TREASoURcE

Rigid plastic composition study

TAMK Project work course

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Introduction

This report presents the findings of a project conducted by TAMK students of Environmental Engineering in collaboration with Ekokumppanit Oy. The project focuses on potential management solutions for rigid plastic waste derived from municipal and household sources in the Tampere region. While plastic waste generation has increased significantly, the only fraction that has been effectively recycled so far is plastic packaging, which accounts for a relatively small portion of plastic waste by mass. Therefore, it is crucial to investigate solutions for recycling the rest of the plastic waste. This project is part of the " TREASoURcE " project rigid plastic collection and recycling pilot conducted by Ekokumppanit with close co-operation with Pirkanmaa Waste Management Company.

Our specific objective in this project was to gain insights into the types, condition, and composition of the plastic waste collected. Our research involved identifying the different types of rigid plastics commonly found in municipal waste streams, as well as planning and conducting physical work. Our group of students undertook the task of quantifying and characterizing the rigid plastics based on their composition, providing valuable data for subsequent groups to develop effective waste management and recycling strategies.

In this report, we will detail the methodology employed in our study, explaining the sample collection process, the analysis techniques used, and the methods of interpreting the data. Additionally, we will present our findings regarding the composition and categorization of rigid plastic waste, estimate the margin of error, and highlight the fractions that constitute the largest share of the waste. Finally, we will propose potential recycling and upcycling methods for these materials, with the aim of reducing the environmental impact of rigid plastic waste in our community. We hope that our findings will inspire further research and encourage collaboration between academia and waste management companies.

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Description of the composition study

A collective study on the diverse types of plastics was done before the field visit for the sampling. Ensuring the representation from diverse sources, the key municipal and household waste collection point in the Tampere region was identified i.e., Tarastenjärvi Waste Center. Further research was done on the types of plastics so that it would be easier on the sampling day. Table 1 shows a list of the types of plastics used for sorting which made the entire process smooth and easy.

TABLE 1. Types of plastics with their corresponding examples.

HDPE	Recycling bins, cereal box, food and beverage containers, toys, laundry shampoo, cleaning products (A&C Plastics Inc N.d.)
LDPE	Plastic bags and bubble films, pipe, and tubing, medical or clean room equipment (medical devices and semiconductor manufacturing), clean room garments, computer hardware & electrical components, consumer goods (squeezable bottles, garbage bags, plastic gloves, individual use containers) (Kuo 2023)
PP	Plastic chairs, plastic furniture, gears in machinery and vehicles, bleaches packaging, first aid products, syringes, pill containers, specimen bottles, plastic plates, bottles, cutlery, package for hot beverages and warm food (Adreco Plastics. N.d)
PS	Insulation panel, packaging foam, containers, trays, plates, egg cartons, compact disks, Petri dishes, test tubes, yoghurt containers, smoke detector housing, hinges (Mohan et al., 2022)
ABS	Printers, Lego, computer keyboard, protective housing for power tools, protective head gears, vacuum cleaners, faxes, medical instruments and plastic toys, outside items (Adreco Plastics N.d)
PVC	Windows, water pipes, sprinkler systems, office furniture, non-food packaging, membership, or bank cards (HARD PLASTIC); Wire and cable jacketing, garden hoses, rainwear and boots, plumbing, electrical cable insulation, inflatable products, imitation leather (SOFT) (Preferred Plastics N.d)
PET	Soft drink bottles, Juice bottles, Water bottles, Shampoo/conditioner bottles, Liquid hand soap bottles, Carry-home food containers (Retlaw Industries N.d)

The sorting of the samples was a bit challenging and time consuming due to the weather conditions and the snow. After arriving at the waste center, protective overalls and safety shoes were provided as the sorting was done on the open ground. Several bins were taken and weighed which were then used to weigh each type of sorted plastic one by one. The best technique used for this analysis was the visual inspection. The plastics were collected in an organized way into categories based on the visual characteristics such as color, size, hardness, softness, material type, brand marking and so on. Each type of plastic was sorted in one place and then they are transferred into the bin and weighed to record their masses.

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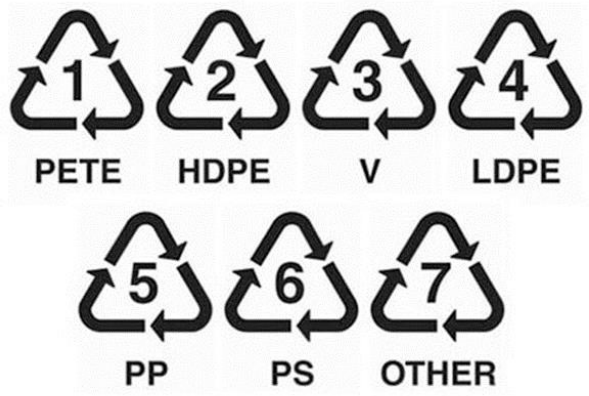
Another technique that was used during the sorting process was the plastic recycling symbols. Most of the plastic waste that had been collected had these markings on them which eased our sorting study. Picture 1 shows several types of plastic denoted by symbols like #1, #2, #3 and so on (Barret 2023).



