Problem of municipal solid waste of Ukraine and ways to solve it

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Abstract. Currently, Ukraine is among the countries with the largest absolute volume of waste generation and accumulation. Situation with landfills in Ukraine is uncontrolled. This is evidenced by unspecified landfills. The situation is constantly worsening due to harmful chemical emissions of landfills. The paper describes how pollution by landfills affects environmental components. Foreign experience, domestic waste management and methods of waste disposal were analyzed. The publication contains statistical data about dumps, landfills of household waste in Ukraine and describes normative-legal acts regulating issue of waste management. This paper outlines several recommendations for decreasing of environmental pollution from landfills on the territory of Ukraine. Following measures should be taken to solve the problem: sorting municipal solid waste; recycling; control and landfills registration; landfill placement; construction of waste-recycling and waste-burning plants; increasing awareness through environmental education on responsible attitude to waste.

1. Introduction

Currently, almost continuous production provides modern citizens with necessary needs such as food, clothing, household things and technics. It leads to overconsuming which causes waste amount increasing. Almost all this waste go to landfills and its amount is increased every year. New problem appears - we just throw out things and buy new ones instead of fixing.

Environmental pollution issues are growing drastically every year all around the world. It leads to environmental catastrophe of global scale. So, it needs fast-decision-making process or at least measures implementation that can minimize damages to the environment. Most developing countries constantly try to solve problems with pollution at all possible levels.

Ukraine is not a difference. Problem of environmental pollution became large-scale. Therefore in 2017 the “National Waste Management Strategy for Ukraine until 2030” was approved. It is aimed at addressing problem of environmental pollution in Ukraine. This Strategy is addressed to critical situation with formation, accumulation, storage, processing and disposal of waste. It is characterized by the further development of environmental threats.

The main problem is annual increase in the household waste amount and its irrational use. Ukraine is ranked ninth among the countries with the highest amount of waste produced per
capita. Thus, annual amount of household waste per person is 10.6 tons; the total annual amount of waste is 474.1 million tons. Among them 448 million tons are hazardous [1].

In general, problem of waste in Ukraine is large and significant due to dominance of resource-intensive multi-waste technologies in the national economy, and due to lack of long-term adequate response to its challenges. Significant scales of resource use, energy and raw material specialization of the national economy together with the outdated technological base determined and continue to determine high rates of waste generation and accumulation. Such circumstances lead to deepening environmental crisis and aggravation of the socio-economic situation in society. It necessitates reform and development taking into account domestic and international experience of the entire legal and economic system governing use of natural resources in general and waste management in particular. The problem of waste is one of the key environmental problems and is more important in terms of resources [2].

During 2020-2021, the amount of household waste is increased as a result of coronavirus COVID-19. Plastic bags, disposable masks and rubber gloves were added to waste. Importance of protective means use is emphasized everywhere, and no information about their features.

2. Analysis of research and publications
Number of legislative documents, scientific publications and information resources were analyzed while researching the problem of solid domestic waste (SDW) and ways to solve it. Result of the analysis showed that outlined by us problem is considered and described in the following areas:

- administrative and legal regulation in the field of waste management [1,3–5];
- analysis of foreign experience in waste management [2,6,7];
- modeling of domestic waste generation process for planning of management system and forecasting impact on the environment [7–10];
- collection and transportation of solid waste, solving problems of processing and disposal of it [11–13];
- reclamation of solid waste landfills [1,14,15].

Thus, it is clear that solid waste problem and its disposal is relevant for different countries. In Ukraine there are number of legislative documents. Also there are gross violations of these regulations and insufficient control by government agencies, especially mass emergence of unauthorized landfills. So, SDW sorting is almost non-existent. It directly affects increase in waste in landfills and increase landfills area.

3. Research aim and objectives
The aim is to investigate problem of solid waste management in Ukraine and to describe the landfills impact on environmental components. Tasks:

(i) Describe impact of landfills on environmental components;
(ii) Analyze foreign experience in household waste management and ways to dispose them;
(iii) Consider solid waste landfills on the territory of Ukraine;
(iv) Outline recommendations for reducing pollution of environmental components by landfills in Ukraine.

