impact on the environment of the landfill, in the way of conversion the landfill into the poplars forest**;** recreation zone creation on the former landfill**;** creation of the complex recycling enterprises**;** formation of the bio-polygon for the production of the natural fertilizers; installation of the biogas reactors for methane production; decrease contamination by waste water; reforestation of the territory; gaining the economic benefits by the way second raw material usage.* ***Discussion.*** *Implementation of this complex for prevention danger for people, first of all. The complex waste treatment technology includes successive steps that take into account the ecological, economic and social spheres of life. After analysis of economic efficiency of the cement blocks system and the biogas reactors, we can recommend both for generating income from garbage disposal.*

Keywords: waste; landfill management; bio-fertilize; biogas; reforestation; recreation zone

1. Introduction

In Ukraine, there are 6.5 thousand landfills and about 35 thousand illegal, the total area of which is 7% of the country's territory.

Annually Ukrainians produce 700-720 million tons of garbage of various origins. The total mass of accumulated waste is already about 36 billion tons [1]. And every year the numbers are getting bigger. But, in Ukraine, only 4% of household waste is recycled at waste incineration plants generating positive energy.

2. Analysis of the latest research and publications

Four bills have been registered in the parliament, which are called to introduce new rules for the use of waste. Among them, the draft Waste Act (No. 4838), the draft amendments to some laws of Ukraine on the promotion of the use of household wastes as an alternative source of energy (No. 4835), on amendments to the Tax Code (regarding taxation of household waste) (No. 4836), on amendments to the Budget Code (regarding the use of certain types of environmental tax) (No. 4837) [2].

The recycling market has become very lucrative in Europe, while in Ukraine it simply is not available. Residents of Poland pay about 100 euro per year for garbage processing, in Ukraine - only 20-30 UAH, the expert noted. Also, for example, almost 90% of glass containers in Germany are made from recycled secondary raw materials. And for each put a plastic bottle you can get a coupon for 50 cents. For 25 years, Germany has managed to reach 95% recycling and sorting waste, which has helped to avoid significant environmental problems.

A similar situation has arisen in Switzerland. In 2000, a ban on garbage polygons was introduced. Garbage that can't be sorted - burned, and from it receive electricity and heating for part of the buildings.

If in Germany the sorting of waste is based only on the conscience of citizens, then in Switzerland, the legislation is under its control. For not sorting garbage is a fine. For every 5 pounds 2-3 francs (about 65 UAH).

The record winner is Sweden. It recycles 99% of its waste. In addition, it imports almost 700 thousand tons of garbage from other countries!

Studies have shown that 4 tons of waste is tone oil. Currently, there are about 30 power plants in the country that burn 5.5 million tons of garbage per year. Waste utilization provides 20% of heat in Swedish homes, which is about 900 thousand households. For example, in Stockholm, 45% of the supply of heat and electricity is provided by incinerators [1].

It should be note that Ukraine takes the first step in the waste management according to the National Strategy of Waste Management till 2030 (No.820-p) at the national level [3] and Programs of Municipal Waste Management at the level of local executive authorities.

Problem Statement. First, there is no built-up infrastructure for the separate collection, sorting and utilization of solid household waste.

Secondly, problems in the legislation related to the treatment of domestic waste.

So, development and implementation of the complex waste treatment technology is very expedient.

3. Purpose and objectives of the work

The aim of this scientific investigation is:

- to analyze issues of the solid municipal waste landfills;
- to develop the complex waste treatment technology;
- to make a conclusion about efficiency and opportunities of landfill management.

4. Methods of research

The statistical and theoretical methods based on reliable sources, analysis, comparison.

5. Research results

A landfill site (also known as a tip, dump, rubbish dump, garbage dump or dumping ground) is a site for the disposal of waste materials by burial and the oldest form of waste treatment (although the burial part is modern; historically, refuse was just left in piles or thrown into pits). Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world.

Some landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). Unless they are stabilized, these areas may experience severe shaking or soil liquefaction of the ground during a large earthquake.

There are two ways to bury trash:

Dump – an open hole in the ground where trash is buried and that has various animals (rats, mice, birds) swarming around.

