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WASTE USAGE AS SECONDARY RESOURCES*

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Abstract

The current state of waste management in Poltava region is summarized in this article. In this article were determined places of accumulation and the influence of population size on the volumes of domestic solid wastes formation. Here also was analyzed dynamics of changes in the production of domestic solid wastes in rural areas and in cities. The morphological composition of domestic solid wastes was determined due to researches during 2017-2019. In the article was conducted comparative analysis of the data of changes in the percentage of components, which are part of domestic solid wastes depending on the time of year. It is determined that about 55% of the waste is the organic part of domestic solid wastes. Using certain technologies organic part of domestic solid wastes can be processed into valuable products. The technology of processing the organic component of domestic solid wastes into compost adapted to conditions of private farm households is offered in this article. Here are justified the design parameters of small-sized household chopper for compost production and are given technical conditions of machine usage the in conditions of private farm households. Here also was calculated economic feasibility of machine usage for three farm households for the purpose of processing the organic component of domestic solid wastes into compost. The costs for equipment, materials and inventory were about 2.835 thousand EUR. Costs for electricity, water, wages, etc. were 4.379 thousand EUR. The cost of production of one kilogram of compost was 0.093 EUR/kg. The payback period of the project is 9 months. The use of new developed equipment for the processing of organic component of domestic solid wastes makes it possible to reduce the ecological environmental impact to a considerable extent. In addition, the use of wastes as secondary resources makes it possible to obtain funds for private farm households.

Keywords: biomass, compost, machine, processing, technology, waste

1. Introduction

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Recently the consequences of human activity are becoming more tangible under conditions of intensification of production, expansion of agricultural activity. The global environmental problem becomes the pollution of natural ecosystems as the consequence of human activity.

Ukraine annually produces about 13 million tons of garbage, about 4% of which is processed. The collected domestic solid wastes are accumulated in dumping sites and overflowing landfills. The total area with wastes is about 7% of the territory of Ukraine, and this number is increasing annually. As of today, about 40 billion tons of various wastes are stored at 170 thousand hectares of land.

The growth of consumer activity leads to the accumulation of waste. It is urgent to resolve the issue of management and processing of domestic solid wastes.

The problematic issue is the processing of organic component of domestic solid wastes, because when they get into the environment, they are quickly subjected to natural processes of biodegradation and adversely affect the environment (soil and surface-water contamination, bad odor, the spread of pathogens, diseases). The successful solution of the mentioned above problem is possible only on a scientific basis with the use of technology of composting the organic fraction of domestic solid wastes. The most important for the solution of the given task is the development of theoretical foundations and practical methods for obtaining high productivity of machine and corresponding fractional composition of chopping the organic component of domestic solid wastes for compost production.

Authors set a goal to study the technology of processing the organic component of domestic solid wastes into compost in conditions of private farm households in Poltava region.

The following tasks were solved in order to achieve this goal:

- To adapt the technology of waste use as secondary resources for conditions of private farm household
- To improve technical means for chopping, mixing and screening the organic component of domestic solid wastes
- To calculate the economical effectiveness of waste use as secondary resources for the conditions of private farm households.

The scope of presented study is in conduction of technological, technical, and economic assessment of the use of small-sized household machine. There was justified the compost production from organic component of domestic solid wastes for the conditions of private farm household.

2. Material and methods

Technical, technological, agricultural and economic factors were used in the research. The researches were conducted during 2017-2019 in the Poltava region. The research program included:

- analyze the state of domestic solid wastes management in Poltava region;
- assess the resource potential of domestic solid wastes of the studied region;
- determine the volume of Poltava region resource components produced per year and which can be used as secondary resources;
- study the features of the main methods of domestic solid wastes management;
- analyze the technologies of processing of organic component of domestic solid wastes;
- explore the advantages and disadvantages of industrial machines for compost production;
- justify the technical characteristics of small-sized domestic chopper for compost production;

- offer the adapted technology of processing of organic component of domestic solid wastes into compost for conditions of private farm households;
- present the economic calculations of waste use as secondary material resources in the conditions of private farm household.