4. Impact of landfills on humans and environment
Industrial revolution was precondition for environmental pollution. In contrast there are a lot of shortcomings along with achievements of technological progress. One of the main is global pollution of the planet with various wastes [16].
Emergence of plastic and other synthetic materials exacerbated the environmental situation on the planet. Such materials are almost non-degradable and cause great damage to flora and fauna within radius of hundreds of kilometers from the territory of organized landfills. The amount of plastic waste discharged into the ocean is shown in figure 1.

**Figure 1.** Plastic waste emitted to the ocean per capita vs. GDP per capita, 2019 [17, 18].

The situation is deteriorated by the fact that producers pursue only their own interests, caring for profit, forcing consumers to buy more goods and get rid of old things, throwing them in landfills. There they lie for many years, poisoning everything around. Over time, more developed countries realized that it is not possible to build landfills of different types of waste (figure 2). It includes plastic on their territories. This caused transportation (so-called “waste migration”) from developed countries to poor countries in Africa.

Such decision caused some damage to the inhabitants of cities and towns close to such landfills. Many settlements on the Atlantic coast migrated because it is impossible to live in such places. Waste may contain toxic substances, chemicals, heavy metals, which together with precipitation can enter water bodies through groundwater. The vast majority of this waste is plastic. It is decomposed over millions of years, releasing various harmful substances in the process. Plastic is incinerated to free space for new waste in most of these landfills. Its combustion releases heavy metals that deplete the ozone layer. In addition, combustion produces smoke, which can lead to life-threatening diseases and even death during breathing. Decay products of plastic is risen into the air and then fall back to the Earth’s surface in the form of acid rain [16].

Impact of landfills is pollution of air, groundwater and surface water and soil itself by hazardous components of waste and their decomposition products. These hazards are significantly exacerbated in the case of fire at the storage site. Large-scale multifactor emergencies occupying significant areas of the landfill are particularly dangerous for the
Figure 2. Uncertified landfill on the territory of Ukraine.

environment. It should be noted that waste burning cause unpleasant odor and air pollution. Such illegal actions lead to release of toxic substances, including carbon monoxide, dioxins and other. In addition, combustion of solid waste releases ash residues into the atmosphere. They may contain toxic metals such as mercury, lead, chromium, cadmium, arsenic.

Landfills and especially SDW dumps are powerful centers of environmental pollution - like a biochemical reactor. In its thickness there is formation of significant amounts of toxic gases (“landfill gases”) and liquid filtrate, breeding flies, development of pathogenic microorganisms (carriers of dysentery, hepatitis, tuberculosis, even typhus); landfills attract small rodents and birds. Landfills (especially natural) are prone to spontaneous combustion. During combustion large amount of harmful gases are emitted into the atmosphere. It includes hydrogen chloride (solid waste contains up to 10% of plastics, including chlorinated polymers) and others. It should also be noted that nature is damaged by emissions of so-called biogas, which contains carbon dioxide and methane and other compounds.

Another problem is groundwater pollution. Rainwater (meltwater) is “enriched” with various chemicals formed during the decomposition of waste by seeping through layers of buried waste. Such water with dissolved in it pollutants is called a filtrate. Particularly toxic filtrate is formed when it passes through untreated waste. Waste in landfill contains iron, mercury, zinc, lead and other metals from cans, batteries and other electrical appliances, organic residues, all flavored with dyes, pesticides and detergents, agents and other chemicals. Illiterate choice of burial sites and neglect of security means allows this toxic mixture to reach aquifers. Waste decreases in volume during decomposing and soil subsides. In the formed depressions water is accumulated. This activates formation of toxic filtrate. Burial site can turn into a swamp after certain period of time [10]. Figure 3 shows sources of waste and their impact on humans and the environment [19]. Figure 4 includes illustrations of landfills and wastewater treatment plants sources [20].

Spreading further along different trophic chains, various toxic substances formed at landfills cause degradation of biosystem (flora and fauna, aquatic organisms) and adversely affect human health (through water, air, food) [21, 22].
Figure 3. Possible source of solid waste and their impact on human and environment [19].