Landfill – carefully designed structure built into or on top of the ground in which trash is isolated from the surrounding environment (groundwater, air, rain). This isolation is accomplished with a bottom liner and daily covering of soil. A sanitary landfill uses a clay liner to isolate the trash from the environment. A municipal solid waste (MSW) landfill uses a synthetic (plastic) liner to isolate the trash from the environment [4]. According to [5] the placement of municipal solid landfills should be at distance, not less than: 15 km from the airport; 3 km from open water reservoirs, resort town, nature reserves; 1 km from the city; 0.5 km from residential and public buildings; 0.2 km from the farmland and railway and highway; 0.05 km from the forest not intended for recreation.

The purpose of our investigation is to develop a comprehensive waste management technology and further implementation of an environmental safe program for depleted landfills, so the following main steps must be included:

- Neutralization the negative impact on the environment of the landfill, in the way of conversion the landfill into the poplars forest;
- Recreation zone creation on the former landfill;
- Creation of the complex recycling enterprises;
- Formation of the bio-polygon for the production of the natural fertilizers;
- Installation of the biogas reactors for methane production;
- Decrease contamination by waste water;
- Reforestation of the territory;
- Gaining the economic benefits by the way second raw material usage.

In the Fig. 1 we presented scheme of landfill:

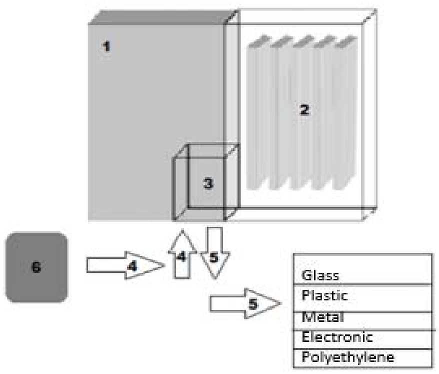

Fig. 1. Landfill scheme
1 – poplars field; 2 – recycling of biowaste (biofertilizers and biogas) ; 3 – permanent field of collection wastes; 4 – transportation from waste bank to landfill; 5 – transportation separate waste to recycling plants; 6 – waste bank

Strategy of waste management and exhaust landfill recultivation:

1. *Prepare landfill surface for further use (align territory).*
2. *Remove a 1.5-2 meter layer of soil from the territory nearby and cover the landfill.*
3. *Plant a poplar.*

When creating a series of pyramidal poplars, the distance between the trees should be 1.5x3 m or 2.5x4 m. The poplar has a long and wide root system, and, accordingly, the pit should be up to 1 meter deep when planted. Poplar grows well on fertile soils, which contain turf, peat and sand. If the soil is heavy – a drainage layer is placed on the bottom of the hole, they fill one third of the pit. Light-loving - for poplar alleys choose sunny places. Water the tree abundantly. About 25 liters of water are used to water one plant. In the first year after planting, watered 2-3 times a month, it is also necessary to water during the drought period. During the first years of life, the seedlings are recommended to loosen the circumferential circle after each irrigation, in order to save more moisture. In spring, after the melting of snow, this area is necessarily trumped to a depth of up to 15 centimeters. The same procedure is carried out in the autumn, preparing the plant for winter. Trees older than 6 years in the loosening do not need, the soil near the trunk in this case can be sown with lawn grass.

4. *Construction the bio-polygon.*

On the plot of land it is necessary to make internal drainage. The minimum depth of the excavation for installation is approximately 1600 mm, width 200x200 m. The bottom is leveled with gravel (or sand) to a depth approximately 25-30 cm. The height of the visible part above the ground level is approximately 920 mm. The pit should be large enough for installation. In depth, a reserve should also be made for minor leveling. Before filling with cement, you need to perform a number of preparatory works. The first thing to do is to conduct a geodetic survey of the site, determine the type and depth of soil freezing, the amount and location of groundwater. Then, in accordance with the results, determine the correct load on the future cement.

