Sugam Bimali

Mechanical Recycling of Plastics

Metropolia University of Applied Sciences

Bachelor of Engineering

Degree Programme in Environmental Engineering

Bachelor’s Thesis

November 2019

Author(s) Title Number of Pages Date	Sugam Bimali Mechanical recycling of plastics 18 pages + 1 appendices November 2019
Degree	Bachelor of Engineering
Degree Programme	Environmental Engineering
Specialisation option	Renewable Energy Technology
Instructor(s)	Esa Toukoniitty Title (Senior Lecturer, Metropolia University of Applied Sciences)

Plastics have become a concern to everyone as it has become a necessary part of our lives. However, there are also consequences because linear consumption and circular based consumption still needs to be done a lot to reduce the plastic pollution. In this report, plastics type and its production along with its usage is generalized. Effect of plastics on parameters socio-economy and environment are broadened.

Existing mechanical mechanism of plastics recycling along with the emerging methods are described. But more innovation is needed on mechanical separation of polymers as there are still some proportion of plastic waste ending in the landfill. From the statistics view, Finland is doing quite well within the European Union territory when it comes to plastics recycling, energy generating via incineration and landfills. An average EU statistic data shows more is needed to be done especially when plastic production outperforms plastic recycling by more than tenfold.

Keywords	Mechanical recycling, polymers, SPW, Plastics

Contents

1 INTRODUCTION

An incredible number of plastic products are manufactured today, touching every aspects of our lives. Plastic, as we know of, has an impact on every sector of life and has made daily life convenient. It is used to make numerous products used, for example, in households to health services, buildings, automobiles, electrical equipment and electronics. Almost all aspects of our lives relate to plastic-based products. With the rise of plastics-based industries after the second world war, the manufacturing scale of plastic has skyrocketed. Population increase on a global scale has also enabled an exponential growth in the sale and consumption of plastics, making a plastic industry a booming business. As a result, plastics have become waste and a dire health and environmental issue The main problem with plastic waste is that its unability to degrade in a relatively manageable time. Thus, dumping it in a landfill site is not a sustainable solution. Rather, reducing its production, re-using and recycling it would be a feasible way of managing it sustainably. Previously, a linear consumption-based system was intact, therefore, recycling was at 0% during 1980s. Until 2012, in a period of about thirty years, a circular consumption was practiced at a recycling rate of just 8% of total production. The incredible fact is that the production level has increased more than 80 times of that of 1980s *(Beckman, 2019),* which shows that very low interest has been shown in plastics recycling. The fact that recycling methods are not 100% efficient and costly mechanism might be the reason. However, new methods are constantly being developed theoretically and in laboratory, of which many are not feasible in industrial practice.

Beside landfill, micro and macroplastic particles are also ending up in an ocean polluting the sea environment that is leading to the death of many aquatic animals and fishes. Animals have been unknowingly feeding up in plastics, since they cannot digest it, they, ultimately, die. Humans are also ingesting some microplastics through drinking water. Micro plastics are basically very small or invisible to the naked eye. Apart from harming human and animal health, burning plastics have been polluting the atmosphere with the release of greenhouse gas carbon dioxide. Until the alternative to plastics is found and implemented on a mass scale, recycling plastic waste is the only sustainable way to minimize its impact. For that, more and more recycling companies must be established. The practice of recycling has to overgrow the current production ratio and then only we will be able to see the positive changes *(West, 2019)*.

Plastics are polymers or chains of molecules derived from different substances. A polymer is basically an extremely long chain of molecule of any matter that has higher elasticity. The more number of times a molecule is added, the longer the polymer is and the higher elasticity it has *(Bellis, n.d.)*. Polymer length also determines the types of plastics. With the higher elasticity, it is easier for a polymer to bend and mould in different shape and sizes. Higher elasticity is inversely proportional to the strength of the material. From the ancient time, humans have been deriving and using plastics in a daily life. Before the industrial revolution, plastics were derived from organic matter; for example, ancient indians used to derive organic plastic from wood. It had higher elasticity and was composed of hydrocarbon. They used to call it gum-elastic until an English chemist Joseph Priestley proposed a name 'rubber' due to its ability to erase pencil marks if rubbed against them *(Knight, 2014).*