Figure 4. Conceptual site model for landfills and wastewater treatment plants [20].
5. The world experience of waste management

Figure 5 shows general management of global waste [23]. It is shown that open and closed landfills are dominated. Slightly smaller part is recycling and incineration. The smallest part is composting and anaerobic fermentation.

Governments in many parts of the world are looking for effective ways to manage waste, but the problem of environmental pollution still remains unresolved. European environmental policy is aimed at building specialized plants for processing of wide range of waste, including glass and plastic. Activities of such enterprises are very profitable from an economic point of view. About 80% of all waste coming for recycling finds “second life”. As a result, most economically developed countries are gradually abandoning solid waste landfills and switching to new methods of disposal that can improve the environment and receive additional funds and raw materials from recycling and energy [4].

The greatest attention is paid to the organizational and economic mechanism of waste management in developed countries. This is a comprehensive system of goals, incentives, functions, consisting of organizational and economic levers of waste management and implement the most effective policies at different hierarchical levels to balance environmental and economic interests of society and economic entities. In particular, Japan pays special attention to use of secondary raw materials. Japan uses administrative, financial and legislative levers to encourage producers to use secondary raw materials. The main areas of “recycling” in Japan are: disposal of waste as raw material for manufacture of raw materials, use of waste to obtain any marketable products, use for construction of dams, roads and embankments, fertilizers and biogas. Active introduction of the “recycling” system allowed to create new jobs, expand production, reduce production costs, reduce consumption of primary material and energy resources [4].

Sweden is currently the world leader in recycling. According to the Swedish waste management association Avfall Sverige, 99% of all household waste is recycled in Sweden. Almost half of the waste in the country is incinerated, but only after careful sorting. Plastic, paper, food waste go to the processing or production of biogas. Thus, 50.6% of household waste is recycled in the country for the second time, 48.6% is incinerated for energy production and only 0.8% goes to landfills [6].
Germany is considered to be one of the world leaders in waste recycling. In a typical German yard or house you can find at least 5 multi-colored waste containers (black - for unsorted waste, brown - for organic waste, blue - for paper, yellow - for packaging and plastic, green - for colored glass, green with a white stripe - for colorless). Every year, every resident of Germany receives by mail an information letter with a detailed description of the schedule of waste sorting services for the next year [4].

Therefore, Sweden, Germany, Switzerland, Austria and Japan can be called the world’s leading waste recycling countries. These countries use waste recycling to heat buildings, generate electricity, make various household items, and so on.

6. Landfills of SDW in Ukraine

Ukraine is one of countries with the largest absolute volumes of waste generation and accumulation [4]. Ukraine generates about 10 tons of waste per capita per year, compared with 5.5 to 6 tons of waste per capita in the European Union according to the National Institute for Strategic Studies. Ukrainian volumes are of serious taking into account the extremely insufficient level of their utilization and disposal [24] compared to the indicators of waste accumulation in the European Union.

According to the Minister of Health of Ukraine Viktor Liashko in 2020 Ukraine generated 462 million tons of waste: 79.5% - waste from extractive industry, 6% - metallurgy, 2.5% - solid waste and 1.6% - agricultural waste. Solid waste is the most difficult to manage. 10 million tons of solid waste are generated annually in Ukraine. 79% of the population is covered by household waste removal services. 93% of waste is taken to landfills. Only 4% of waste goes to recycling. There are 33,000 unauthorized landfills in Ukraine [25].

According to the analytical portal “Slovo i dilo” [26], today in Ukraine there are officially 5,455 landfills and dumps with total area of over 8.5 thousand hectares. Such data are provided by the Ministry of Development of Communities and Territories of Ukraine. The largest city in the country Kyiv is served by only two official landfills - landfill №5, located in the village of Pidhirtsi of Obukhiv district of Kyiv region (area 63.7 hectares) and construction waste landfill №6 on the street Pirogovsky Shlyakh, 94-96 (area 11.6 hectares). At the same time, Vinnytsia region has the largest number of landfills and dumps - 741, which on average occupy an area of 10-15 hectares. There are 675 landfills in Poltava oblast, 659 in Chernihiv oblast, and 608 landfills in Odesa oblast. The least official landfills are in Ivano-Frankivsk (17), Luhansk (18), Lviv (20), Cherkasy (21), Ternopil (31) and Khmelnytsky (35) regions [26]. Figure 6 presents map of landfills and dumps in Ukraine.