5. *Installation of the biogas reactors.*

Biogas reactors can be brick-constructed domes or prefabricated tanks, installed above or below ground, depending on space, soil characteristics, available resources and the volume of waste generated. They can be built as fixed dome or floating dome digesters. In the fixed dome, the volume of the reactor is constant. As gas is generated it exerts a pressure and displaces the slurry upward into an expansion chamber. When the gas is removed, the slurry flows back into the reactor. The pressure can be used to transport the biogas through pipes. In a floating dome reactor, the dome rises and falls with the production and withdrawal of gas. Alternatively, it can expand (like a balloon). To minimize distribution losses, the reactors should be installed close to where the gas can be used [6].

6. *Setting up the process of garbage collection and its sorting (building up the sorting enterprise if it is absent).*
7. *Distribution of garbage by class and its sending to specially equipped processing plants.*

In the Fig.2 we present the distribution of reception point of the recyclable waste.

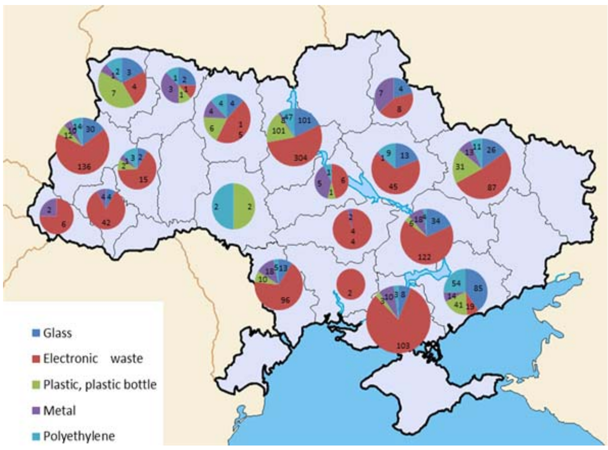

Fig. 2. Map of the reception points of recyclable materials

8. *After analysis, choose the recycling enterprises which build on the complex territory.*

- Analyze types of wastes which come to the landfill;
- After that we analyze the nearby recycling enterprises and waste volumes which region produce, and determine where each type of waste must be transported;
- Conclude what type of plant we must build based on analysis.

9. Coffin production.

When poplars will have grown we will cut them for production of coffins. The poplar tree has porosity and humid structure and that is why we cannot use it for furniture production.

Not all trees together we cut down because this is can influence on the soil condition (selective cutting is a prevention of landslides and erosion of soil). That is why we will cut them in staggered rows.

10. Formation recreation zone

During the formation of the poplar forest, we can create the small recreational zone. The poplar fluff will not disturb a good time in the park, because if do not trim the tops of trees, then the amount of poplar fluff will not reach critical volumes, and even the opposite will create a mysterious and unusual atmosphere.

Thus, the poplar will breed independently and thereby strengthen the soil planted on the landfill.

11. Receiving the bio-fertilizers from the organic waste

To build a landfill for bio-waste, technology which we use based on the composting method (that is, natural decomposition of organic substances). Organic waste is placed on a cement area and left in open air for natural decomposition. Once a year, these wastes are turned over and the next year they can be used as a fertilizer. In our understanding, the bio-polygon includes the allowable amount of cement lines with a width of up to two meters and the length permissible range for the proposed polygon. This choice of parameters is conditioned by the convenience for the operation of heavy equipment.

12. Yield of biogas

The digestion period or retention period is typically between 10 and 30 days depending upon the type of digestion employed. The anaerobic digestion systems of today operate largely within the mesophilic temperature range.

Natural gas is used for many different applications such as power generation, domestic use, transportation, and as a feedstock for the production of ammonia-based fertilizers. It is the dominant alternative road transport fuel in addition to ethanol. Since natural gas contains mainly methane, biomethane can be used as a substitute. Combustion of one cubic meter yields 38 MJ (10.6 kWh). Natural gas has the highest energy/carbon ratio of any fossil fuel, and thus produces less carbon dioxide per unit of energy.

13. Assessment of biogas production from landfill.

Amount of biogas from 1 ton of waste during 20 years equal 30-100 m^3 [7].

$$V = S \times h \times d \times V_0, \qquad (1)$$

where V – general biogas production during 20 years; S – area of landfill; h – height of waste hill; d – density of waste; V_0 – specific biogas volume (from 1 ton of waste).

