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ANALYSIS OF FACTORS INFLUENCING THE CIRCULARITY OF PLASTIC PACKAGING WASTE RECYCLING: A CASE STUDY IN THE BALTIC STATES

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Since the discovery of polyethylene and polypropylene during the 1950s, polymers materials have been become popular and they are widely used for many applications of our daily life [1]. On average, global plastics production grows by around 9% each year. Just for the period 2018-2021, global annual plastic production increased from 365.5 million tonnes to 390.7 million tonnes, or around 7% [2]. Plastic production, as well as demand, is growing rapidly due to the outstanding properties of plastics and the cheapness of their production. According to the Eurostat data, up to 30 million tonnes of plastic waste is generated in Europe every year. Looking at the use of plastics by industry, it can be seen, that the packaging (around 40%) and the building sector (around 20%) are the biggest end-use markets for plastics. In 2020, the EU generated around 15.5 million tonnes of plastic packaging waste.

Most common used polymers for package are thermoplastics, which covers almost 85 % of overall plastic market demand (such as polyethylene terephthalate (PET), high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinyl chloride (PVC), polypropylene (PP), and polystyrene (PS)), while the thermosets account for 15% overall plastic market (duroplast, polyurethane (PU), polyester resin) [3]. Recycling of plastic products made from different polymers is also different, due to the different physicochemical properties of plastics.

According to the Plastics Europe, in 2020 approximately 17% of the post-consumer plastic packaging waste went to landfill and 37% were incinerated for energy recovery. Around 46% of the plastic waste were recycled. However, it found, that the amount of waste exported out or within the EU is included in the recycled rate. Then, a recycling rate possibly up to three time lower is estimated for the EU when the extra-EU exports are excluded [4]. Insufficient recyclability of plastic packaging waste leads to increased generation of plastic waste and further use of fossil fuels for the production of new plastic products, which causes significant negative environmental impacts. In addition, the EU has set ambitious targets for recycling packaging waste, aiming to recycle 65% of all packaging waste by 2025 and 70% by 2030. Meanwhile, the recyclability of plastic packaging is expected to reach at least 50% by 2025 and at least 55% by 2030 [5]. The only solution to achieve these objectives – is to develop a circular economy to replace the current, linear, economy. In a circular economy, products and materials are being re-used, refurbished, or recycled according to the waste hierarchy, instead of being incinerated or disposed.

According to the Eurostat data, the amount of plastic packaging waste generated in the three Baltic countries (Lithuania, Latvia, and Estonia) in 2020 was around 86, 46.7 and 53.6 thousand tonnes or

30.8, 24.6 and 40.3 kilograms per capita respectively, while the recycling rates for it were as follows around 56%, 36% and 41% respectively. Despite the fact that Lithuania has already reached the 2025 recycling rate for plastic packaging waste (according to the Eurostat data), there remains a lot of room for improvement in the recycling system for plastic packaging waste, in Lithuania as well as in the other Baltic countries.

To evaluate the possibilities of increase of the package waste recyclability and recovery rates in the Baltic States and analyze the factors influencing the circularity of plastic packaging waste recycling, in 2023 was performed a quantitative and qualitative analysis of plastic packaging waste flow in the municipal waste management systems of Kaunas (Lithuania), Tallinn (Estonia) and Daugavpils (Latvia) municipalities. The aim of investigation is to analyse the morphological composition of packaging waste collected separately, also collected from mixed municipal solid waste (MMSW) flow. The analysis of the mixture of paper, plastic, and metal packaging waste also of the MMSW was performed in the summer-early autumn of 2023 in the waste management companies: mechanical biological waste treatment (MBT) facility – VšĮ "Kauno regiono atliekų tvarkymo centras" (Lithuania, Kaunas), waste sorting facility – AS "Tallinna Jäätmete Taaskasutuskeskus" (Estonia, Tallinn) and waste sorting facility – SIA "AADSO" (Latvia, Daugavpils).