The following sections demonstrate the application of this program for technical and economic assessment of processing of organic component of domestic solid wastes into compost in Reshetylovsky village Council (Poltava region, Ukraine).

3. Result and discussion

Wastes are any substances, materials and objects that are formed in the process of human activity and have no further application at the place of their formation or where they were found and which their owner must get rid of by means of utilization or removal ((Decree 1065, 2019), (Kalinichenko et al., 2018), (Kalinichenko and Havrysh, 2019)). Definition of the term domestic solid wastes is given in the industry regulatory documents of Ukraine, in particular in the "Rules for the provision of services for the collection and removal of solid and liquid domestic wastes" (Waste utilization, 2011).

According to these rules: domestic solid wastes are the wastes generated in the process of human activity and they are accumulated in residential buildings, social and cultural facilities, public, medical, commercial and other institutions (they are food wastes, household articles, garbage, fallen leaves, wastes from cleaning and current repair of apartments, waste paper, glass, metal, polymer materials, etc.) and they have no further application at the place of their formation (Decree 318, 2019).

In accordance with the State Classifier of wastes SC 005-96 (SC 005-96, 2008) the following groups of wastes classified as domestic are separated: domestic solid wastes, food wastes, indoor and back yard garbage, waste paper, boxing, packaging materials, wood, metal.

Locations of formation of these wastes are residential buildings, administrative and public organizations, trade enterprises, cultural and welfare facilities, etc., adjacent territories, green plantings.

Analyzing the places of accumulation of the mentioned above domestic solid wastes, the following percentage is observed: about 10% get into the places of illegal dumping; 6% settles on the territory of places of residence and industrial enterprises; 80% is delivered to suburban landfills intended for their burial; 4% - goes to reprocessing. The summarized results of inventory of landfills and dumping sites of domestic solid wastes, unauthorized dumping sites located in the territory of Poltava region are presented on Fig. 1.

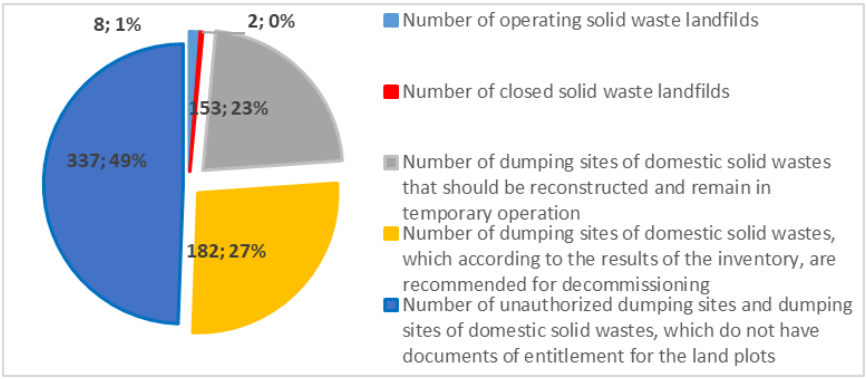

Fig. 1. Diagram of inventory of landfills and dumping sites of domestic solid wastes in Poltava region

It can be seen from the diagram that of the total number of authorized landfills and dumping sites of domestic solid wastes, there are 672 unauthorized dumping sites. The unauthorized dumping sites and dumping sites of domestic solid wastes, which do not have documents of entitlement for the land plots, have the largest numbers – 337. As a rule, they are unauthorized dumping sites in forest belts, in suburban and unoccupied urban areas. Along with the ecological problems of environmental pollution, the issues of assessment of resource potential connected with DSW have become relevant in recent years. In particular, it concerns the insufficient use of DSW as a source of secondary raw materials and for energy purposes. The detailed analysis of resource potential of domestic solid wastes is presented on Figs. 2-5.