For analysis we have chosen special landfill near Vinnitsa city – Stadnytske landfill. The area of the landfill is 16.0128 hectares, 2 hectares from all area use for sorting enterprise.

$$V_{min} = 140128 \times 10 \times 2300 \times 30 = 9.6 \times 10^{10}\ (m^3)$$

$$V_{max} = 140128 \times 10 \times 2300 \times 100 = 3.2 \times 10^{11}\ (m^3)$$

The V_{min} and V_{max} are minimal and maximal biogas production during 20 years. Therefore, during 1 year V_{min}=4.8×10^8 (m^3) and V_{max}=1.6×10^{10}(m^3). Average value during 1 year equals 8.2× 10^8 (m^3).

The landfill biogas has content of methane equals approximately 60% (4.92×10^9 m^3).One cubic meter of methane costs 15.50 UAH [8].

So, for all year we will receive 4.92×10^9×15.50=75950000000 (UAH).

This methane we can use as fuel for vehicle. Average usage on 100 km – 9 m^3 [9]. It means that given amount of methane can satisfy movement of 546 000 000 km. If calculate this in gas-cylinder we will receive: 50-liters gas-cylinder = 0.05 m^3. When compressed 200 times (200 atmospheres) - 200 × 0.05=10 cubes of methane should be placed in the cylinder [10]. It means that we can fill up 492 000 000 gas-cylinders.

Calculation of the organic waste volume from the whole landfill:

$$V_{org} = S \times h \times d \times k, \qquad (2)$$

where V_{org} – organic waste volume from whole landfill collecting during 1 year (m^3); S – area of landfill; h – height of waste hill; d – density of waste; k – organic waste coefficient (part of organic waste from solid municipal waste).

Coefficient k includes organic residue, timber and paper, and equal 0.52.

$$V_{org} = 140128 \times 10 \times 2300 \times 0.52 = 1675930880 \backslash 20 = 83796544\ (m^3).$$

The mass of organic waste:

$$m = \rho \times V_{org}, \quad (3)$$

where m – mass of organic waste collecting during 1 year; ρ – density of organic waste; V_{org} – organic waste volume from whole landfill collecting during 1 year.

The density of organic waste equals 0.14 (m^3/t).

$$m = 0.14 \times 83796544 = 11731516\,(t)$$

Biogas reactors profit. Calculation of the biogas income:

$$V_{biogas} = m \times n, \quad (4)$$

where V_{biogas} – volume of the biogas income; m – mass of organic waste collecting during 1 year; n – amount of biogas generated from 1 tone of the organic waste.

The 350 m^3 of biogas generated from 1 tone of the organic waste.

$$V_{biogas} = 11731516 \times 350 = 4106030656\ (m^3)$$

Calculation the volume of methane present in biogas:

$$V_{methane} = \eta \times V_{biogas}, \quad (5)$$

where $V_{methane}$ – volume of methane present in biogas; η – percentage of the methane content in biogas; V_{biogas} – volume of the biogas income.

The approximate percentage of methane content in biogas equals 80%.

$$V_{methane} = 0.8 \times 4\,106\,030\,656 = 3\,284\,824\,525\ (m^3).$$

Calculation of the methane cost (income after 1 year of exploitation):

$$\tilde{N} = V_{methane} \times b, \quad (6)$$

where C – the methane cost (UAH); b – one cubic meter methane cost.

One cubic meter of methane costs 15.50 UAH.

$$\tilde{N} = 3\,284\,824\,525 \times 15.50 = 50\,914\,780\,134 (UAH).$$

Calculation the cost of fertilizer from biogas reactors:

$$C_a = \eta_1 \times V_{org} \times f, \quad (7)$$

where C_a – cost of fertilizer from biogas reactors; η_1 – the percentage of the dry fertilizer from amount of organic waste; f – the fertilizer cost from 1 m^3.