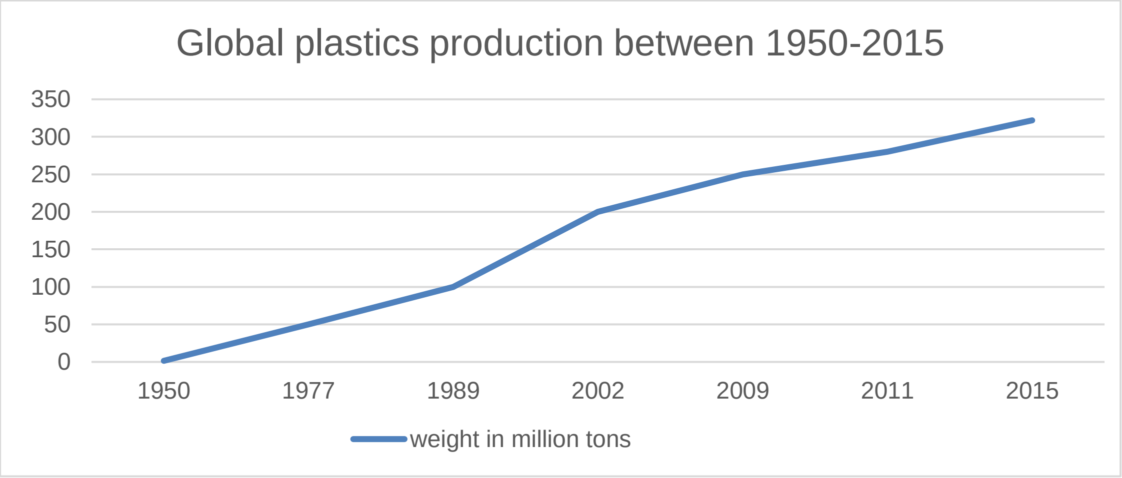

Figure 1: Global plastic production from 1950 to 2015, (theconversation.com)

As industrialization began, numerous types of plastics were introduced and manufactured, primarily monomers treated chemically in the presence of a catalyst to form a polymer. Mass manufactured plastics were widely accepted by people and society as it made their lives easy and convenient in different socioeconomic aspects. Firstly, mass industrial production made plastic cheap, and since plastic is light, it is used to manufacture, for example, different household materials, safety equipment, electronic equipment, sports and leisure activity equipment, food packaging and bottles. It eventually became an integral part of human society.

2 PLASTIC TYPES

As of today, plastics have become a means of convenient lifestyle, and their use has grown coherently with the increasing human consumption of materials. Plastics production begins when the crude oil is distilled in a refinery, producing naphtha, which is the crucial component in the production of plastics. Many plastics types exist according to its polymer structure, length, and they vary in their chemical and physical properties along with their malleability and ductility. Furthermore, plastics also behave differently when treated with heat. When plastics are recycled based on their polymer structure and length, It is hard to obtain the same form of plastics after recycling. Rather, the breakage of polymer length creates a new type of plastics after recycling which is called downcycling. There are basically two primary processes to produce plastics which are polymerization and polycondensation. In an industrial production, polymerization is frequently used and therefore, most of the plastics types also fall under two categories in polymerization process *(General Kinematics, 2014)*:

a) Thermoplastics
Thermoplastics are the type of plastic that is mostly used by us humans. They include, for instance, beverage bottles, packaging containers, grocery bags, piping, footwears and children toys. Thermoplastics are mainly recognised because of their malleability and ductility, which gives them recyclable property. Therefore, they have high elasticity. They are prone to heat and can easily be bent or recycled in desired shapes and sizes. However, they are generally expensive to manufacture.

b) thermosets
Plastics that are un-recyclable are generally understood to be thermosets. They are resistant to heat and high temperature. Hence, they also lack elasticity. Still some of the important products are made from thermosets. Examples of thermosets are vehicle tyres, shoe sole and foams. They have rigid structure and are also used to build parts of the houses.

Figure 2 indicates what type of plastic products can be made of different types of thermoplastics and thermosets.

Figure 2. types of thermoplastics and thermosets

THERMO-PLASTICS	**example**	**THERMO-SETS**	**example**
Acrylonitrile butadiene styrene (ABS)	Door liners and handles, seatback and seat belt, keyboard, rice cooker, iron, grinder etc.	Epoxide (EP)	Epoxide resin generally used for coating and glueing
Polycarbonate (PC)	Sheets for roofing and wall, green house sheet etc	Phenol-formaldehyde (PF)	Used in making electrical plugs, switches, cabinets and plywood
Polyethylene (PE)	Trash bag, milk jug, bread and frozen food bags etc	Polyurethane (PUR)	Used In making car seats, doors, tires, windows, print rollers
Polyethylene terephthalate (PET)	Water and cold drink bottles, plastic fruit container, synthetic jackets	Polytetrafluoroethylene (PTFE)	
Polyvinyl chloride (PVC)	Wires and cables, toys, clothing, pipes, windows frame	Unsaturated polyester resins (UP)	Resin is Used to make eltrical wires, ships, tanks, buildings
Polymethyl methacrylate (PMMA)	Eye lens, plastic tooth, light bulbs		
Polypropylene (PP)	Chair, basket, syringe, food container, shampoo container		
Polystyrene (PS)	Test tube, plastic glass, water jar, mobile phones		
Expanded Polystyrene (EPS)	Package cushioning, plastic plates, glass and spoons		