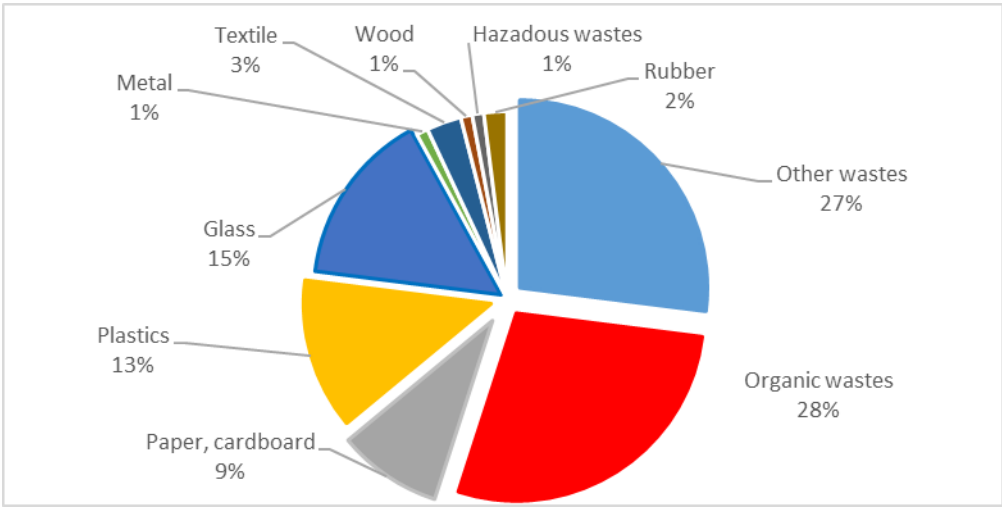

Fig. 2. Cities with population ≤ 5000 people high-rise housing

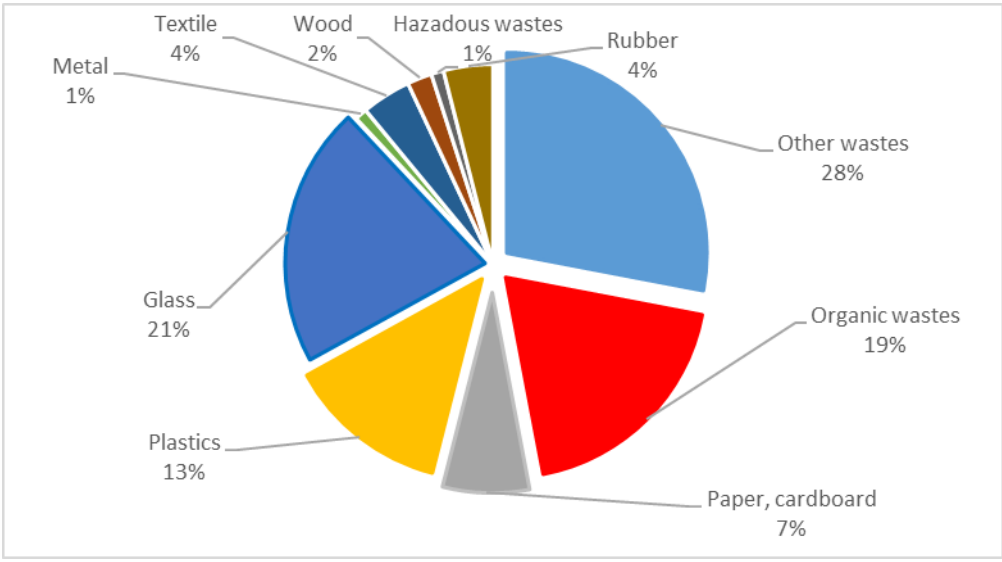

Fig. 3. Cities with population ≥ 5000 people high-rise housing

The conducted comparative analysis of the data on the changes in the percentage of components that are part of domestic solid wastes, over the past 5-8 years is as follows: the percentage of polymer materials is increasing; packaging paper is increasingly replacing polymer material; there is a tendency to increase the production volumes of aluminum cans for drinks. In recent years, the amount of boxing and disposable tableware made of polymeric materials within the domestic solid wastes has increased rapidly (Kalashnyk, 2011). Typical morphological composition of domestic solid wastes (Fig. 6) is characterized by the following main components: food and vegetable wastes; paper; cardboard; wood; textile; rubber; leather; plastics (including polyethylene bottles); glass; ceramic materials; black and non-ferrous metals; stones; bones and other garbage.