The approximate percentage of the dry fertilizer from all amount of organic waste equals 25%.This explained by drying of the organic fertilizers for further usage, from the one hand, and by the second usage of the residue as a substrate for new cycle in the reactor, on the other hand. The fertilizer cost from 1 m^3 equals 250 UAH.

$$C_a = 0.25 \times 83\,796\,544 \times 250 = 5\,237\,284\,000\ (UAH)$$

Biogas reactors installation is represented in Fig. 3.

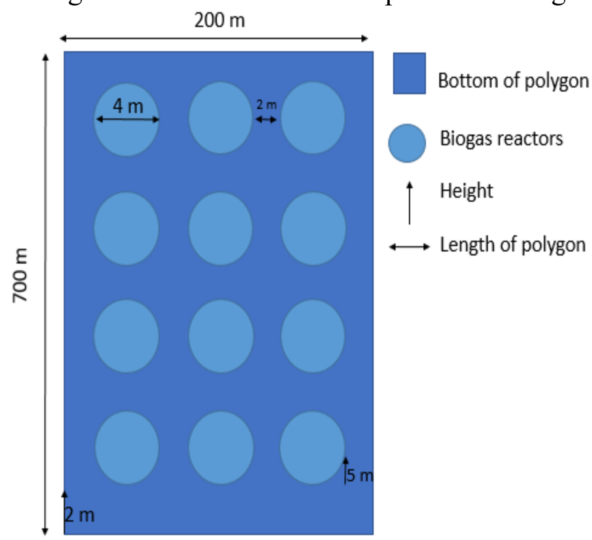

Fig. 3. Scheme of polygon with biogas reactors

$$V = \pi \times R^2 = 3.14 \times 4\ m^2 \times 5\ m = 62.8\ m^3,$$

where V – is volume of one bio-reactor.

If area of polygon is 140 000 m^2, then A = 140 000 m^2: $(4+2)^2$ m^2 = 3890 – amount of reactors.

C_1 = 950 y.e. – is cost of one bio-reactor.

C_2 =3890×950 y.e.=3 700 000 y.e.=110 833 334 UAH.

Cement blocks profit. Calculation the cost of fertilizer from cement blocks:

$$C_b = \eta_2 \times V_{org} \times f, \quad (8)$$

where η_2 – the percentage of the fertilizer from amount of organic waste; f – the fertilizer cost from 1 m^3.

The approximate percentage of the fertilizer from all amount of organic waste equals 95% (relatively all organic mass become a fertilizer).

$$C_b = 0.95 \times 83\,796\,544 \times 250 = 19\,901\,679\,200\ (UAH).$$

Cement blocks installation is represented in Fig. 4.

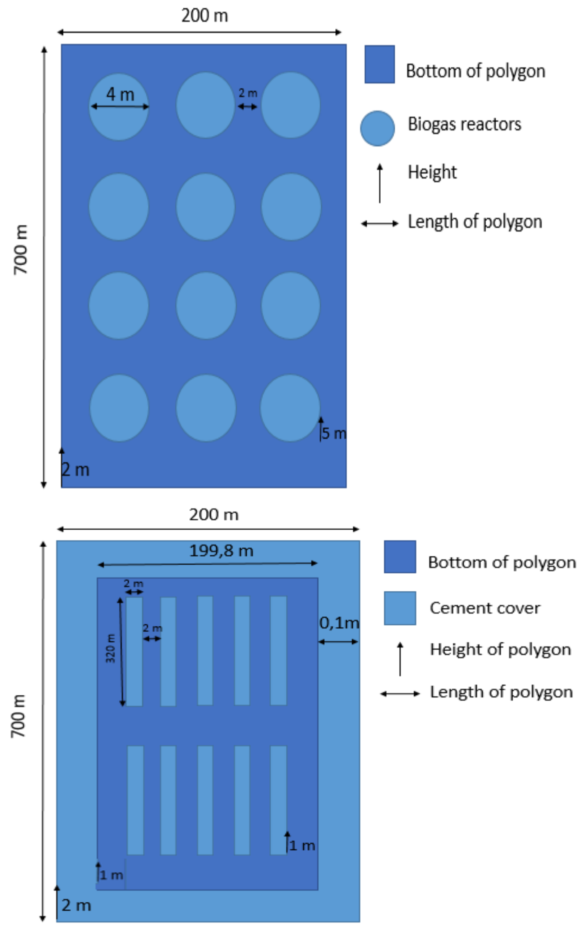

Fig. 4 Scheme of polygon with cement blocks

$S = 140000$ m^2, where S – is area of polygon.

