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MANAGEMENT EFFICIENCY FOR CERTAIN TYPES OF PLASTIC WASTE

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Abstract. The issue of segregating plastic waste from the general stream of municipal solid waste and its recycling and disposal is a pressing environmental and socio-economic problem. Given that existing plastic waste recycling facilities in Ukraine are underutilized and partially operate on imported raw materials, the problem of separating and processing certain types of plastic waste from Ukraine's overall solid waste flow is extremely urgent. Plastic wastes are categorized by disposal complexity into three groups:
1.With good properties (clean, sorted, easily disposed of, and up to 90 % of similar materials can be used during recycling);
2. With medium properties (containing a certain amount of pollutants, that require sorting, and their processing involves additional costs such as selection, washing, etc., resulting in only 20–30 % of their initial quantity being recycled);
3. Difficult-to-dispose wastes (heavily contaminated and mixed, their processing is often not cost-effective).
Polyethylene is one of the most common types of plastic wastes in Ukraine, accounting for 34 % of all plastic waste. It was discovered that low-pressure or high-density polyethylene is one of the most marketable types of secondary raw materials in Ukraine, making the separation and collection of this type of plastic waste economically beneficial.
The aim of the study is to justify the possibilities of extracting and disposing of plastic waste from the flow of municipal solid wastes in specific cities of Ukraine. This has been implemented by the public organization "City of the Future" in partnership with the Odesa State Environmental University.

Keywords: plastic waste, low-pressure polyethylene or high-density polyethylene, waste management, secondary raw material, microplastics.

1. Introduction

Effective management of valuable components of municipal solid waste (MSW) is influenced by several factors, namely: the urgency of efficiently handling MSW in the context of European integration processes; minimizing the impact of MSW on environmental components; the possibility of using MSW as an additional source of funding for certain sectors; and the potential for using waste for Ukraine's energy independence.

Among the resource-valued components of municipal solid waste, plastic material waste (PMW) holds a special place. Its primary sources are the production sector and service sector. While production enterprises and service enterprises are compact sources, the population represents a distributed source of PMW. In regions of Ukraine, there is no clearly defined system for managing PMW. Potential methods of dealing with PMW include: landfilling in MSW landfills and dump sites; incineration (with/without obtaining energy); recycling and utilization as secondary raw materials. The most preferred approach is to prevent the formation of PMW. Among recycling methods, reusing the waste is given the highest priority since its negative environmental impact is minimal, while landfilling in MSW landfills and dump sites is the least preferred. The incineration of PMW and their conversion into secondary material resources (SMR) and energy hold an intermediate position in the waste management hierarchy.

2. Materials and Methods

In 2021, Ukraine generated over 51 million m³ of municipal solid waste, or over 10 million tons, which were buried across approximately 6.000

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landfills and dump sites covering an area of nearly 9.000 hectares. Out of the total flow of municipal solid waste, about 7.64 % was recycled and utilized. Specifically, 1.14 % was incinerated, and 6.5 % of the waste reached secondary raw material procurement/aggregation/collection/ points and waste processing lines (Ministry of Development of Communities and Territories of Ukraine, 2023). It's worth noting that municipal solid wastes are a source of a significant amount of secondary material resources. If an efficient management system for specific types of plastic waste is organized, they can become a source of financial support for Ukraine, especially during wartime.

It was discovered that low-pressure or high-density polyethylene (HDPE) includes items such as water and milk bags; bleach, shampoo, detergent, and cleaning agent bottles; food wrap; bottle caps; bags and containers for motor and other machine oils, etc. These products are deemed safe for human health. They can be used for prolonged periods, but may release formaldehyde which negatively affects the respiratory and nervous systems. They are easy to recycle (by grinding into granules) and reuse, making them one of the most marketable types of secondary raw material in Ukraine, thus, the separation and collection of this type of PMW is economically beneficial.

Special attention worldwide is given to the optimal handling of plastic waste, which constitutes an average of 12.9 % of Ukraine's MSW (Safranov et al., 2020). It is known that plastic products have numerous valuable properties, such as high plasticity, durability, and a relatively low cost. That is why over the past 50 years, global plastic production has reached approximately 9.1 billion tons with an annual growth of 8.7 % (Geyer et al., 2017).

Global production of plastics and plastic products surged from 2 million tons in 1950 (Geyer et al., 2017) to 368 million tons in 2019 (Wang, 2020). After that, between 2019 and 2021, production sharply rose to 390 million tons, partly due to the COVID-19 pandemic, reflecting a high and constant demand for plastic (Plastics Europe, 2022). Projections indicate that plastic production will reach 670 million tons by 2040 (Delangiz et al., 2022).