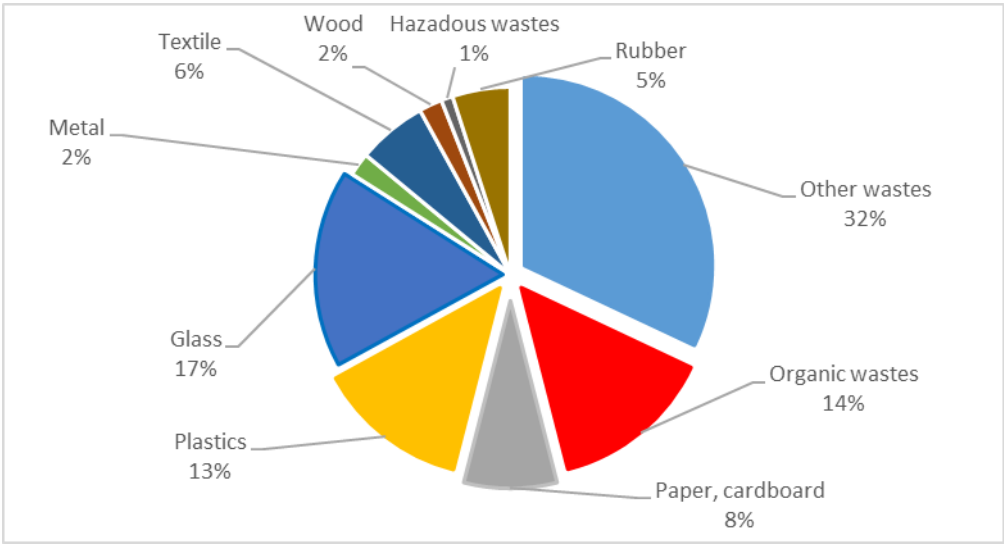

Fig. 4. Major population centers with population 1000-5000 people

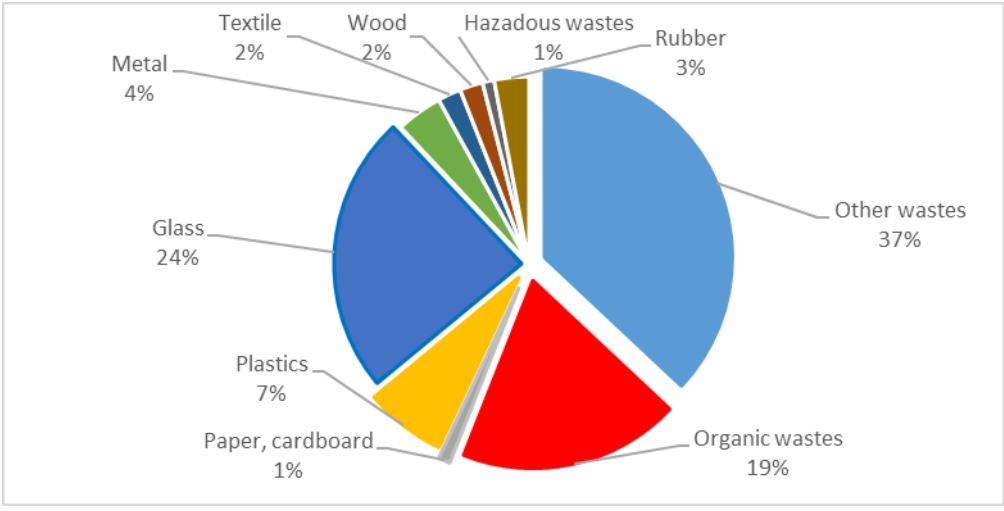

Fig. 5. Small settlements with population less than 1000 people

As can be seen from the data (Figs. 2-6), the morphological composition of domestic solid wastes differs in the residential sector and in the industrial sector. But in general, the organic fraction of wastes of residential sector is about 73% of all domestic solid wastes (Hoornweg and Bhada-Tata, 2012).

