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Makarchuk Oksana, PhD (Economics), Associate Professor of the Department of Statistics and Economic analysis, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine

ORCID ID: 0000-0002-5997-5879

e-mail: makarchukoks@gmail.com

Assessment of Waste Generation and Efficiency of Their Use in Economic Activity

Abstract. Introduction. The problem of waste accumulation and efficient use in Ukraine is particularly large and significant. This is due to the dominance of resource-intensive and waste-intensive technologies in the country's economy, as well as the low degree of their processing. At the same time, the high level of resource use of the national economy, as well as energy and raw materials orientation in combination with the outdated technological base continue to determine the high rates of generation and accumulation of various types of waste.

The unresolved problems lead to a further deepening of the environmental crisis and, accordingly, to the aggravation of the socio-economic situation in society. Therefore, there is a need to regulate the use of natural resources in general and effective waste management using foreign best practices.

Purpose. The purpose of this article is to study the formation and use of waste in Ukraine and the efficiency of their use. The specific objectives of the study include evaluation of the waste management pyramid that is the base to find appropriate way to deal with waste overall the country; and evaluation of the linkage between utilization of wastes from environmental protection expenditures by regions in Ukraine.

Results. Waste disposal is an urgent problem for Ukraine, as waste generation is quite high, in the average it equalled to 462,373.5 thousand tons in 2020, but there are not enough plants for proper processing, in particular, the dynamics over the past 5 years shows their growth in 2020 compared to 2015 on 48%.

It was found that the largest share in the structure of waste was occupied by mining (85.7%) and manufacturing (11.5%). The lowest amount of waste generation is observed in such areas as: construction; water supply, sewerage and waste management.

Getting results of research are shown that the leading positions in the share of recycled waste in the total amount of generated waste by region in 2020 were Khmelnytsky (81.7%), Zaporizhia (63%), (55.6%), Cherkasy (56.4%), Chernivtsi (39.5%)) and Ivano-Frankivsk (30.4%). At the same time problems with utilization were observed in Kyiv city (4.1%), Zakarpattia (0.2%), Odesa (0.4%), Mykolaiv (3.5%), Kyiv (0.8%) regions. In general in Ukraine this indices in 2020 was low and amounted approximately to 22%.

In Ukraine landfills play crucial role for waste disposal. However, in new circular economy concept is expected to transform the current waste management system (WMS) pyramid into a sustainable WMS pyramid in which the landfill will have a minimal amount of waste after reducing, recycling or composting energy recovery options.

In the article was evaluated the efficiency of the waste management by regions in Ukraine, where was estimated the dependence of utilization of wastes from environmental protection expenditures. Data for the regression was taken by regions from the State Statistics Service of Ukraine for 2020. Obtained results confirmed the dependence and showed that the increase of environmental protection expenditures on 1 mln. UAH leads to increase of waste utilization on 5.23 thousand tones.

Conclusions. In perspective Ukraine needs to optimize its waste management policy and introduce modern technologies for their recycle to reduce harmful influence on environment. By 2025, the country can provide an environmentally friendly solid waste management system and recycle up to 40% of waste. Achieving waste reduction in Ukraine by 30-40% requires investments amounting to approximately 13 billion euros. This, in turn, would reduce the demand for landfill expansion by 30% and generate additional revenues from the sale of secondary materials and energy to 300 million euros.

Keywords: waste; waste generation; waste management; waste management pyramid; efficiency.

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Макарчук О. Г., кандидат економічних наук, доцент кафедри статистики та економічного аналізу, Національний університет біоресурсів та природокористування України, м. Київ, Україна

Оцінка формування та ефективності використання відходів господарської діяльності

Проблема накопичення та ефективного використання відходів в Україні відзначається особливою масштабністю та значимістю. Це пов'язано як з домінуванням у економіці країни ресурсомістких і багатовідходних технологій, так і низьким ступенем їх переробки. Невирішеність даних проблем призводить до подальшого поглиблення екологічної кризи.