$V_1 = 140000$ m^2 × 0.1 m = 14000 m^3 – volume of cement for bottom of polygon.

$V_2 = (200$ m × 700 m × 1,99 m) – (199.8 m × ×699.8m×1.99m)=278600m^3 – 278240m^3 =360 m^3 – volume of cement for borders of polygon.

$V_3 = (2$m × 320m × 1m) – (1,8m × 321.8m × 1m) = 640 m^3 – 579.2 m^3 = 60.8 m^3 – volume of cement for one block of polygon.

$A = 200$ m: 4 m = 50 – amount of cement blocks.

V_{cement} = 14000 m^3 + 360 m^3 + 50×60.8 m^3 = 17 400 m^3 – volume of cement for polygon.

1 ton of cement costs approximately 600 UAH.

$C = 17400$ m^3 × 600 = 10 440 000 UAH.

6. Discussion

After formation whole unique complex we are getting benefits. On national level we must analyze economy operation of construction of this system.

In the Fig. 5 and Fig. 6 present the economic efficiency of the waste treatment enterprise. In the Fig. 7 we present the sustainable development of waste management.

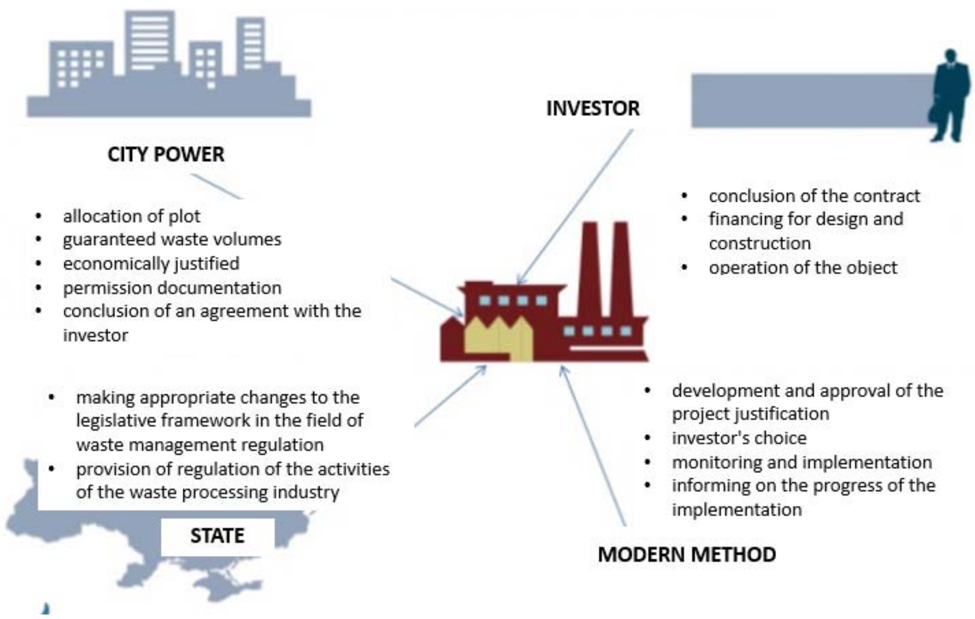

Fig. 5. Scheme of responsibilities

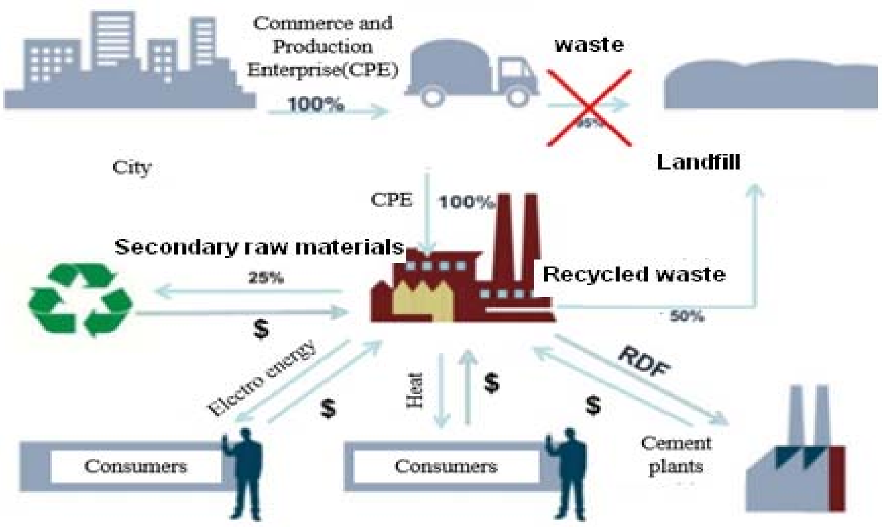

Fig. 6. Economic efficiency

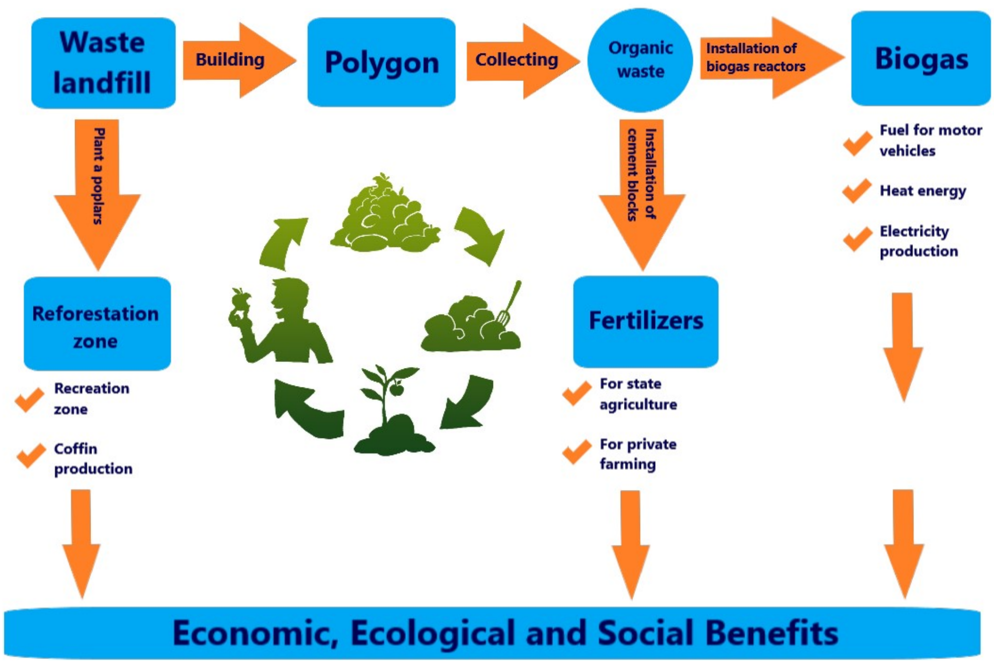

Fig. 7. Sustainable development of waste management

On polygon we can installation cement blocks for receiving bio-fertilizers or biogas reactors for production biogas and receiving bio-fertilizers.

After comparative analysis of economic efficiency of the cement blocks system and the biogas reactors (Fig. 8), we recommend install in the waste treatment complex the system of the cement blocks for the organic fertilizer production. This choice is explained by the fact that the payback is higher than when installing biogas reactors, although, the amount of net income is lower, but the installation itself is cheaper.