A group of students manually sorted a randomly picked pile of packaging waste. First, the waste was sorted by different morphological fractions – plastics, paper, glass, fine residues etc. After this the plastic waste fraction was separated into different sub-fractions by the type of polymers according to the identification marks of international standards on the packaging (1 PET, 5 PP, 6 PS, etc.) (European Parliament and Council Directive 94/62/EC). Further, each of the waste fractions, as well as the plastic sub-fractions, were weighed to quantify the amount of waste fractions and sub-fractions.

The results of the morphological analysis in waste management companies in Kaunas, Daugavpils and Tallinn municipalities are presented in Figure 1.

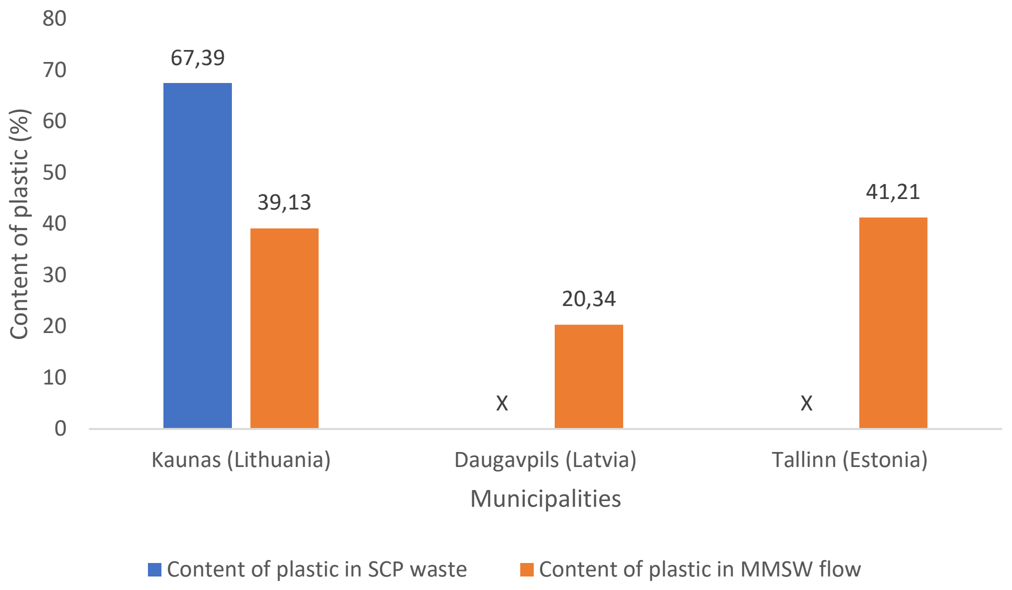

Fig 1. The content of plastic (%) in the SCP waste and from the MMSW flow

It is important to note that morphological investigations of separately collected plastic (SCP) packaging waste (from separate plastic waste collection containers) were performed only in Kaunas municipality. The reason is that Daugavpils and Tallinn municipal waste management companies did not have the possibility to analyse SCP packaging waste, as they did not have a "door-to-door" plastic packaging waste collection system (packaging waste is not included in organised waste transport) [6]. The results showed that up to 68% of the SCP waste stream contains plastic. Meanwhile, the plastic content of the MMSW flow was around 39% (for Kaunas), 20% (for Daugavpils) and 41% (for Tallinn). Figure 2 shows the distribution by sub-fractions in the SCP flow (only for Kaunas). The results of the morphological analyses show that LDPE polymer packaging accounts for the largest share of the SCP - around 29%. About one-sixth of SCP waste is metal waste. In the Lithuanian waste collection system, household plastic packaging and metal waste are collected in one container, so it is the reason why part of metal was found in the SCP waste. Nevertheless, it is worth mentioning that ferrous waste is efficiently separated in waste sorting plants (in the case of Kaunas – MBT facility) by using magnets [7]. Up to 20% of SCP waste is PP packaging.