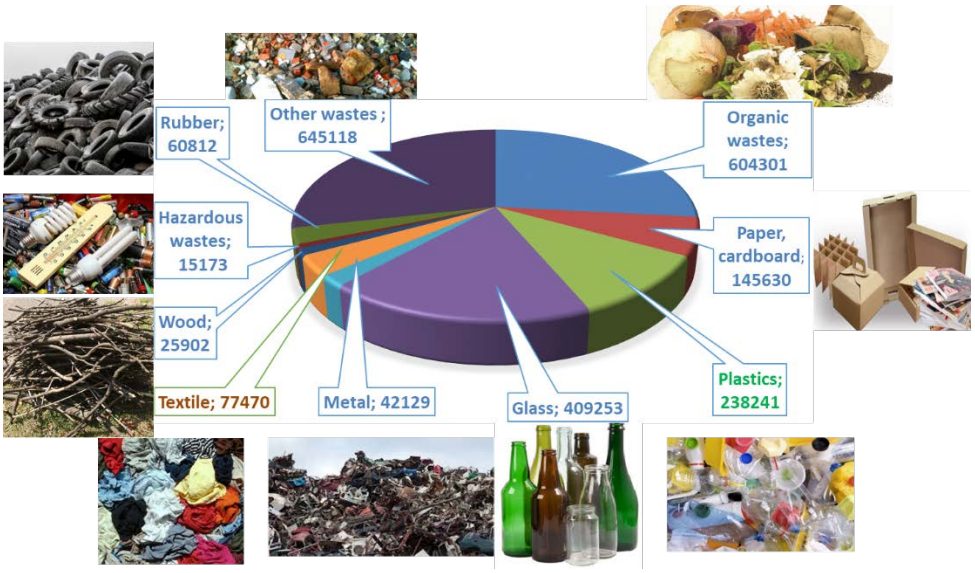

Fig. 6. Volume of resource components in Poltava region, m^3/year

3.1. Alternatives

Waste management includes actions for prevention of its generation:
- Collection and stowing
- Sorting
- Burning
- Pyrolysis
- Composting.

The disadvantages of simple stowing are obvious: limited areas of landfills; penetration of toxic wastes into groundwater; spontaneous combustion. Sorting involves additional financial costs. Burning in the open air is forbidden by law. Pyrolysis is an expensive technology. Composting involves removal of fertile land areas for placing the piles. But this technology is the most optimal in the conditions of private farm households.

3.2. Composting technology

Since the organic fraction of domestic solid wastes is subject to processing, therefore, the best solution is to use the composting technology.

All organic wastes, which are formed in private farm household, can be conveniently classified into three groups.

1. Wastes suitable for composting. This group includes food wastes, plant waste of agricultural crops, apple pomace, grape pomace, material of plant origin, used as litter, manure.

2. Wastes suitable for preliminary application into the soil. These wastes include pulp, pomace and oil meal from grape seeds, manure. Usually it is wastes, which application into the soil results in temporary biological fixation of available nitrogen by microorganisms.

3. Wastes suitable for use as fertilizers without restrictions. This group includes manure of all kinds of animals contained in the farm, fallen leaves and plant residues, mowings.

The most common way of processing the organic fraction of domestic solid wastes is composting, or vermicomposting using earthworms. The purpose and final product of biotechnological processing of organic fraction of domestic solid wastes is to obtain useful products, primarily fertilizers (Kallistova et al., 2016).

Researches of industrial technology of composting made it possible to note the following features.

1. The formation of storage piles mainly from manure and plant residues of agricultural crops;

2. Intensive mixing with simultaneous chopping;

3. Maturation of compost;

4. Introduction to the fields using the spreaders.

The presented technology requires appropriate power machines and special mixers. It is not suitable for conditions of private farm households.

Composting technology adapted to the conditions of private farm households is as follows:

1. Sorting of domestic solid wastes in order to select their organic component;

2. Mixed loading of the components of organic part of domestic solid wastes to the machine (small-sized domestic chopper for wastes);

3. The content of food waste should be not less than 25-30% of the total weight of material prepared for composting;

4. Chopping to the fraction, where particle size does not exceed 50 mm;

5. The content of particles up to 50 mm should be about 90% of the total volume;

6. Laying in piles with the height up to 1.2 m;

7. The chopped material in the storage piles should be moistened to 50-60% of moisture content by weight;

8. Application into the household plots or sale.

Therefore, it is recommended to use the small-sized domestic chopper of biomass for realization of the technology of processing the organic component of domestic solid wastes, adapted to the conditions of private farm households.