У цьому контексті метою статті є дослідження формування і використання відходів господарської діяльності в Україні та ефективність їх використання; аналіз піраміди поводження з відходами; оцінка зв'язку між утилізацією відходів та видатків на охорону навколишнього середовища за регіонами України у 2020 році.

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Результати показали, що утилізація відходів є актуальною проблемою для України, оскільки утворення відходів є досить високим, у середньому 462 373,5 тис. тонн у 2020 році. Однак, відмічається недостатність заводів для належної переробки відходів, зокрема динаміка за 5 років свідчить про їхнє зростання на 48% у 2020 р. у порівнянні з 2015 роком.

Встановлено, що найбільшу питому вагу в структурі відходів займали видобуток корисних копалин (85,7%) та обробна промисловість (11,5 відсотків). Найменший обсяг утворення відходів спостерігався у таких сферах, як: будівництво; водопостачання, водовідведення та поводження з відходами.

Ефективність поводження з відходами оцінено за допомогою регресійного аналізу залежності утилізації відходів від витрат на охорону навколишнього середовища за 2020 рік. Отримані результати показали високу залежність між даними ознаками, зокрема збільшення видатків на охорону навколишнього середовища на 1 млн грн призводить до підвищення утилізації відходів на 5,23 тис. тонн.

Ключові слова: відходи; утворення відходів; поводження з відходами; піраміда поводження з відходами; ефективність.

Formulation of the problem. The issue of waste in Ukraine is particularly large-scale and significant, firstly due to the dominance of resource-intensive and multi-waste technologies in the country's economy, and secondly, due to the low degree of response to such challenges over a long period. The large scale of resource use of the national economy, as well as energy and raw materials orientation in combination with the outdated technological base are the main and continue to determine the high rates of generation and accumulation of different types of waste.

The above mentioned problematic issues lead to further deepening of the ecological crisis and, accordingly, aggravation of the socio-economic situation in society. In turn, this necessitates the regulation of the use of natural resources in general and waste management, in particular, taking into account the best foreign practices. The problem of waste remains one of the main environmental problems and significant in terms of resources.

Analysis of recent research and publications. Discussion of waste management issues is covered by many domestic and foreign scientists, public authorities, the media etc.

Marone P., Sica E. and Makarchuk O. researched the waste management system in Ukraine and its transition to sustainable development [6]. They concluded that the issue of waste management should be considered a national priority, thus ensuring the effective implementation of the waste management program, especially at the local level, in particular by turning waste into valuable secondary resources.

In the Global Waste Management Outlook was stated that the right decisions regarding waste management are an important factor for humanity, which in turn can reduce the negative impact on the environment. It is emphasized that environmental sustainability is a major issue that needs to be addressed for further development and focus on human well-being, as the planet's power is limited in time. Therefore, improving the environment through rational waste management is a key element of sustainable development [3].

Matveev Y. and Geletukha G. investigated the prospects of energy utilization of solid waste in Ukraine. According to them, this will provide an opportunity to increase the depth of waste processing, especially with

regard to thermal treatment methods in order to further minimize landfilling and the need for new landfills; obtaining an additional energy source; obtaining additional income through the sale of electricity and heat [5].

Suetnov E. and Lazebna A. analyzed the issues of normative and legal regulation of waste management. They came to the conclusion that in order to regulate the field of waste management in Ukraine it is necessary to ensure the gradual and effective implementation of measures, which in turn are enshrined in the National Waste Management Strategy in Ukraine until 2030, to systematize legal documents related to waste management and accordingly start their implementation [9].

The National Strategy for Waste Management in Ukraine until 2030 is also designed to address the issue of effective waste management in Ukraine [10]. Adoption and implementation of the Strategy is to direct the critical situation that has arisen with the generation, accumulation, storage, processing, disposal and disposal of waste and is characterized by the further development of environmental threats. This Strategy also identifies the main directions of state regulation in the field of waste management for the coming decades, taking into account European approaches to waste management.

In this regard, there is a need for analytical assessment of the formation and use of waste in economic activity and efficiency of their use at national level.