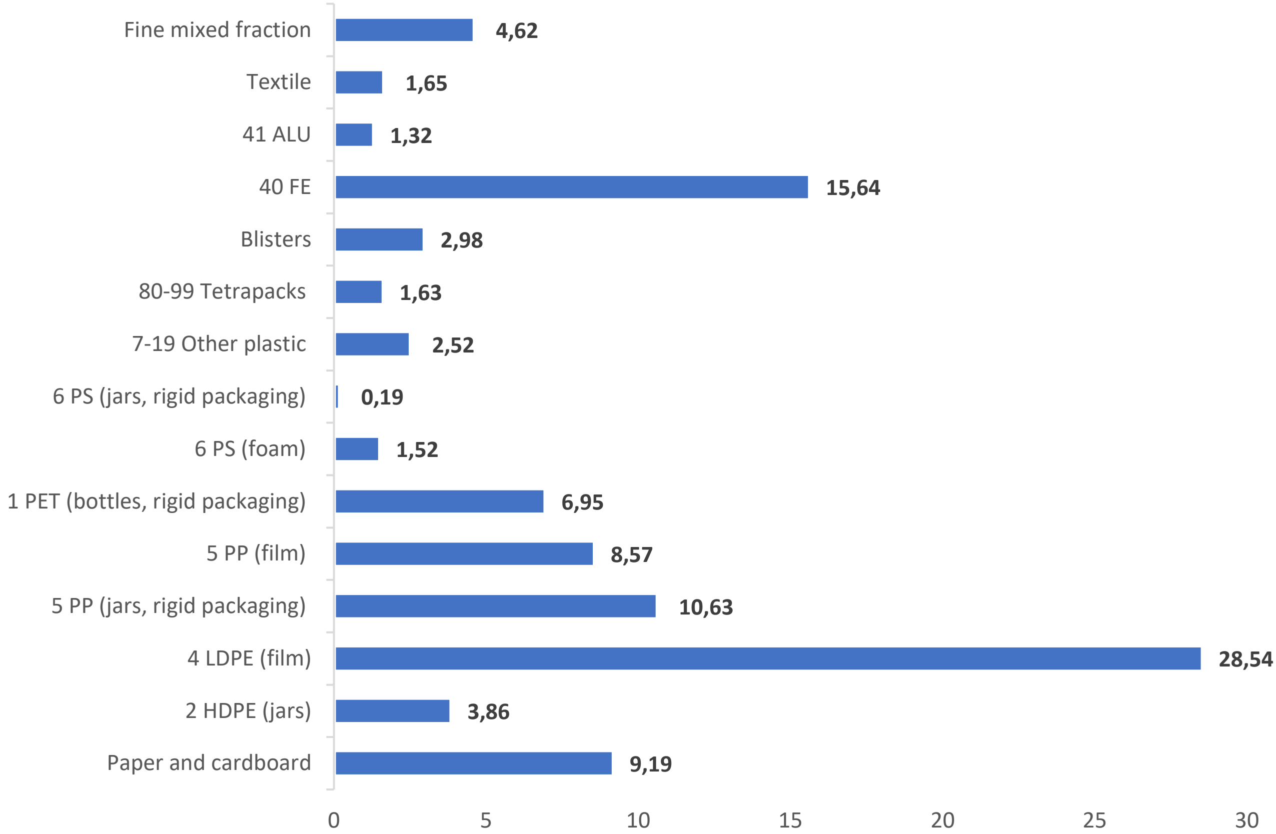

Fig 2. The sub-fractional distribution of the SCP fraction (%)

Figure 3 shows the results of the sub-fractional distribution of the MMSW flow (for Kaunas, Daugavpils, and Tallinn).