Basically, we understand Thermoplastics when the term *'plastic recycling'* mechanism is considered *(Fantastic Plastics, 2014)*. Within European Union, the rate of recycling plastic is about 31% according to the statistical report of year 2016 (Figure 3). About 41.5% is recovered as an energy. Approximately 23% of plastics waste still is still landfilled. In Finland, the recycling rate is close to 24%. However, about 72% plastics waste is used for energy recovery, which is impressive and only about 5% is disposed of in a landfill. In other words, any amount of plastics that is not recycled goes either to energy production or to the landfill. In 2016, 27.1 million tonnes of plastic waste were collected through official schemes in the European Union in order to be treated. Hence, for the first time, more plastic waste was recycled than landfilled.

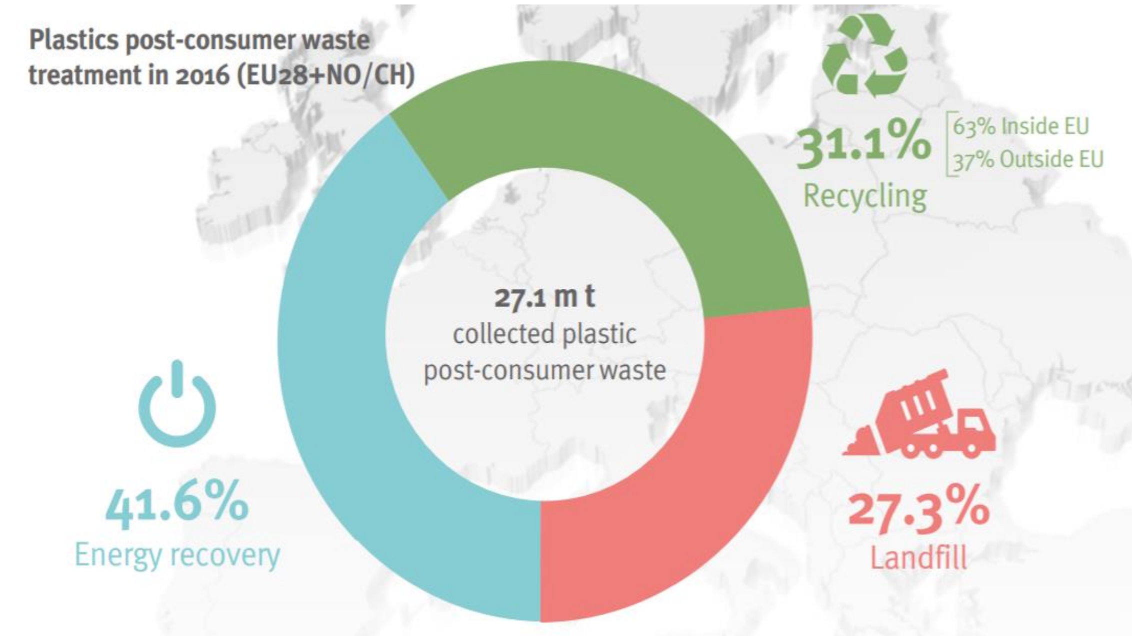

Figure 3: EU statistics, (plasticseurope.org)

3 PLASTICS PRODUCTION IN FINLAND / QGIS LOCATIONS

There are more than a hundred companies currently in Finland manufacturing thermoplastics and thermosets. According to the Finnish Plastics Industries Federation (FIPIF), the number of companies is about 105. FIPIF is a collaborative organization in Finland representing all the plastics manufacturers. The organization also represents as a common voice when it comes to making a plastic related governmental regulation. Many types of plastics manufacturing related firms belong to this organization, for example, firms producing plastics pipes, doors, windows, insulations, bottles, tubes, syringes, food packaging, transportation packaging, machine parts, engine parts and electronics. Some of the firms, for instance, Fortum oy both recycle and manufacture plastics *(Europe, 2017)*.

QGIS software was used to create a map to illustrate the number of plastics manufacturing companies around Finland. A dataset for the raster map of Finland was downloaded from PaiTuli. Addresses of all plastics manufacturing firms were derived from FIPIF. Addresses dataset was accumulated through the FIPIF web portal. First, the MMQGIS plugin was downloaded and installed on the QGIS software. The MMQGIS plugin was used to create geocodes, which did not work. Then, the Geocodes were created using Google sheets. The acquired coordinates were saved in a .csv file. The .csv file was used to put the addresses to the map. Unfortunately, the map and coordinate layers did not seem to match as shown in Figure 4 below.