The machine for chopping the organic component of domestic solid wastes is designed for processing the organic fraction of domestic solid wastes (food waste, gardening waste, waste from residues of agricultural production, plant residues) into the material of a given fraction prepared for composting (Lyashenko et al., 2018).

The main purposes of the machine:

- for primary chopping of organic component of domestic solid wastes in the conditions of private farm household;
- for mixing and additional chopping of material for compost;
- to prepare compost for briquetting with subsequent use as a fuel.

Machine for chopping the organic component of domestic solid wastes by its design is just a simple machine that operates from the electric main (Fig. 7).

Technical parameters of the developed machine for chopping the organic component of domestic solid wastes are:

- type of raw material: organic component of domestic solid wastes;
- ability to work from an electric motor 2.2 kW;
- rate of rotation of cutting blade is 1480 rpm;
- cutting blade diameter 340 mm;
- number of knives 3 units;
- number of additional chopping knives 12 units;

- weight (without engine): 55 kg.

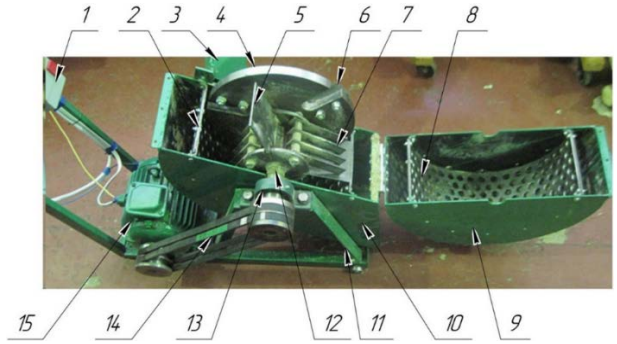

Fig. 7. Small-sized domestic chopper for compost preparation: 1 – control panel; 2 – fixing strip for screen; 3 – charging hopper; 4 – disc for fixing the blades; 5 – fan blades; 6 – cutting blade; 7 – grinding hammers; 8 – screen; 9 – upper housing; 10 – lower housing; 11 – frame; 12 – working shaft; 13 – support bearing; 14 – V-belt transmission; 15 – electric motor

Small-sized domestic chopper works as follows. The necessary raw materials intended for chopping are fed into the loading chute of the grinding chamber. The raw material, getting into the chamber, is chopped using knives and additionally chopped by the hammers and is thrown onto the walls of the screen. And it is separated through the holes in the screen walls, until the particle size distribution of the particles is less than the diameter of the screen holes, and then they are thrown out through the outlet under the action of the air flow from rotor.

Feed of raw materials is carried out manually, in other words it is stuffed into the loading chute in turn, and then the material is dragged in by itself due to the special configuration of the knives (Lyashenko et al., 2018).

According to the results of industrial tests the machines received the following indicators while chopping the organic component of domestic solid wastes:

- machine capacity – 95 kg/h;
- electricity consumption per hour – 0.208 kilowatt-hour;
- maximum diameter of loading material - 80 mm;
- moisture content of chopping material - 15...45%;
- set of screens with hole diameter of 10 mm, 20 mm, 30 mm.

As a result of tests the advantages of using the presented machine include:

- knives are made of spring steel 65G, which have excellent cutting properties;
- regulation of the output fraction of the chopped material using screens;
- reinforced frame for stable machine operation;
- safe chute for material feeding;
- high-quality bearing unit for reliable and long-term operation;
- special mount for collection of the chopped material directly into the bag;
- V-belt transmission prevents jamming of the disc in case of intrusion of foreign objects;
- quickly removable housing for easy cleaning;
- high productivity.