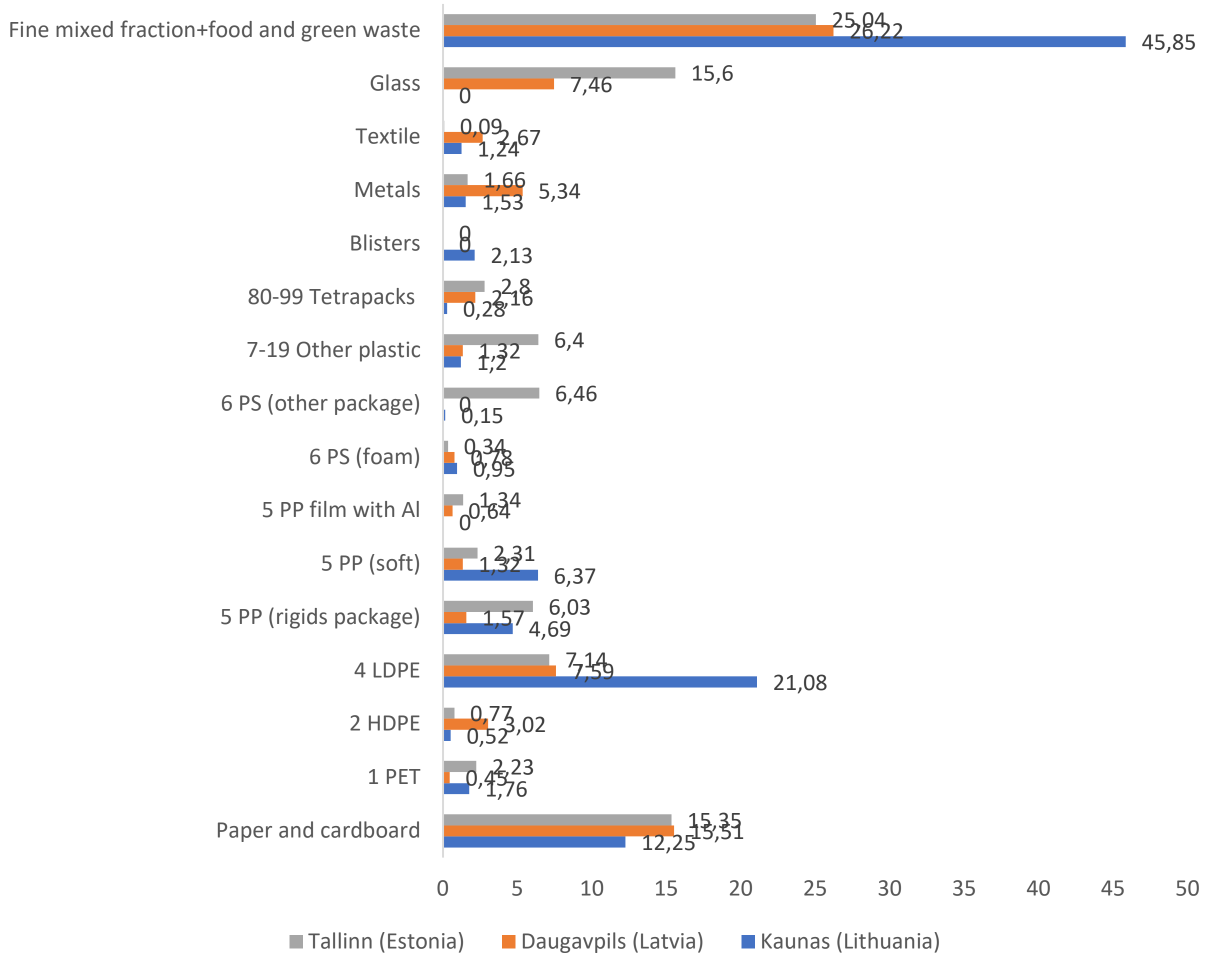

Fig 3. The sub-fractional distribution of MMSW (%)

The data presented in the figure make it possible to compare the morphological composition of MMSW flow in Tallinn, Daugavpils, and Kaunas municipalities. The largest part of the MMSW (up to 26% in Latvia and Estonia cases, and up to 46% in Lithuania case) flow consist of the fine fraction (0-80 mm), as well as green and kitchen waste. It is important to note that the fine fraction contaminates the entire MMSW flow, including plastic packaging waste. In the case of Lithuania, the largest part of the MSW stream (excluding the fine fraction) consists to LDPE plastic packaging waste (approximately 21%). In Estonia and Latvia, the largest part of MMSW is allocated to paper and cardboard waste, as well as packaging made from these materials (around 15%). It is worth paying attention to glass waste in the MMSW flow (it can be up to 16%), as it can contaminate plastic packaging waste, making it difficult (or even impossible) to recycle these components [7].