PICTURE 1. Plastics Recycling Symbols

Finally, the plastics that were not identified as any of the types mentioned were collected separately and weighed just for the comparative study of composition and further analysis on them. Due to the weather, some plastics remained untouched, which might affect the project's overall composition study.

Results

This section provides research on the major plastic types found during the field day and all the calculations and results of the plastics found.
There were eight containers used throughout the day, all of them were weighed in the beginning as to not interfere with the actual weight of the plastics. Table 2 shows the weight of each container.

TABLE 2. Weight of containers in kg

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Container (kg)	36	32	28	34	37,5	37,5	35	37

During the field day the weight of the plastic and the container were weighed and written down in a notebook. These results can be seen in table 3 below. It must be noted that each column is in respect to the container and containers 6,7 and 8 were all used to weigh unknown types of plastic. Also, the pale orange square represents PS, and the pale blue square represents ABS.

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TABLE 3. Weight of container and plastic type in kg.

	PP	HDPE	PET	PVC	LDPE	UNKOWN		
Container + plastic weight (kg)	108,5	59,5	48,5	74	62,5	71,5	64,5	51,5
	61	51,5	31	87	57,5			
	78	64,5		73	58,5			
	85,5	53		55	42			
	71	67,5		47,5				
	77	66,5						
	62,5	52,5						
	65,5	73,5						
	64	58						
	71,5	52,5						
	79	57						
	69	48						
	61,5	53,5						
	74,5	56,5						
	86,5							
	84,5							
	96,5							
	76,5							
	75,5							
	79,5							
	84,5							
	80							

As seen above container 1 was the one that was used the most as type PP was the plastic that was most collected and found. After the field sorting day, calculations were done to find out the weight of the plastic. Equation 1 shows an example of how it was done.

$$Weight\ of\ plastic = (Weight\ of\ container + weight\ of\ plastic) - weight\ of\ container$$
$$example: 108{,}5kg - 36kg = 72{,}5kg$$

This was done for all weights and the final results can be seen in table 4 below.

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TABLE 4. Weight of each plastic type in kg.

Weight of plastic (kg)								
	72,5	27,5	20,5	40	25	34	29,5	14,5
	25	19,5	3	53	20			
	42	32,5		39	21			
	49,5	21		21	4,5			
	35	35,5		13,5				
	41	34,5						
	26,5	20,5						
	29,5	41,5						
	28	26						
	35,5	20,5						
	43	25						
	33	16						
	25,5	21,5						
	38,5	24,5						
	50,5							
	48,5							
	60,5							
	40,5							
	39,5							
	43,5							
	48,5							
	44							

After all this was done, the total weight of each plastic type was added and can be seen in table 5.

TABLE 5. Total weight of each plastic type

	PP	HDPE	PET	PVC	LDPE	ABS	PS	UNKOWN
Total Weight (kg)	900	366	23,5	132	70,5	13,5	21	78
Estimation								234

The full total of all plastic types came to 1604,5kg. The estimated total weight that could have been sorted was 1838,5kg.

An estimation was done after the field day on how many unknown plastics could have been weighed. For most of the day the field group did not put aside plastics that were unidentifiable. After a discussion with one of the supervisors, for the last two hours there were containers that were used to weigh the unknown plastics. After the day finished and the group looked back on how much plastic was sorted, it