The main legal act regulating relations in the field of waste management in Ukraine is the Law of Ukraine “On Waste” dated 05.03.1998 № 187/98-VR. It stipulates that waste should be disposed. It is defined as any substances, materials and objects, formed in the process of production or consumption and goods (products) that completely or partially lost their consumer properties and do not have further use at the place of their formation or discovery and which their owner gets rid [27].

Ukraine committed to sort all waste by type of material and dividing it into reusable, landfill and hazardous from January 1, 2018. This is stated in Article 32 of the Law of Ukraine “On Waste” [27]. Relevant paragraph was added to this law in 2012. This item corresponds to two EU Directives - 1999/31/EC and 2008/98/EC. It regulates management of waste in European countries, provide clear sequence of actions to be taken with waste, classify waste, set strategic goal to reduce amount of waste taken out to landfills.

National Strategy for Waste Management in Ukraine until 2030 [28] was approved in order to reform and improve the waste management system. The Strategy defines main directions of state regulation in the field of waste management taking into account European approaches to waste management. Main goal of the Strategy is “to create favorable conditions for raising
living standards by introducing systematic approach to waste management at the state and regional levels, reducing waste and increasing the amount of waste recycling, reuse”. At the same time the National Waste Management Plan until 2030 was approved to implement the measures of this Strategy [29]. However, many points in these documents are grossly violated by both individuals and legal entities in practice.

Ban on the use of certain types of plastic bags in Ukraine is implemented through adoption of the Law of Ukraine “On Restrictions on Circulation of Plastic Bags in Ukraine” [30]. The article 2 of this Law prohibits distribution in retail, catering and provision of services of ultra-thin, thin and oxo-decomposable plastic bags (is not applied to biodegradable plastic bags and ultra-thin plastic bags used by retail outlets as primary packaging). These changes will start on March 9, 2022.

There are measures aimed at banning plastic bags encourage producers to produce biodegradable products, and producers of plastics in primary forms. They are aimed to produce biopolymers that compost and biodegrade as raw materials for the production of biodegradable products. Raw materials for the biopolymers production are various natural substitutes for plastic, for example: starch (potato, corn, etc.), bran cereals (oats, wheat, corn, etc.), algae extracts, grain waste (straw, corn leaves). However, limited use of natural raw materials for the biopolymers production is caused by their high cost compared to PET raw materials [31].

However, existing regulations on governing waste management are imperfect to create effective management system that meets challenges of times and European directives. Existing acts contain somewhat outdated definition of industrial and household waste, based on which it is impossible to establish management process.

Figure 6. Map of landfills in Ukraine [26].
Important aspect for SDW problem solving is adequate forecasting and modeling of waste generation. Publications [8, 9] describe different models and regression analysis, time series analysis. Certain indicators were used as initial variables: population, age, life expectancy in cities, total amount of solid waste, etc. Therefore, models of household waste generation are necessary for adequate planning of the management system and forecasting of environmental impact.

The study [9] shows that increase in solid waste is caused by increase in housing, growth in industrial production, retail and catering, increasing incomes. Methods of system dynamics were used to estimate volume of municipal solid waste. Simulation was performed using the AnyLogic 7 environment. Projected population and garbage generation by 2025 are presented. Simulation modeling of waste generation is performed. The model is not complex. It will be possible to add factors without changing its structure in the model. Each region suffers from difficulties related to environmental logistics of solid waste: changes in morphological composition (paper, polyethylene); getting into containers of hazardous and specific waste; minimum separate waste collection; low investment dynamism of the subjects of economic activity of ecological logistics of solid waste.

The Ministry of Environmental Protection and Natural Resources of Ukraine began in 2016 process of inventorying landfills in Ukraine. In particular, interactive map of landfills and dumps is developing. It has about 3,000 elements. Unfortunately, at the time of writing, there is no access to the developed interactive map of landfills and dumps in Ukraine, the site https://ecomapa.gov.ua/.