To clarify the situation, the distribution of sub-fractions (by polymer type) has been recalculated only for the plastic fraction (from the MMSW flow). In general, the results of the distribution of plastic packaging by polymer type in the MMSW plastic fraction are shown in Figure 4.

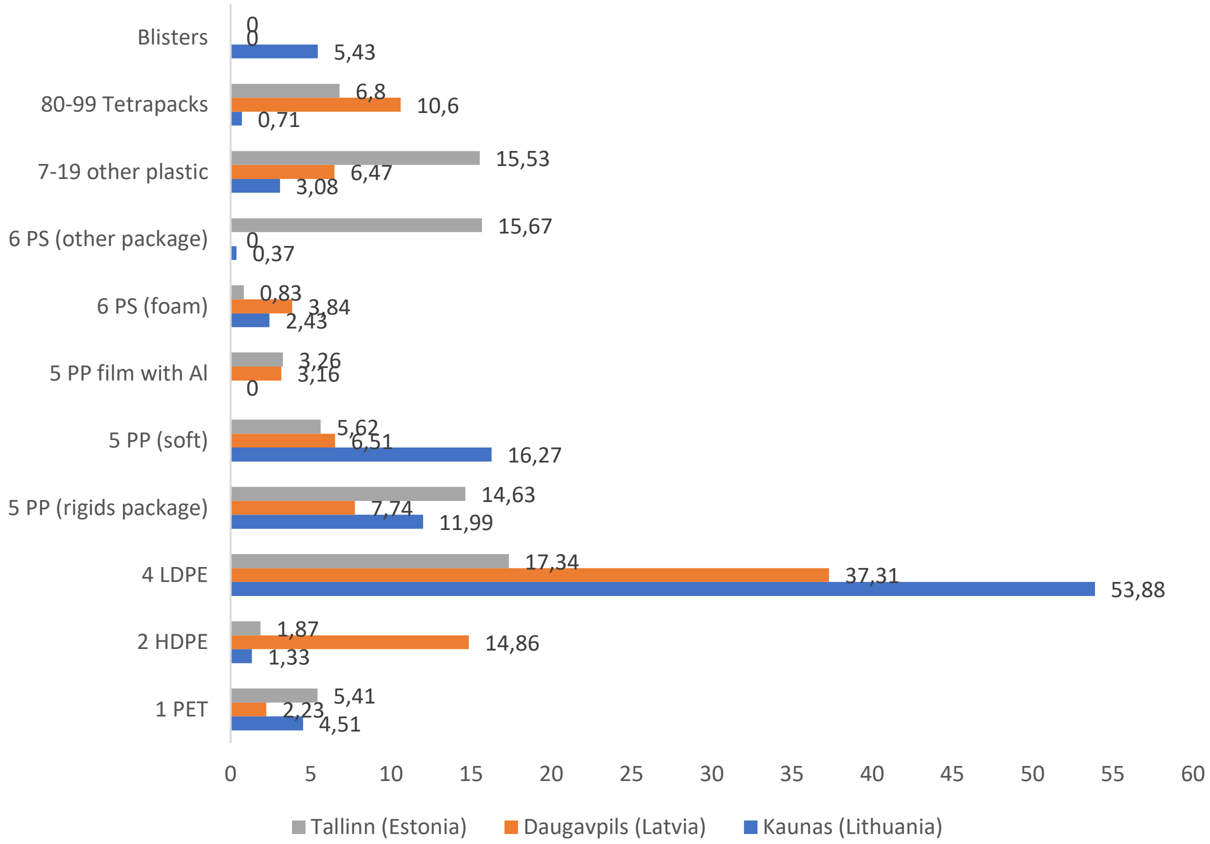

Fig 4. The sub-fractional distribution of plastic fraction in MMSW (%)