According to (Plastics Europe, 2021), 40.5 % of the produced plastic materials are used as single-use packaging, resulting in plastic waste. Despite increasing recycling rates, the prevalent portion still ends up in the environment. For instance, approximately 250 million tons of plastic waste entered the marine environment in 2015 (Defu et al., 2018). Based on the data (Eriksen et al., 2014; Wright et al., 2017), around 5.25 trillion units of plastic waste, weighing a total of 268,940 tons, are floating on the surface of the World Ocean. Furthermore, according to plastic (Plastics Europe, 2022), China's share of plastic production is rapidly increasing (34 % of global plastic production), and the competitiveness of EU plastics may be reduced due to the energy crisis following the war in Ukraine. This will directly lead to an increase in the volumes of plastic waste on a global scale.

Plastic wastes entering the environment degrade mostly due to ultraviolet radiation. Weathering doesn't structurally alter polymers but breaks them down into smaller fragments (Wang et al., 2020). These fragments are typically classified by size as macroplastic (> 2 cm), mesoplastic (5 mm to 2 cm), microplastic (< 5 mm), and nanoplastic (< 1 µm) (Blettler et al., 2017; Bouwmeester et al., 2015). Microplastics are further divided into primary and secondary types. Primary microplastics are intentionally produced, for example, for shampoo packaging, toothpaste, and other daily use items, while secondary microplastics form during the physical and chemical degradation of larger products (Khalid et al., 2020). Prolonged accumulation of these plastics can have repercussions for terrestrial and marine ecosystems (Surendran et al., 2023).

Today, microplastic particles are widespread in the environment. They are found in soil and aquatic ecosystems, including seafood. Compared to oceans, terrestrial ecosystems and soil cover are more susceptible to PMW pollution. According to current estimates, the amount of PMW entering terrestrial ecosystems annually is 4–23 times higher than that entering marine ecosystems. That is why in the USA microbeads in cosmetics are banned due to health concerns (Huang et al., 2020).

Humans can inhale up to 272 microplastic particles from the indoor environment daily. These dense particles settle when they reach lungs and are phagocytosed by macrophages that enter the circulatory and lymphatic systems. Despite a relatively high exposure/intake through air, food, and drinking water remain the primary sources of human exposure (from 39.000 to 52.000 particles annually). The scheme of the microplastic intake by the human body is depicted in Fig. 1.

PMW of the coastal zone of the Northwestern Black Sea is a major component of marine litter (accounting for 83 % of marine litter found in the Black Sea). Macroplastics can be subject to long-term transport by marine currents, winds, and waves, posing a direct threat to the marine ecosystem. The process of biodegradation of macroplastics is hampered in marine conditions, hence the transformation is limited to processes of destruction into micro and nano particles.

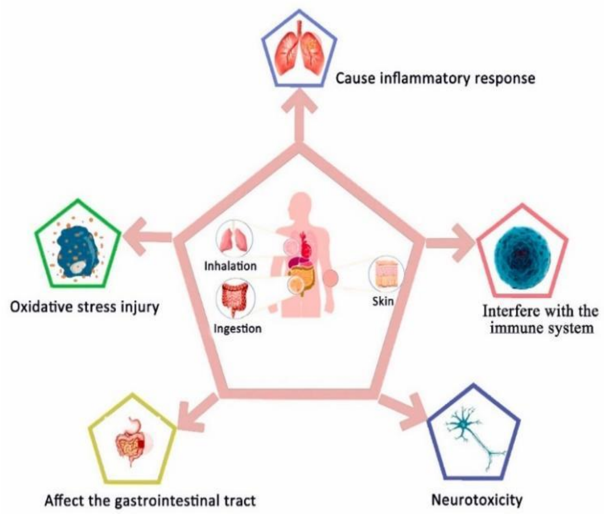

Fig. 1. Human exposure to MPS through inhalation, ingestion and skin contact (Huang et al., 2020)

According to (Shanina et al., 2015), in Ukraine, polyethylene (PE) comprises 34 % of the total plastic waste stream. It's worth noting that it is divided into low-pressure or high-density polyethylene (HDPE) and high-pressure or low-density polyethylene (LDPE). However, data on the proportion of these types in the total PE stream are lacking. Nonetheless, considering that PE is the dominant plastic by mass in the overall MSW stream, it can be concluded that minimizing the volume of this type of plastic entering the environment is a priority. It's worth reminding that PMW is not only a source of environmental pollution but also holds value as a secondary material resource (SMR). The objective of this study is to justify the efficiency of dealing with specific types of plastic waste. The subject of the study is to justify the scheme for managing low-pressure or high-density polyethylene in particular cities of Ukraine.