3.3. Assessment of compost production cost

The realization of the project of processing the organic component of domestic solid wastes into compost was implemented in three private farm households of Reshetylovsky

district of Poltava region, Ukraine. The daily capacity of the machine for chopping the organic component of domestic solid wastes in the conditions of three private farm households was: $Q = 100$ kg/day. Production of compost from the organic component of domestic solid wastes would be: $Q = 365$ t / year.

Calculation of consumption of raw materials and other materials is based on the standards of consumption established by industrial sector norms, standards and technical regulations, the selected technological solution (Maznev et al., 2001). The results of calculations are presented in Table 1.

Table 1. Calculation of the cost of raw materials and other materials

Raw materials and other materials	*Consumption per year*		*Consumption per unit of product*		
	Number, units	*Sum, EUR*	*Number, units*	*Cost, EUR /m³*	*Sum, EUR*
1. Main raw materials: organic component of domestic solid wastes	36.50 t	0.00	1.40 kg	0.00	0.00
2. Auxiliary materials:					
Tap water	750.00 m³	343.00	0.02 м³	0.46	0.01
Peat	340.00 m³	2491.00	0.18 м³	7.33	1.32

The calculation of the amount of depreciation is presented in Table 2.

Table 2. Calculation of the amount of depreciation

Object	*Quantity*	*Balance-sheet value of the object, EUR*	*Depreciation rate, %*	*The amount of depreciation, EUR./year*
Machine for chopping	1	440	10	44
Raw material receiving room	1	2199	10	220
Amount of depreciation				264
Tools				125
Production and household equipment				55
Total				708

We will calculate the electricity by means of multiplying the estimated amount by its prime cost. The tariff for electricity for consumers within the Poltava region is 0.083 EUR/ kWh (including VAT).

The calculated values for the equipment are written down in the Table 3.

Table 3. Calculation of the cost of raw materials and other materials

Equipment	*Power, kW*	*The quantity, units*	*Demand factor*	*Overall power*	*Rate of power increase*	*Effective working time, h/year*	*Total power consumption, kW/year*
Chopping machine	2.2	1	0.9	2.2	1.1	61	134.2

The cost of consumed electricity is calculated by: $T_e = E \cdot C$, where C is the market value of electricity, UAH, E – total power consumption, kW/year.

$$T_e = 134.2 \cdot 0.083 = 11.14 \text{ EUR}$$

The calculation of the cost of energy is presented in the Table 4.

The calculation of the basic and extra wages. The wages fund of production workers (directly working at production) is determined based on the list numbers, tariff category,

tariff rate, the number of working days, taking into account the operating schedule from 1 hour per day.

Table 4. The calculation of the cost of power consumption

Energy carrier	*Consumption per year*		*Consumption per unit of product*		
	Number, units	*Sum, EUR*	*Number, units*	*Cost EUR./un.*	*Sum, EUR*
Electricity	134.2 kW	11.1	0.4 kW	0.083	0.03
Water	750 m^3	343.4	0.02 m^3	0.460	0.01
Total		354.5			0.04

The duration of the working cycle is T_{prod} = 243 h / year,

T_{pers}=365/7·40=2086 h/year.

The number of workers required for production is determined as follows: n_{pers}=365/2086 = 0.2 ⇒ 1 person.

The effective fund of working time of the worker in standard working conditions during the year is: T_{ef} = 243 h / year, where 243 is the number of working days of one worker per year, 1 is the duration of the working shift, hours/day.

Calculation of wage schedule is based on the tariff rate of employees of the 1st category and the corresponding coefficients. When calculating the wages, the minimum wage in Ukraine should be taken into account. According to the data as of 01.01.2019, the minimum wage is 152.86 EUR. Then the tariff rate should not be less than:

$$TR = (152.86 \cdot 12)/(243 \cdot 8) = 0.95 \text{ EUR/hour}$$

The charges on payroll are 22%.

The annual wages fund is given in the Table 5.

Table 5. The annual wages fund of employees

Position	*Number of employees, persons*	*Wages of one employee, EUR*	*Total wages of employees per year, EUR/year*	*Charges on the wages fund, EUR/year*
Operator	1	20.7	248.5	54.7

Calculation of current expenses. Current expenses include basic and extra wages of personnel, expenses on maintenance and current establishment of production and facilities, power consumption, water supply and water disposal, depreciation of industrial buildings and structures, expenses on repair and operation, etc. Data are given in Table 6.