Formulation of research goals. The goal of this paper is to investigate the formation and use of waste in Ukraine in economic activity and their efficiency use. The specific objectives of the study include evaluation of the waste management pyramid, the presentation of links between utilization of wastes from environmental protection expenditures by regions in Ukraine.

Outline of the main research material. The problem of waste generation, storage, recycling and disposal has become an important issue for immediate resolution. This situation is further characterized by the development of environmental threats to the country. The problem of waste in Ukraine is distinguished by its scale, as well as the presence of resource-intensive multi-waste technologies that dominate the national economy. The large scale of resource use and energy and raw

materials orientation of the national economy together with the outdated technological base continue to determine high rates of waste generation and accumulation. These factors lead to a deepening of the ecological crisis, which in turn necessitates the reform and development of the legal and economic system, taking into account domestic and foreign experiences [1; 7].

In order to solve these problems, as well as to improve the state of the environment, a number of normative legal acts of Ukraine are designed, which contain the necessary basic requirements for waste management and comply with certain norms of European legislation. Thus, the current Law of Ukraine "On Waste" generally takes into account the requirements of the Framework Directive 75/442/EU on waste and the Directive on hazard waste 91/689/EU. At the same time, one of the important areas of cooperation in the field of environmental protection, sustainable development and green economy (according to the Association Agreement between Ukraine and the EU) is management of waste and resources [4].

According to the Law of Ukraine "On Waste", the term "waste" means any substances, materials and objects that are formed in the process of human activity and have no

further use at the place of formation or detection and which their owner must dispose of by utilization [4].

Waste disposal is an urgent problem for Ukraine, as waste generation is quite high, with an average of 462,373.5 thousand tons in 2020, but there are not enough plants for proper processing. The negative is that over the last 5 years their quantity is growing, i.g. when compare 2020 to 2015 their number was increased by 48% (table 1).

Comparing the generation of waste per capita in 2010 to 2020, we can see that their number decreased by 19%, i.e. there is a somewhat positive trend. The amount of household and other waste in 2020 amounted to 12634.9 thousand tons or 2.4% of the total amount of waste generated.

In 2020 the amount of imported waste decreased and equalled to was 2.7 thousand tons, and the amount of waste destined for export in 2020 is amounted to 257.8 thousand tons.

At the same time, statistics are kept on the disposal of waste in landfills that are not legal. In 2010 there was 0.1 thousand tons of waste dumped in landfills. In recent years the statistics do not record their amount, which indicates an improvement in the situation of waste management in the country.

Table 1. Main indicators of the wastes generation and management

Indices	Years				
	2010	2015	2018	2019	2020
Generated, thsd.t	425914,2	312267,6	352333,9	441516,5	462373,5
• including from economic activity	419191,8	306214,3	346790,4	435619,8	456423,8
Waste generated per person, kg	9285,0	7288,0	8335,0	10505,0	11074,0
Collected, received household and similar waste, thsd.t	9765,5	11491,8	11857,2	11792,7	12634,9
Imported, thsd.t	4,1	3,4	89,4	22,0	2,7
Total incineration, thsd.t	1058,6	1134,7	1028,6	1059,0	1008,0
• including for the purpose of receiving energy	840,3	1086,3	951,2	960,1	902,2
Utilization (R2-R11), thsd.t	145710,7	92463,7	103658,1	108024,1	100524,6
Prepared for utilization (R12-R12K), thsd.t	-	1940,5	3193,6	2810,4	2641,3
Waste disposal to the managed dump-sites (D1, D5, D12), thsd.t	313410,6	152295,0	169523,8	238997,2	275985,3
• including specially equipped landfills (D5)	207445,1	31142,8	26305,6	90883,0	25815,3
Disposal by other removal methods (D2-D4, D6, D7), thsd.t	24318,0	55248,1	57674,1	57503,1	46768,1
Neutralized (D8, D9), thsd.t	-	2616,0	212,2	379,9	464,8
Placed on landfills, thsd.t	87,4	14,4	2,5	3,4	-
Exported, thsd.t	281,3	675,4	190,8	260,6	257,8
Removed due to leakage, evaporation, fire, theft, thsd.t	1367,6	6,5	6,7	12,0	-
Accumulated waste during operation in waste disposal sites at the end of the year, mln.t	13267,5	125059,0	12972,4	15398,6	15635,3

• per 1 km ² of the country, t	21984,2	21692,8	22498,9	26706,9	27115,9
• per person, kg	289236,0	291888,0	306896,0	366392,0	374457,0

Source: generated and supplemented by author based on materials [8]

Let's analyse the generation of waste by type of economic activity (table 2).