Important place in Ukraine in the process of waste disposal is occupied by incinerators. There were 5 incinerators in Ukraine at different times (Kyiv, Dnipro, Kharkiv, Rivne and today’s occupied Sevastopol). Now only the “Energia” plant in Kyiv operates. Today, issue of chemical flue gas cleaning is acute at the enterprise. Similar problems are common to all incinerators. The products of waste combustion contain almost all elements of the periodic table, the most dangerous heavy metals, acids and sulfur dioxide. Modern technologies for flue gas cleaning can completely neutralize the negative effects of these substances [32].

In 2020, the Energia waste incineration plant in Kyiv (figure 7) began installing a chemical flue gas cleaning system. However, this is one permanent incinerator in Ukraine, which disposes only quarter of solid waste in Kyiv. This means that almost all other waste goes to landfills, and only small part of solid waste goes to waste collection points for processing.

Of course, environmental safety ensuring of incinerators and the introduction of modern methods of purification of exhausted gases significantly increase cost of construction of such plants. Such costs can be up to 50% in the structure of total cost of construction. The building cost of new plant for processing of 500 thousand tons of waste per year ranges from 300 to 400 million dollars. Concentrating such funds is extremely complicated task for the most local governments. Therefore, many of them are actively looking for investors to build incinerators [11].

Currently waste can be used to produce clean energy resources. It provides many potential benefits for sustainable development. Producing and using biogas implements closed economy idea. It brings benefits from reducing greenhouse gas emissions, improving waste management and improving resource efficiency. Energy security is one of the most pressing issues in different countries. Renewable energy became an integral part of the modern economy. Also, there was significant difference in the development in the construction of biogas plants compared with the development of other renewable energy sources. Waste is converted into product (biogas) and valuable organic fertilizer, closing the cycle from soil to harvest, to product, to waste and back to soil in the process of processing. Active government support for the development of biogas technologies is largely caused by increased greenhouse gas emissions and their devastating impact on the environment [33].
Biogas extraction systems are installed at 26 landfills in Ukraine, and installations for production of electricity with a capacity of 30 MW are in operation according to expert estimations. The amount of utilized biogas in 2020 amounted to 64.0 million m³ (50% methane). The amount of electricity produced in 2020 is 112.3 GWh. Example of Jenbacher generator at the landfill in Zhytomyr with a capacity of 1 MW is shown in figure 8 [34].

7. Measures to improve the environmental situation in Ukraine

Waste sorting by every citizen and processing of primary and secondary waste can significantly improve Ukraine’s environmental situation. It is borrowing of more developed countries
experience. This turns waste into valuable resources: energy, fuel, household items and more.

Unfortunately, there is no waste management policy in Ukraine. This leads to loss of millions of tons of valuable materials each year. These wastes can be potentially put into circulation. Solid waste can contain up to 40% of valuable materials on average according to environmentalists. Potential secondary raw materials are spoiled and polluted and amount of valuable resources is reduced to 5-10% given that in Ukraine most waste is collected in “common” containers [11].

Waste sorting is one of the biggest problems for our country. People do not know how to properly separate waste and why. Meanwhile, proper disposal and sorting of waste can solve many environmental and financial problems. It is important to understand why sorting is needed in order to be motivated to separate waste for everyone. There are several good reasons why you should not put all your waste in one container and then send its contents to landfill. It is important to understand that all waste can be divided into safe and dangerous. Safe include: organic residuals, cardboard and paper, cellophane, garden waste - wood, leaves. These wastes do not poison water sources and soil, are not dangerous to humans, animals and plants when decomposed. Moreover, organic waste is beneficial because it is suitable for production of fertilizers and mulch. Hazardous waste is: batteries and accumulators, expired drugs and vaccines, paints and varnishes, car tires, polyethylene, mercury lamps, thermometers, etc. Hazardous waste is toxic and poisons land and water sources within radius of several tens of kilometers when getting to landfill with ordinary waste [4].