The methodological foundation of this work rests on a critical analysis of the existing information about the scale of generation of specific types of PMW in Ukraine's regions. The research employed published data from both domestic and foreign authors, as well as materials from independent findings. The results are summarized in tables constructed using the MS Excel program. Furthermore, statistical and comparative-geographical methods of information analysis were utilized.

The research is based on information regarding the mass of collected plastic during the implementation of the "Plastic Saves Lives" project by the NGO "Future City". In particular, one of the authors of the article, Vladyslav Mykhailenko, serves as the leader and coordinator of this project. The enterprise handling this type of PMW is the "Vtorma" company located in Odesa (VTORMA Odesa, 2023). Within the scope of the "Plastic Saves Lives" project, there was a plan to raise $4.000 USD to financially support the Armed Forces of Ukraine (AFU).

3. Results and Discussion

The project's realization consisted of five main stages, as illustrated on Fig. 2.

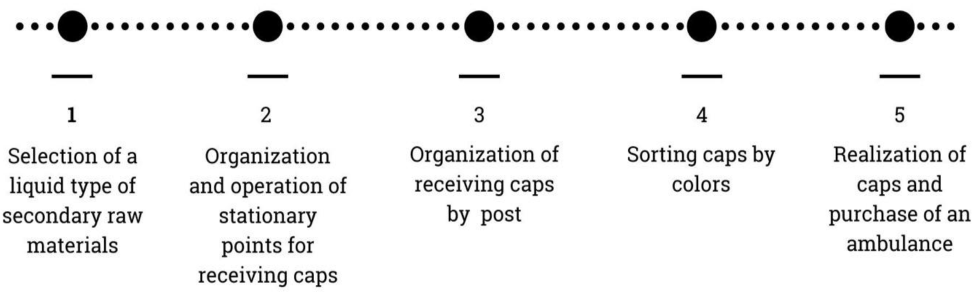

Fig. 2. Stages of implementation of the "Plastic saves lives" project

1. Selection of a marketable secondary raw material: During this stage, members of the public organization "City of the Future" and representatives of the Odessa State Environmental University analyzed the secondary raw material market of Odessa. It was discovered that the majority of sorted waste in Odesa ends up at “Vtorma”. Consequently, we analyzed the prices for different types of secondary raw material and selected the most cost-effective component of PMW for large-scale collection. A comparative table of the most common types of secondary raw material accepted by “Vtorma”, as well as the analysis of the advantages and disadvantages of collecting the analyzed waste fractions, is presented in Table 1.

Table 1

Advantages and disadvantages of selling different components of raw material (according to “Vtorma” rates)

Number	Type of a Secondary Raw Material	Price UAH/kg	Main advantages for collection	Main disadvantages for collection
1	Waste paper, cardboard	4	Easy to sort, a large mass in relation to the general solid waste flow, mostly clean (provided a relatively quality sorting has been conducted)	Take a lot of space in collection and temporary storage sites/branches and big financial expenditures for transportation
2	Glass, mixed broken glass	0.6	One of the most common types of raw material that residents collect, easy to sort	Take a lot of space for storage, specific rules of transportation and storage; significant expenditures for transportation; low financial equivalent
3	Aluminum can	15	High cost of the resource	insufficient quality of raw material due to contamination with residues of sweet or alcohol beverages; lack of a culture of compressing such type of waste before throwing it away
4	Iron can, ferrous scrap metal	1.5	Ease of sorting in everyday life, provided there is a magnet	low cost, insufficient quality of raw material due to contamination with food residues; decrease in collection rates due to the need for cans for the manufacturing of “trench candles” for the AFU
5	Polyethylene bottle	6	A significant amount of used bottles in the household; ease of washing of such type of waste before submission (to the collection points)	Requires a lot of space at the collection points and reduction of the volume of the bottle before submission by compressing (currently, there is no culture of doing so)
6	HDPE caps (general stream)	5	A significant amount of used bottles in the household; easy to sort; a relatively clean waste stream	low weight of a single cap; necessity of a large-scale collection; logistics costs
7	HDPE caps (sorted stream)	14*	High cost; presence of a buyer of this resource in Ukraine; a significant number of used caps in the household; ease of sorting; a relatively clean waste stream	Low weight of a single cap; necessity of a large-scale collection; logistics costs; necessity to organize the sorting of caps by color

It's worth noting that the price set by “Vtorma” for sorted by color HDPE is 11 UAH/kg. However, for the needs of the AFU, an agreement for the price of 14 UAH/kg was reached. Based on the information in Table 1, during the first stage, we chose the color-sorted HDPE stream for collection.