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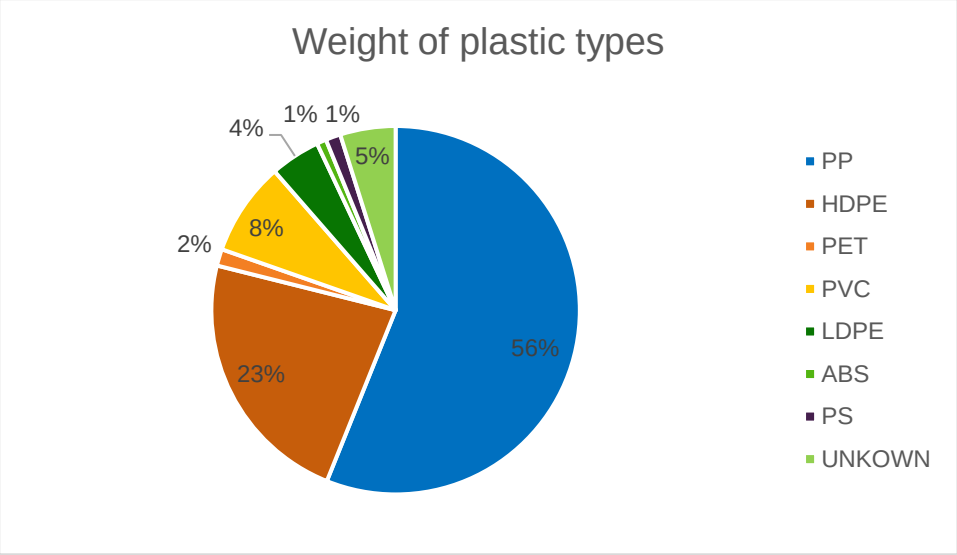
was estimated that around one third was sorted. This was then taken into consideration for the unknown plastic types.

The field sorting day was on a Friday and during the beginning of the week there was a snowstorm which covered all the plastic waste that needed to be sorted. Due to this, as the day progressed there was snow that accumulated into the bottom of the containers that were most used (1 and 2). After the day ended, these two containers were weighed once more to see if there was any significant weight gained. It was noted that there was a 1,5kg weight difference compared to the beginning of the day. Therefore, there is an error margin of ±1,5 kg for plastic weights in PP and HDPE. This does not massively affect the total weight of the plastic types, but it must be considered.

A pie chart (graph 1) shows the composition in percentages of the plastics.



GRAPH 1. Composition of plastics in percentages

As seen above, PP contributed to more than half of the plastics that were sorted. This is due to the amount of outdoor furniture that was thrown away by citizens (mainly plastic chairs). Table 6 shows the different types of objects that were found for the most abundant plastics that were found (PP, HDPE, and PVC).

TABLE 6. Types of materials found.

	Materials
PP	Plastic chairs, plastic tables, car parts, toys, suitcases
HDPE	Pipes, big cylindrical containers, fuel containers
PVC	Pipes

During the research phase of the project, these were indeed the types of plastics that were stated to be PP, HDPE, and PVC.

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Conclusions

The sorting and identification of plastic types were crucial steps in the project. However, the unavailability of equipment led to visual and tactile sorting as the collection method used, potentially affecting the accuracy of plastic identification. This limitation, along with other potential uncertainties, could impact the reliability of the results. Nevertheless, it's important to note that identification numbers or names were present in a large majority of the plastic waste.

All categories of plastics were found, particularly those that could be recognized visually. Among these, it was possible to identify Polypropylene (PP), which was one of the most collected and recognized plastics due to its wide range of applications, from textiles and packaging to medical devices, laboratory materials, or automotive components. High-density polyethylene (HDPE) constituted the second most collected amount, easily identifiable in domestic and household products, as well as in bottles, containers, toys, helmets, cosmetic and food containers. The third biggest batch consisted of industrial plastic products like PVC, widely used in industrial pipes, electrical cable coverings, computers, telephone cases, window insulation, windows themselves, vehicle interiors, packaging, or water pipes, among other uses.

Other categories, including LDPE, PET, ABS, PS, were not in bigger quantities due to their low density are fragile, small, and prone to breakage, making identification difficult. This group also included the unknown category, present in large quantities in the collection—broken plastic, small parts, items without any identification. These comprised products that were a mix of plastics.
It can be recognized that polypropylene was the most abundant in the entire collection, being a resistant and easily moldable plastic, although challenging to recycle. Plastics sharing these characteristics, such as PVC with high resistance and low density or PS releasing plastic chemicals upon thermal exposure, and LDPE with high resistance to impacts or chemicals, are also difficult to recycle but not impossible.

Products that are easy to recycle and commonly found include high-density polyethylene (HDPE), used for household products, and PET, used as packaging for consumer liquids, which are very popular today. These plastics also exhibit great resistance to impacts, temperatures, and chemicals.
Plastics that are challenging to classify are those mixed with various types of resins. The limitations faced, such as the lack of equipment and potential misidentification, underscore the importance of addressing these issues in subsequent projects.

To enhance future initiatives, securing essential equipment for accurate plastic identification becomes paramount. This investment can significantly improve the accuracy and reliability of results, subsequently enhancing recycling processes and informing the creation of efficient waste collection points. Another important step to improve the results, is the accounting of non-identifiable plastics and non plastics parts like metal and accounting them in the right and precise way and reporting them.

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