Also, waste sorting will significantly help to protect against harmful effects of chemicals because they will not end up in landfills. They will be disposed properly. Moreover, in every city, even a small one, there are collection points: waste paper, glass containers, scrap metal, plastic. Therefore, you can still earn a little by dividing waste and taking it to the collection point.

Waste is sent to processing plants from the collection point. They create secondary raw materials from them and then new products. This is very important because you do not need to extract resources again to create something new, but you can use existing ones [4].

We believe that one of the main indicators of the country’s civilization is its attitude to problem of sorting and disposal of waste. Therefore, in our opinion, it is necessary to create conditions for the most convenient and automated approach to sorting, processing and reuse of various types of waste (figure 9).

Figure 9. Waste sorting.

The first thing to start is to form and develop environmental competence of each citizen. Ideally it is better to start with educating younger generation, instilling in children and young people the habit of sorting waste and awareness of their position as a conscious citizen of their country under auspices “I do for my clean and healthy future!”.
Also, constant informing of population about environmental, economic and social consequences of the accumulation of industrial, household waste and ways to solve this problem is profitable. Thus, informing population (educational activities) is carried out by several groups of methods: through poster agitation, social advertising, conferences and events, environmental tours and more. At the same time, one of the main tasks for solving the issue of waste management is to encourage population to sort waste using financial levers and social advertising in the media.

At the state level measures should also be taken to encourage producers of polyethylene and polypropylene packaging materials to produce biodegradable products and producers of plastics in primary forms to produce biopolymers that are compostable and biodegradable as raw materials for biodegradable products. The raw materials for production of biopolymers are such natural substitutes for plastic as starch (potato, corn, etc.), bran of cereals (wheat, oats, corn, etc.), algae extracts, grain waste (straw, corn leaves). Limited use of natural raw materials for biopolymers production is due to their high cost compared to PET raw materials [35].

Today, Ukraine needs to revise principles of recycling at existing enterprises, as companies that use waste as an energy source cause great damage to the environment. However, it is necessary to spend a lot of money to make these businesses environmentally friendly.

8. Conclusions
Ukraine is one of the countries with the largest absolute volumes of waste generation and accumulation. According to the National Institute for Strategic Studies in Ukraine, about 10 tons of waste per capita is generated annually against 5.5 tons - 6 tons of waste per capita in the European Union.

Situation with landfills in Ukraine is uncontrolled. It is evidenced by illegal landfills. They constantly deteriorate environmental situation in Ukraine by their harmful chemical emissions. And there is only one working waste incineration plant “Energia” in Ukraine. It can not solve the problem of the whole country.

Landfills will remain the main way to accumulate solid waste for a long time. It is possible to reduce impact of various household wastes on the environment through:

- improvement of existing regulations and their implementation;
- forecasting of SDW amount and study of morphological composition due to changes in environmental and social factors that affect the morphological composition of waste is important;
- mathematical modeling of pollutants distribution in the components of the environment which are formed on the territory of landfills;
- control and register of landfills;
- relocation of landfills;
- sorting of solid household waste;
- construction of waste processing and incineration plants;
- informing of population about environmental, economic and social consequences of accumulation of industrial and household waste and ways to solve this problem;
- revision of waste recycling principles at existing enterprises;
- implementation of measures that will encourage producers of polyethylene and polypropylene packaging materials to produce biodegradable products, and producers of plastics in primary forms - to produce biopolymers that compost and biodegradable, etc;
- introduction of environmentally safe technologies of waste processing - biogas extraction systems and installations for electricity production;
information policy and development of educational programs aimed at raising of public awareness of waste management.

Thus, uncontrolled dumping of waste into the environment is no longer acceptable in modern conditions. Even controlled landfilling and incineration of organic waste are no longer considered as optimal methods. Environmental standards are becoming stricter and aimed at recovering energy and organic residues.

It should be understood that if humanity does not start to improve environmental situation now then in a couple of decades we will get poisonous (unfit for drinking) water, land that can not produce organic fruit. These consequences will have very negative impact on life and health. In further research, attention should be paid to waste disposal in Ukraine and abroad.

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