2. Organization and operation of stationary points for cap collection. For the rapid collection of specific types of secondary raw material (SRM), public catering establishments in Odesa were involved as stationary collection points. However, given the active spreading of information about the project, we organized stationary locations for plastic collection in another seven cities of Ukraine. Over the course of 8 months, these locations facilitated collection. The results are illustrated in Fig. 3.

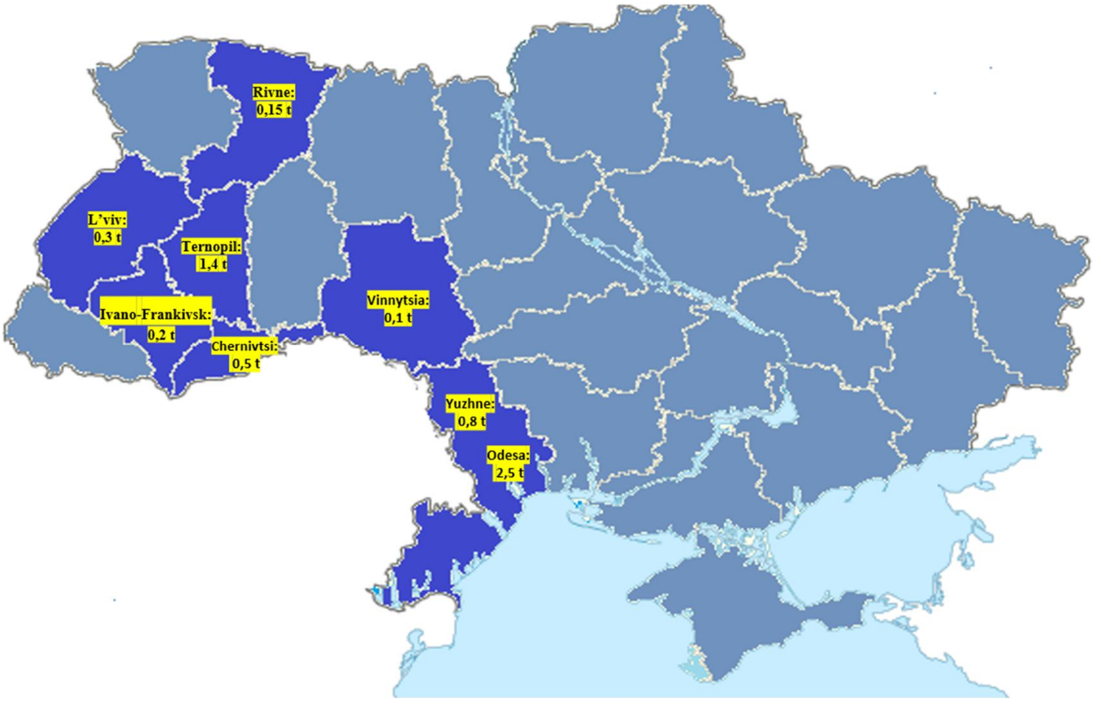

Fig. 3. Location of stationary plastic collection points on the map of Ukraine

It's noteworthy that the largest volumes were collected in the cities of Odesa and Ternopil, as well as in the city of Yuzhne (Odesa region). Even though Yuzhne's population is considerably smaller than that of the larger cities, the substantial collection there illustrates that success depends not only on the population of a city but also on the quality of the organization.

3. Mail collection of bottle caps. All the bottle caps collected as part of the project (excluding those from Odesa) were transported to Odesa using the services of the "Nova Poshta" company. This company provided the free transportation of this type of raw material for our project, covering the most expensive part of the project. In addition to the stationary points, residents of Ukraine could also send their caps to us via Nova Poshta free of charge (for parcels weighing more than 5 kg). This approach allowed us to involve over 40 additional populated areas in the collection of SRM.

4. Sorting of bottle caps by color. To increase the value of the collected SRM, a crucial step was sorting the bottle caps by color groups. Details are given in Table 2.