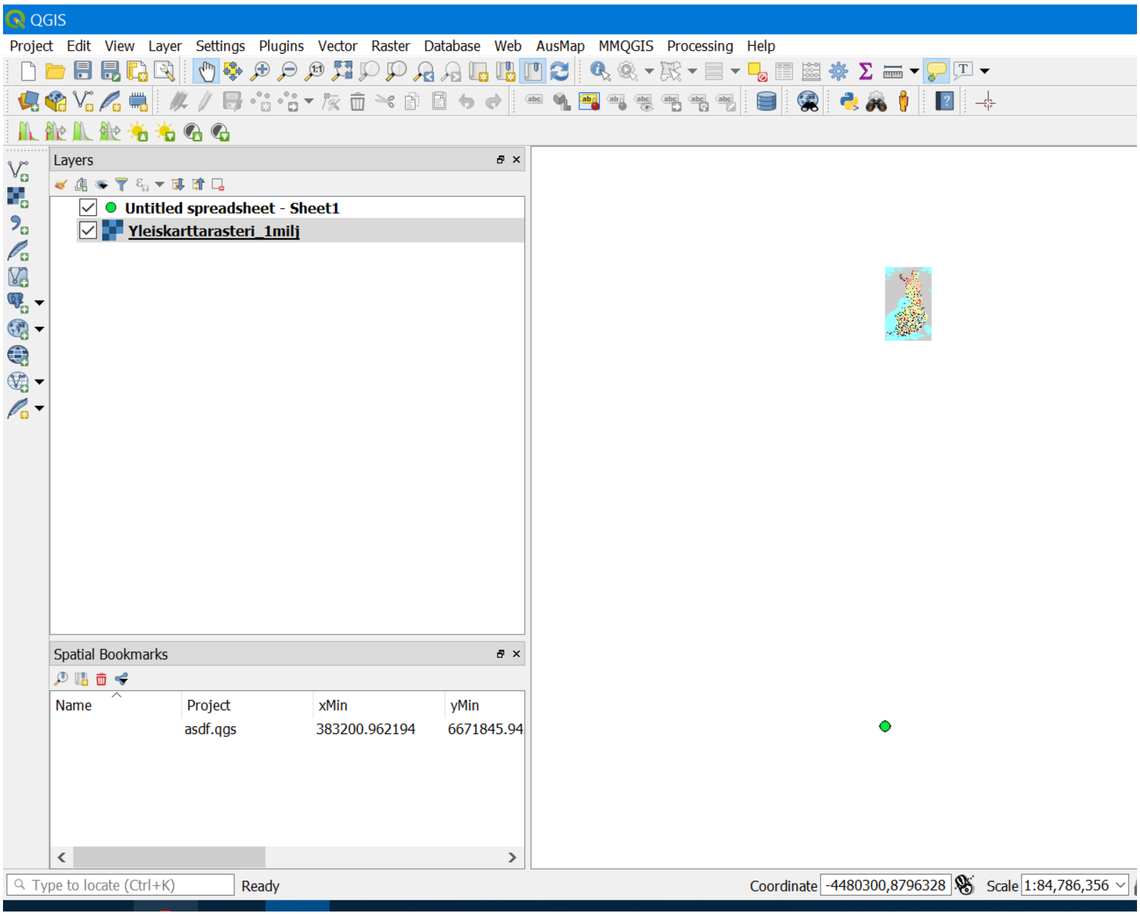

Figure 4: QGIS mapping with unmatched layers

The coordinate reference system for both layers was updated, but the layers still did not seem to match. Therefore, a map with coordinates was created using Google online map service. Coordinates matched with the map while creating it online as shown in Figure 5 below.