The amount of total waste generated in 2020 was 463373.5 thousand tons, of which 98,7% was waste generated as a result of economic activity. In 2020 the amount of waste in the field of agriculture, forestry and

fisheries was equalled to 5315.4 thousand tons and in the structure of the total amount of waste from economic activity this waste amounted to 1.16%. Agricultural production is among those that are most recycled (98%) because agricultural waste can be in larger measures divided on vegetable or animal origin.

Table 2. Wastes generation by economic activity and households

Indices	Years				
	2010	2015	2018	2019	2020
<i>Total</i>	425914,2	312267,6	352333,9	441516,5	462373,5
<i>From economic activity</i>	419191,8	306214,3	346790,4	435619,8	456423,8
Agriculture, forestry and fisheries	8568,2	8736,8	5968,1	6750,5	5315,4
Mining and quarrying	347688,1	257861,9	301448,9	390563,8	391077,9
• coal and lignite mining	37071,3	12084,7	10858,5	14149,7	14576,7
• extraction of metal ores	267544,9	238156,6	282481,9	367083,9	366901,0
• extraction of other minerals and development of quarries	16819,0	1921,6	8038,3	8861,1	9299,7
Manufacturing, including	50011,7	31000,5	31523,2	30751,8	52311,0
• food production	7245,4	4222,2	5818,4	5581,4	4158,7
• beverage production	1522,2	939,2	447,4	342,0	325,8
• production of chemicals and chemical products	2679,0	703,3	1227,8	1199,5	1482,2
• production of basic pharmaceutical products and pharmaceuticals	615,4	10,8	11,5	15,4	14,7
• metallurgical production	32844,2	20725,6	21799,3	21515,3	43650,0
Electricity, gas, steam and air conditioning supply	8641,0	6597,5	6322,7	5959,2	5333,7
Water supply; sewerage, waste management	1698,7	594,2	397,4	411,8	338,3
• waste collection, treatment and disposal; restoration of materials	842,8	180,0	72,5	110,5	10,4
Construction	329,4	376,2	378,8	188,7	14,5
Other types of economic activity	2254,7	1047,2	751,3	994,0	2033,0
From the households	6722,4	6053,3	5543,5	5896,7	5949,7

Source: generated and supplemented by author based on materials [8]

The largest share in the structure of waste was occupied by mining and quarrying (85.7%) and manufacturing (11.5%). The lowest amount of waste generation can be observed in such areas as: construction; water supply, sewerage and waste management.

Household waste generation is singled out. Their number in the overall structure of waste generation in 2020 was 1.3%. There is observed a positive dynamics of their increase over the last years. However, in 2020 household waste decreased on 11.5% comparing with 2010.

The amount of waste from economic activities directly depends on the economic development of the region and the number of operating enterprises. Different regions of Ukraine have different situations

regarding waste disposal. In regions with a large amount of waste, under favourable conditions, it is possible to build recycling plants that can significantly improve the environmental condition.

In Art. 1 of the Law of Ukraine "On Waste" defines the meaning of the term "waste management" as "actions aimed at preventing the generation of waste, its collection, transportation, sorting, storage, treatment, processing, disposal, including control over these operations and supervision of removal sites" [4].