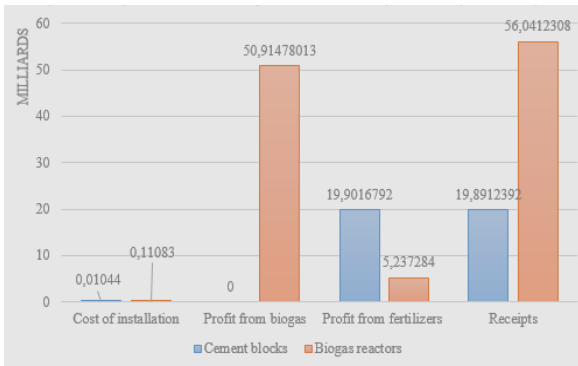

Fig.8. Economic Efficiency of the Cement Blocks System and the Biogas Reactors Installation

7. Conclusions

In this scientific work we have analyzed the waste treatment issues, the world experience of waste management and on the basis of analysis of prototype we have developed a modern waste management technology, which include proposals for further exploitation the territory of depleted Stadnytske landfill.

To reduce the number of landfills in Ukraine, it will not be enough to pass the law, fight corruption, build plants, establish regular waste collection, to provide the population with containers. Most people do not realize the benefits of sorting and recycling waste. At the moment, Stadnytske landfill has negative impact on ground water, air, and peoples, which live near. Therefore, we must use our complex for prevention dangerous for people, first of all. After, reducing free wastes, use them as secondary materials and get from these benefits. It will be able to improve as the environmental so the economic sphere.

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Концепція рекультивації виснаженого муніципального полігону

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Мета і завдання роботи. Ця наукова робота присвячена питанням поводження з відходами. Метою наукового дослідження є розробити сучасну технологію поводження з відходами на основі аналізу прототипу, яка включає пропозиції щодо подальшої експлуатації території виснаженого Стадницького сміттєзвалища. **Методи дослідження:** статистичні та теоретичні методи, аналіз, порівняння. **Результати досліджень.** Нейтралізація негативного впливу на довкілля сміттєзвалища шляхом перетворення сміттєзвалища в ліс тополь; створення рекреаційної зони на колишньому полігоні; створення комплексних переробних підприємств; формування біополігону для виробництва природних добрив; встановлення біогазових реакторів для виробництва метану; зменшення забруднення стічними водами; лісовідновлення території; отримання економічної вигоди шляхом переробки сміття. **Обговорення.** Впровадження цього комплексу, перш за все, запобігання небезпеки для людей. Комплексна технологія поводження з відходами включає послідовні кроки, що враховують екологічну, економічну та соціальну сфери життя. Проаналізувавши економічну ефективність системи цементних блоків та біогазових реакторів, ми можемо рекомендувати обидва варіанти для отримання прибутку від вивезення сміття.

Ключові слова: відходи, полігон, біодобриво, біогаз, рекультивація, рекреаційна зона

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Концепция рекультивации истощенного муниципального полигона

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Цель и задачи работы. Эта научная работа посвящена вопросам обращения с отходами. Целью научного исследования является разработать современную технологию обращения с отходами на основе анализа прототипа, которая включает предложения по дальнейшей эксплуатации территории истащенной Стадницкой свалки. **Методы исследования:** статистические и теоретические методы, анализ, сравнение. **Результаты исследований.** Нейтрализация негативного воздействия на окружающую среду свалки путем превращения свалки в тополевые леса; создание зоны отдыха на бывшей свалке; создание комплекса перерабатывающих предприятий; формирование биополигона для производства натуральных удобрений; установка биогазовых реакторов для производства метана; уменьшение загрязнение от сточных вод; лесовосстановление территории; получение экономических выгод путем вторичного использования сырья. **Обсуждение.** Реализация этого комплекса для предотвращения опасности для людей, прежде всего. После, уменьшив количество свободных отходов, использование их в качестве вторичных материалов и получение от этого преимущества. Технология комплексной переработки отходов включает в себя последовательные этапы, учитывающие экологическую, экономическую и социальную сферы жизни. После анализа экономической эффективности системы цементных блоков и биогазовых реакторов, мы можем порекомендовать оба варианта для получения дохода от утилизации мусора.

Ключевые слова: отходы, полигон, биоудобрение, биогаз, рекультивация, рекреационная зона.

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