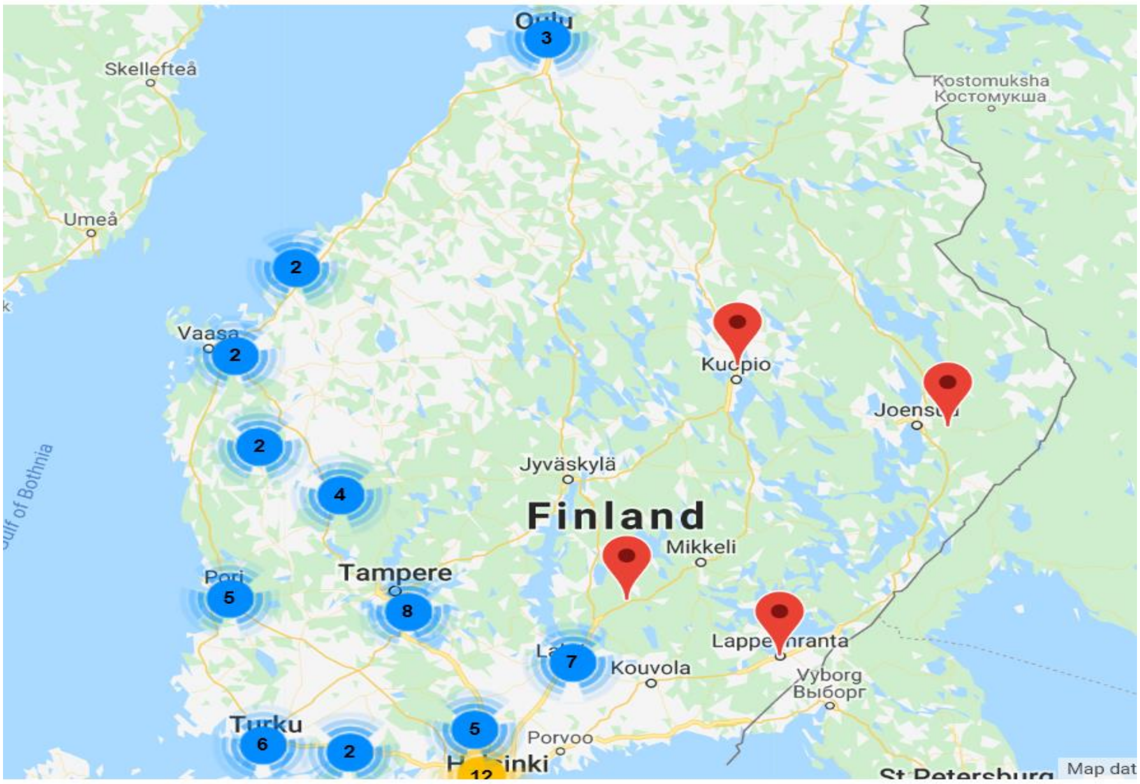

Figure 5: Density of Plastics manufacturing firms in Finland, only one firm is denoted in red, more than one firms are in blue and more than ten firm is in yellow colour

The data from the map shows the cluster of manufacturing firms in all of Finland. Most of the firms lie within the capital region. A significant number of the firms are located in the north-west, while very few firms are located at east of Finland.

4 LINEAR ECONOMY vs. CIRCULAR ECONOMY

Previously, plastics and many other products were consumed linearly, which means products were manufactured, consumed and eventually taken to the landfill (Figure 6). An alternative to this consumption was not sought until its health and environmental impact was realized. Production was high because of linear consumption. As a result, more and more resources were used with negative impacts on human health, environment and atmosphere. Numerous times, plastics are burnt which produce and releases the greenhouse gas carbon-dioxide to the atmosphere *(Europe, 2017)*. Consequently, these emissions help to worsen global warming and climate change. This type of unsustainable behavior is practiced mainly in underdeveloped or developing countries because of lack of awareness and consequences. Aquatic animals and fishes are rapidly dying as they are eating plastics which is abundant in an oceans. Worst of all is that even we wise humans are consuming a small proportion of micro plastics that are invisible to the naked eye through drinking water and food wrapped in plastics. Recycling the used plastics has more benefits than producing them. Recycling saves resources and energy; for example, resources such as water, petroleum and coal are saved. It also helps to minimize the atmospheric pollution since same product is recycled. Furthermore, recycling saves the landfill space as the product is recycled instead of throwing it to the landfill.

Figure 6: simple linear consumption

Such unsustainable practice came to end with the introduction of circular based consumption. Unlike linear consumption, circular consumption includes the recycling and re-use of the materials. However, about 20% of the plastics still goes to the landfill. These are the product polymers that do not blend to recycling after downcycling of plastics polymers or these are the thermosets. Nevertheless, the process is circular, which is sustainable and can recycle about 40% of plastic polymers. An almost equal amount is also used to produce energy. In general, the circular process includes production of materials, consumption, collection and/or sorting before recycling and landfilling a small fraction as shown in Figure 7 *(Ragaert, et al., 2017)*.