Figure 1 shows that the leading positions in the share of recycled waste in the total amount of generated waste by region in 2020 were Khmelnytsky (81.7%), Zaporizhia (63%), (55.6%), Cherkasy (56.4%), Chernivtsi (39.5%)) and Ivano-Frankivsk (30.4%). The biggest problems with utilization were observed in Kyiv city (4.1%), Zakarpattia

(0.2%), Odesa (0.4%), Mykolaiv (3.5%), Kyiv (0.8%) regions. In Ukraine as a whole, this indices in 2020 was low and amounted to 21.8%.

This, in turn, has a negative impact on Ukraine's environment, as the amount of waste increases every year, and with minor and sometimes wrong disposal, it threatens an environmental catastrophe. In general, we can observe the lack of adequate infrastructures for efficient waste management. The high level of waste produced and the low rate of its use as secondary raw materials led to the significant accumulation of waste from the industrial and municipal sectors, which ended up in landfills. In the National Waste Management Strategy to 2030 the priority is the conversion of waste

into energy through extensive technological modernization. The strategy envisages introducing circular economy principles by encouraging waste prevention and recycling [6].

Waste has significant negative impacts not only on the environment, but also on humans if it does not handle properly. The waste creates pollution, increase of greenhouse gas emission (GHG), dirty environment that can create serious economic, social and environmental consequences. Therefore, waste management becomes essential need to minimize the waste negative impacts. The hierarchy of waste management include prevention, reuse, reduce, recycle, remanufacturing, energy recovery and disposal.

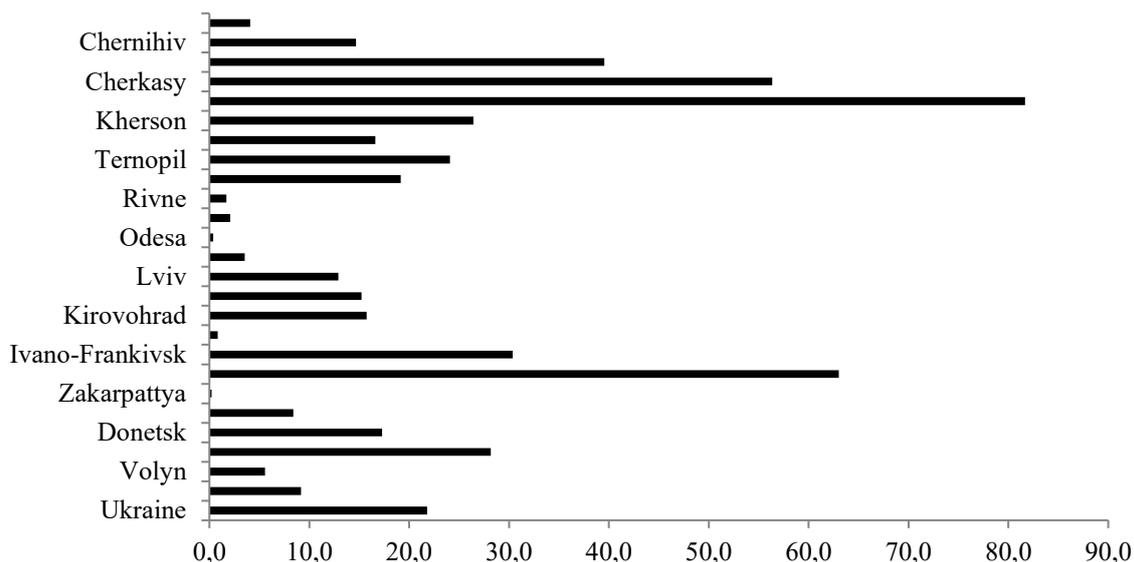


Figure 1 – Share of utilized waste in the total amount of generated waste by regions of Ukraine in 2020, %

Source: own representation based on data of the State Statistics Service of Ukraine, 2021

Indeed, there is necessary to achieve more sustainable waste management (Fig. 2) [6].