When considering only the share of plastic packaging in the MMSW flow, the results show the following trends: LDPE and PP polymers make up the largest share of plastic packaging waste. Up to 54% of LDPE polymer packaging is found in the MMSW flow for Lithuania, up to 38% for Latvia and up to 18% for Estonia. PP polymer packaging accounts for between 16% and 28% of all cases. In the case of Latvia, the amount of HDPE polymer packaging waste is abnormally high compared to the other Baltic states (more than 7 times higher than in Lithuania and Estonia). A certain percentage (from 3% for Kaunas municipality to almost 16% for Tallinn municipality) is accounted by other plastics packaging, such as PU, PLA, and other polymers packaging. Combined packaging (i.e., tetra-packs, blister packs, multilayer films) accounts for a relatively large share of plastic packaging in Tallinn and Daugavpils municipalities - between 10% and 14%, meanwhile, in the case of Kaunas municipality, up to 6% of combined packaging was detected. Recycling technologies for composite packaging are still in a developmental stage, which means that recycling is still very complicated or impossible [8].

Based on the results obtained from the morphological waste composition investigations, a targeted literature review was carried out to identify the main factors influencing the recycling circularity of plastic packaging waste in Lithuania, Latvia, and Estonia. The highlights of study are set out below:

1. Research has shown that personal norms and plastic sorting knowledge significantly influence citizens' intention to separate plastic, with intention and perceived behavioral control positively influencing final separation behaviors. Local authorities should actively campaign for the sorting of waste (especially plastic packaging waste) [9].

2. It was found that the different contamination of the waste stream with impurities (plastic packaging from the SCP flow and from the MMSW flow) leads to the fact, that plastics packaging waste recycling rates are higher when collected separately compared to mixed waste collection schemes (may varied around 13-80 times) [2].

3. Due to the different physicochemical properties of plastic polymers, waste from different plastics (e.g., thermoplastics and thermosets) should be collected separately to increase the potential recycling rate.

4. The collection of plastic waste in the mixed waste stream leads to contamination of plastic waste. Recycling of contaminated plastics is problematic, lower quality products are resulting. In both Latvia and Estonia, there is a high level of plastics detected in the MMSW flow (approximately 40%), which makes it crucial to improve the efficiency of SCP system. Flexible packaging containing aluminum (composites packages) (up to 6% in Lithuania, up to 14% in Latvia an up to 10% in Tallinn) are still not under recycling in the Baltic States. The possibilities of their recycling are currently being investigated by the Department of Environmental Technology of Kaunas University of Technology. Generally, implementation of new recycling methods for plastic waste to improve the recycling of pure and contaminated plastic waste is necessary.

5. Most sorting plants are operated with constant process parameters (e.g., screen cuts, wind sifter speeds, or settings of sensor-based sorting units), which are often optimized during plant commissioning but then rarely adjusted during plant operation. This combination of fluctuating input material flows and constant process parameters can lead to significant performance losses. Therefore, the continuous improvement of the waste sorting line in waste treatment facilities towards higher separation efficiency for plastics of different polymers is mandatory [10].

6. The variation in the quantity and composition of plastic packaging waste is dependent on the seasonality of the year. The seasonality of the year changes not only the amount of plastic packaging generated, but also the composition of the plastic packaging waste flow. Therefore, in order to accurately quantify and qualitatively assess the evolution of plastic packaging waste over the year, morphological investigations of the waste must be carried out at least four times a year ("seasonally") [11].

Further research is needed to improve the plastic waste management scheme and implement technical solutions.

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