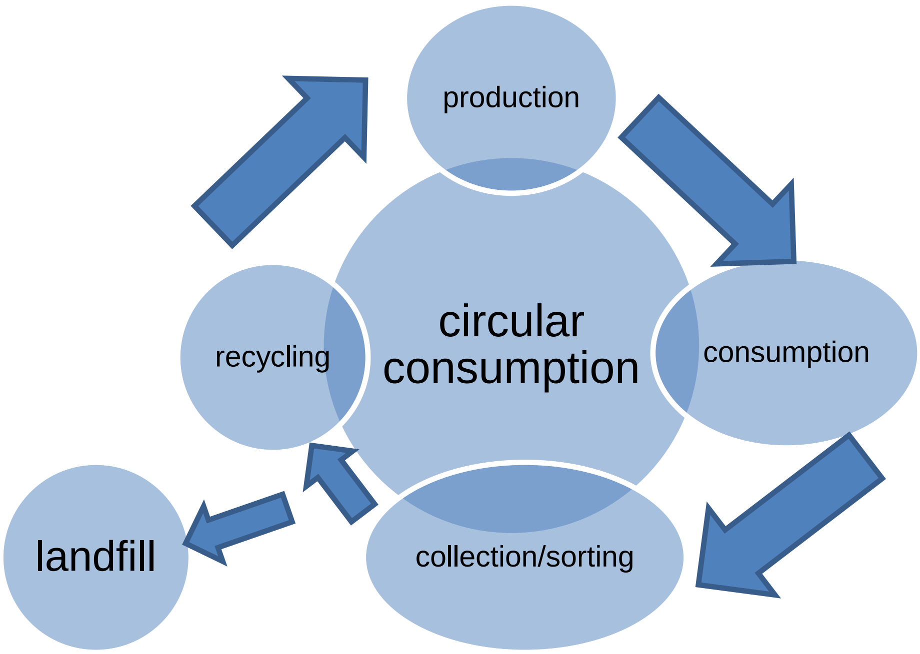

Figure 7: Circular Consumption

The production scale starts to decrease gradually since the 40% of plastics is recycled, resulting in decreased use of resources, reduced environmental harm and enhanced social life.

5 LITERATURE REVIEW

Plastics to be recycled to the same product as it was originally collected, is performed in a close loop recycling process, while the plastics to be recycled in a form different from its recovered form is done in an open loop recycling process. In a closed loop recycling process, a PET bottle is, for example recycled to make similar PET bottles. On the other hand, open loop permits recycling to a different product, for example, a PET bottle can be re-manufactured to a textile fibre or an electronic equipment component can be made from the water bottle’s polycarbonate. Quite often the close loop process becomes an open loop because of the polymer breakdown property of plastic. As the polymer is changed in structure, a similar product cannot be formed and therefore the polymer is downcycled to a different product, for example, a traffic indicator stands.

Polymer degradation is one of the main challenges of recycling mechanically. Due to degradation, the original product is converted to some other products, usually lower quality products, which is called downcycling. There are mainly two parameters responsible for a polymer degradation, which are thermal-mechanical degradation and extrusion of polymers *(Ragaert, et al., 2017)*.

- Thermal-Mechanical degradation
  In this degradation, heat and mechanical shear are the factors responsible for breaking down the polymers. Generally, a carbon-carbon co-valent bond is separated in the polymer backbone, generating free radicals. These free radicals may undergo chain scission or cross linking which is also called branching as shown in Figure 8. Chain scission on the polymer backbone reduces the length and molecular weight of the polymer. With the change in molecular weight, properties of polymer also change. On the other hand, crosslinking increases the molecular weight.

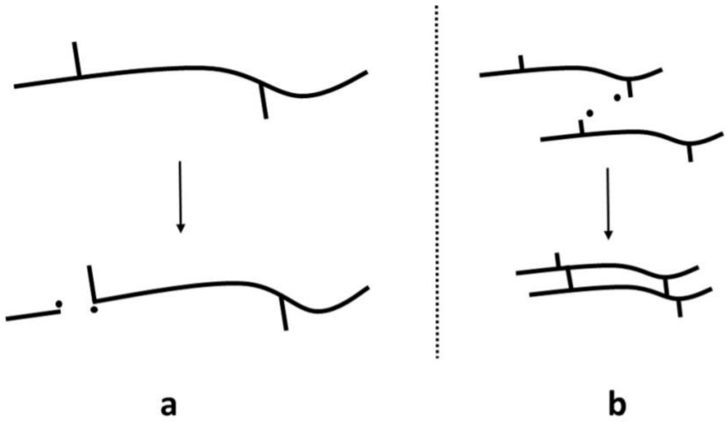

Figure 8: Random chain scission (a) and crosslinking (b)

As a result, the longer the degradation, the more molecular weight is lost. The relationship between degradation rate and molecular weight can be seen in Figure 9.

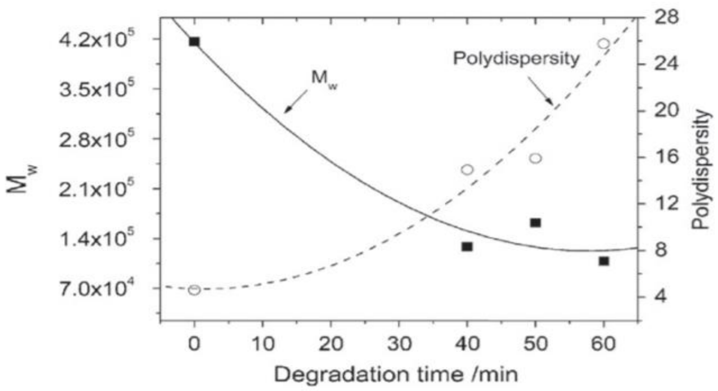

Figure 9: Relationship between molecular weight and degradation rate

- Extrusion:

  The polymer goes through extrusion while making a new product. The number of extrusions is high in re-processing, so the polymer is degraded further in each re-processing and hence the quality of product also changes after each re-processing. The extrusion number is inversely proportional to the molecular weight of the polymer as shown in figure 9.