Table 6. Current expenses

Item of expense	*Expenses, EUR*
Wages of the worker (operator)	248.5
Charges on payroll	54.7
Expenses on maintenance of buildings and equipment:	
- power consumption	11.1
- water supply	343.4
- depreciation	708.0
Expenses on repair and operation	549.5
Expenses on safety and health protection	36.6

Other expenses	54.9
Total	2006.7

Calculation of production cost. The production cost is determined on the basis of the calculation, which is made for the production as a whole. The data for production cost calculation are presented in Table 7.

Table 7. Calculation of the production cost of finished products (compost)

Calculation item	***Costs for annual compost production, EUR***	***Costs per unit of products (kg) EUR***
Main raw material	0.0	0.0
Auxiliary materials (peat)	2491.0	0.034
Energy consumption, water supply	354.5	0.005
Wages of the worker	248.5	0.003
The charges on payroll	54.7	0.001
Depreciation expenses	708.0	0.010
Other expenses	641.0	0.009
Cost of production of fixed assets	2637.4	0.036
Total cost	7135.1	0.098

Therefore, the cost of 1 kg of compost is 0.098 EUR.

3.1. Economical efficiency of the project

The results of calculations of technical and economic indicators are given in the Table 8.

Table 8. Technical and economic indicators of processing the organic component of domestic solid wastes into compost

Indicator	***Value of indicator***	
	Unit of measurement	***Value***
1. Annual output	t/year	73
2. Number of personnel	persons	1
3. Average annual output of the worker	t/pers.	73
4. Capital investment		
- total	EUR	7213.6
- per unit of products	EUR/kg	0.098
5. Cost of production assets:		
- fixed	EUR	2834.2
- current	EUR	4379.4
Payback period of the project	years	0.77
The economic effect from implementation of the project	EUR	2145.3

The payback period of the project for processing the organic component of domestic solid wastes into compost is 0.8 years. The profit will be 2145,3 EUR.

3.2. Recommendations for implementation

In the coming years the main purpose in the field of waste management in private farm households of the Poltava region is the phased introduction of separate collection of domestic solid wastes and the achievement of the European level of waste management. The

main areas of work are:

- to obtain annually about 2,2 thousand EUR from garbage collection and removal and in addition on a monthly basis about 0.18 thousand EUR from the collection and transfer for processing of secondary raw materials.;
- to purchase the chopper for wood and wood wastes (Lyashenko et al., 2019), (Lyashenko et al., 2018);
- arrangement of a sorting line on the plot for several farms, which will allow additional extraction of secondary raw materials and as a consequence to reduce the load on the landfill;
- gradual expansion of the volume of raw materials for compost production through the acquisition of specialized vehicles, which will provide services to other private farm households;
- full provision of the private sector with plastic Euro bins with the volume of 240 liters of different colors;
- purchase of equipment for the production of biohumus from wastes;
- purchase and use of a mobile plant for waste composting.

The indifference of local authorities and population to the farming problems and, as a result, the cleanliness of the settlement should become a certain "trademark" of Poltava region as of today. The implementation of the set goal in the field of waste management will allow to use the experience of the European system of collection of domestic wastes in Ukraine and to spread this experience among other settlements of the region and the state.

4. Conclusions

1. Waste use as secondary resources requires a constant search for new technologies, and subsequently their application. Ukraine and Poltava region in particular has significant opportunities for waste processing into secondary raw materials.

2. As the advantages of applying the modern technologies for waste processing into compost in private farm households should be considered the following: decrease in the cost of cultivated products, substantial material saving, application of new technologies in agriculture, cost saving, increase in productivity, increase in product quality, organizational effectiveness.

3. In addition to economic benefits, technologies of waste reprocessing have an environmental function, as the amount of garbage that is thrown into landfills is reduced, and they are disposed of at the production site.

4. The use of waste as secondary material resources is a strategy that is directed on the economy development, increase in the efficiency of enterprise, decrease in the impact of private farm households on the environment.

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