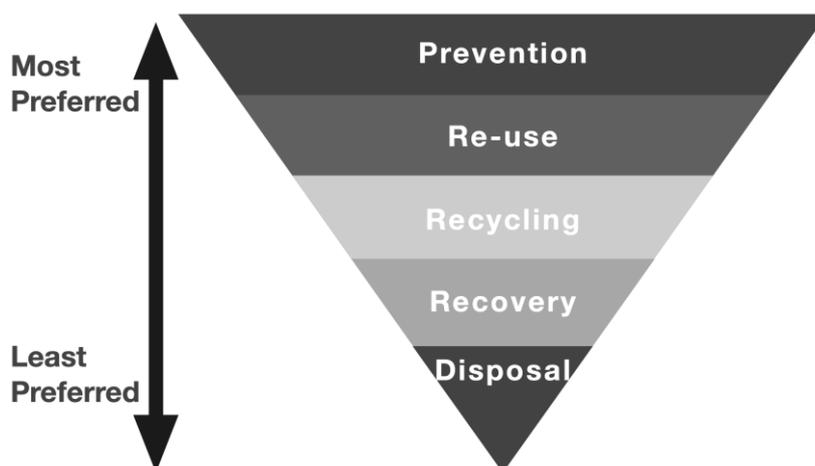


Figure 2 – The waste management pyramid

Source: formed by the author [6]

Landfill is expected to be the last option with little or no stake in the hierarchy, while emission reduction activities are expected to be the top priority in the waste management system. As such, the new circular economy concept is expected to transform the current waste management system (WMS) pyramid into a sustainable WMS pyramid in which the landfill will have a minimal amount of waste after reducing, recycling or composting energy recovery options. This waste management trend involves achieving zero waste through the implementation of appropriate strategies related to

consumer behaviour in relation to treatment technologies.

In order to evaluate the efficiency of the waste management by regions in Ukraine, we estimated the dependence of utilization of wastes by regions in 2020 (thousand tones) from environmental protection expenditures in 2020 by regions (at current prices; mln. UAH). Data for the regression was taken by regions from the State Statistics Service of Ukraine (2021). Results are the following (table 3).

Table 3. Results of regression analysis

Model of the dependence between utilization of wastes by regions and environmental protection expenditures by regions: $Y_x = -4631.94 + 5.23X$	
Indices	Value
1. Multiple correlation coefficient (R)	0,89
2. Multiple determination coefficient (R ²)	81%
3.F-criterion (table value 0,001)	97,96
4.P-value for parameter a ₁	0,00

Source: own calculation

Regression equation means that by the increase of environmental protection expenditures on 1 mln.UAH, utilization of wastes will increase on 5.23 thousand tones. There is obviously observed a significant impact of this variable. Multiple R coefficient is equalled to 0.89, which means high tightness between researched factors. Determination coefficient is amounted 81% and means that utilization of wastes on 81% depends on environmental protection expenditures. The value of P emphasizes the importance of the variable included in the equation.

Conclusions. According to the State Statistics Service of Ukraine, the country accumulates from 700 million tons to 1 billion tons of waste annually, i.e.: recycled waste (2-3%); sorted waste for further processing (7-8%); other waste stored in landfills (90%). At the same time, most landfills do not meet basic environmental standards [8].

Waste is a resource that can and should be turned into raw materials, preserving minerals and other natural resources. Foreign experience shows that in the case of regulating the processing stage by tax policy and environmental legislation, processing plants can receive significant income.

The linkage between environmental protection expenditures and utilization of wastes is significant. Regression analysis showed that by the increase of environmental protection expenditures on 1 mln.UAH, utilization of wastes will increase on 5.23 thousand tones.

In the long run, Ukraine needs to optimize its waste management policy and introduce modern technologies. By 2025, the country can provide an environmentally friendly solid waste management system and recycle up to 40% of waste. Achieving waste reduction in Ukraine by 30-40% requires investments amounting to approximately 13 billion euros. This, in turn, would reduce the demand for landfill expansion by 30% and generate additional revenues from the sale of secondary materials and energy to 300 million euros [2].

Nowadays in Ukraine is used mainly one method of waste management, i.e. landfilling. It has significant shortcomings, including problems related to their safe storage for the environment. In this regard, waste recycling remains an urgent issue, the solution of which depends on a properly organized system of management and treatment of various types of waste.

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