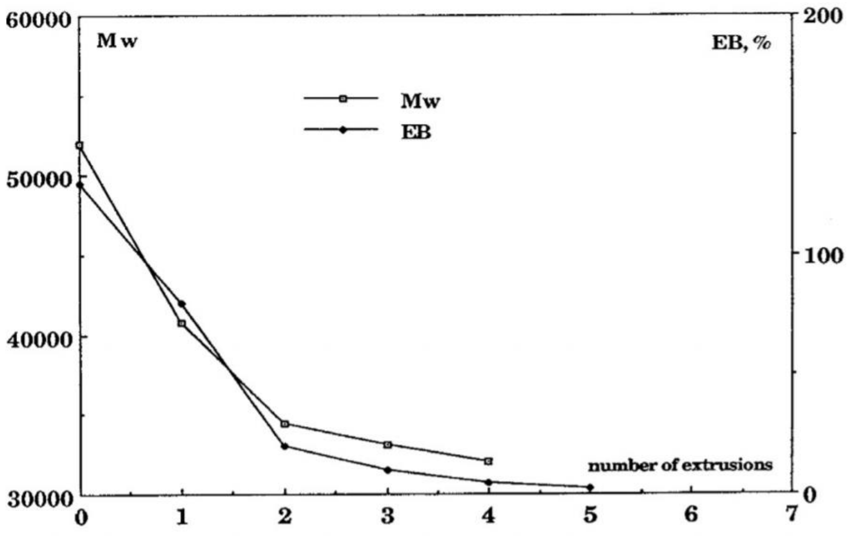

Figure 10: Relationship between extrusion number and molecular weight of polymer

5.1 CURRENT TECHNOLOGY

Solid plastic waste (SPW) is mechanically recycled in six general steps. However, sorting of SPW is much time/energy consuming and can be a quite a hectic task, especially if it is done manually. Basically, post-industrial (PI) SPW is already sorted from other plastic waste. Hence, most of the time when it comes to the sorting of SPW, post-consumer (PC) solid plastic wastes need to be sorted. Figure 11 demonstrates the required overall process for the solid plastic wastes to be recycled. Depending upon the relative process, several secondary steps might be needed *(Ragaert, et al., 2017)*.

Figure 11: mechanical recycling process of SPW

5.1.1 Separation and sorting

Generally, post-consumer wastes such as plastics, metals and drink- carton (PMD) are collected by numerous recycling firms around the city. Designated collection points are located by, for example houses, supermarkets and restaurants. The collected plastics products are accumulated in recycling centres or sorting centres where the separation and sorting process is carried out. The hectic sorting process is carried out for PMD (plastics, metals and cartoon) mixed products, which is followed by separating different plastics from each other as shown at the bottom of Figure 12.