It is important to highlight that black HDPE is accepted at a rate of 5 UAH/kg. The sorting of plastic took place in the facilities generously provided by our partners – Odessa State Environmental University (where the majority of the caps were stored) and the "Spilna Meta" public organization (which provided their office space for the purpose of sorting the caps). Thanks to the efforts and dedication of the volunteers involved, 100 % of the entire HDPE flow was sorted. Based on the approximate estimates, the percentage of HDPE colors is presented as follows (Fig. 4).

Table 2

Color-based classification of HDPE plastic waste

Plastic group	Colors included in this group
Group 1	White, transparent
Group 2	Red, pink
Group 3	Blue, light blue, purple
Group 4	Green, dark brown, light green
Group 5	Yellow, orange
Group 6	Black

5. Selling the caps and purchasing the ambulance. Due to an urgent request for the purchase of an ambulance vehicle, we prematurely announced the end of the collection phase and sold the collected plastic. This covered 70 % of the cost of this vehicle. The remaining 30 % was sourced from other contributions. It was thus proven that environmental projects related to the collection of recyclable materials can significantly assist the AFU during wartime.

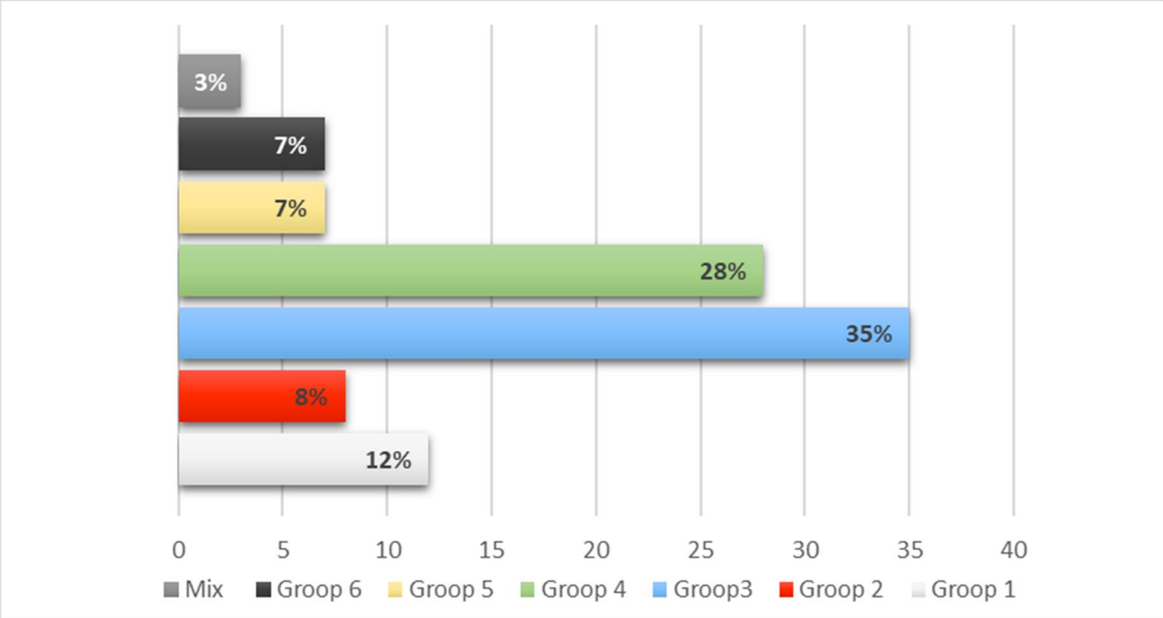

Fig. 4. The percentage of HDPE colors is presented as follows

4. Conclusions

The following conclusions can be drawn from the conducted research:

– Plastic waste is among the most prevalent ones in the overall MSW stream, necessitating a focus on minimizing its creation.

– The separation and collection of low-pressure or high-density polyethylene (HDPE) are economically beneficial.

– The general flow of low-pressure or high-density polyethylene (HDPE) can be made more marketable by introducing color sorting, making its financial efficiency almost comparable to aluminum waste.

– The collection of low-pressure or high-density polyethylene (HDPE) by the public organization "Future city Ukraine" over the period of 9 months made possible raising 70 % of the amount required for the purchase of the ambulance vehicle for the AFU. However, industrial-scale collections could cover much more significant needs of the AFU.

– Implementing similar projects effectively addresses both environmental protection issues and provides financial aid to the AFU and those affected during the wartime.

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