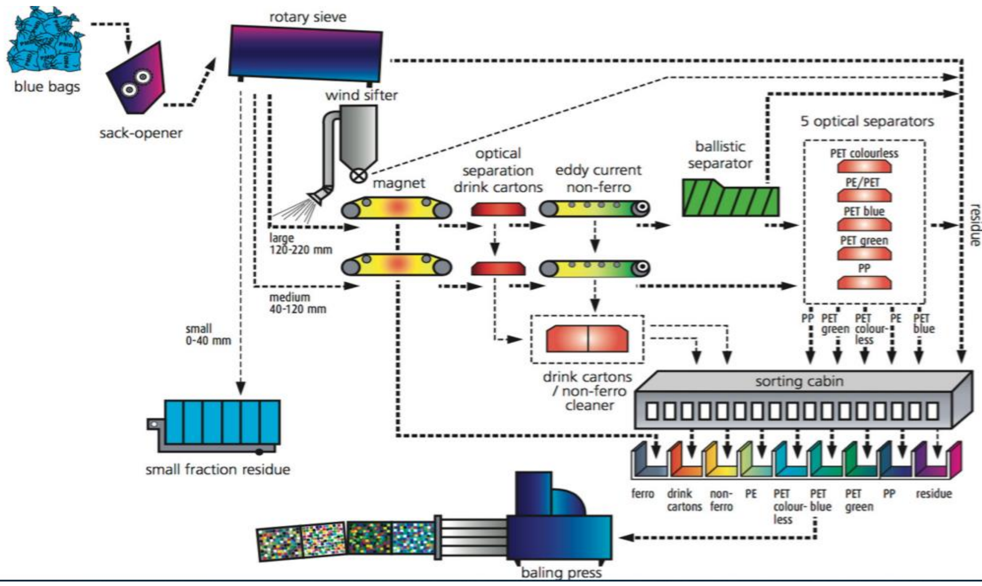

Figure 12: PMD plastics waste sorting

Collected PMDs go through the rotary sieve and wind sifter to remove unequal densities of impurities. The materials are sent through the magnetic chamber to eliminate any metals or magnetic impurities. The remaining material then travels through a ballistic separator to be separated by optical separators according to the colour of the products. Furthermore, the separated products are collected in a sorting cabin according to its type and colours *(Ragaert, et al., 2017)*.

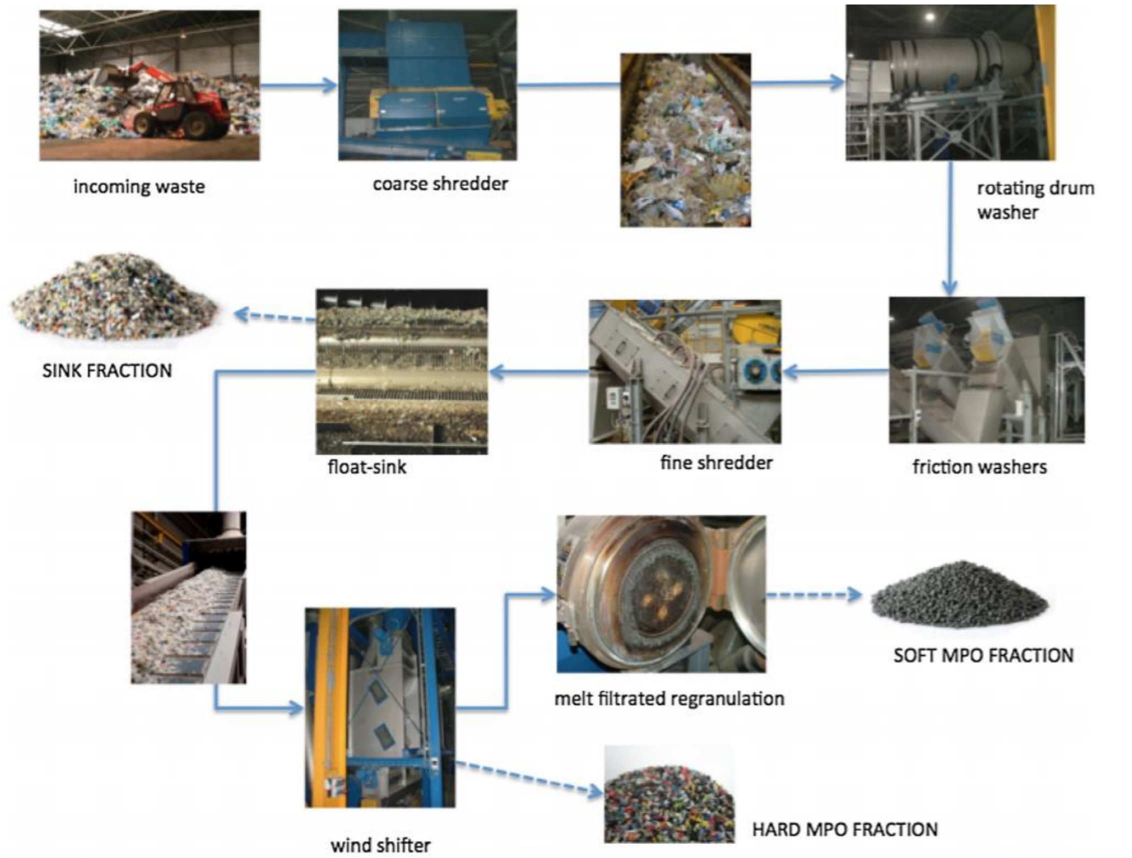

Figure 13: Post Consumer plastics sorting

5.1.2 Baling

The products sorted according to their types and colours are then heavy pressed mechanically to produce a slab of plastics. The plastics slab is then transported to the designated recycling centres.

If the sorting is performed in places other than recycling centres, plastics that are separated are baled and wrapped in order to transport it to the recycling centres.

5.1.3 Washing

Sorted plastics are washed to remove any impurities or organic contaminants. The plastics are washed mechanically in a rotating drum, which is followed by a friction washing process.

5.1.4 Grinding

Washed plastics are sent to the grinding machine via a conveyer belt. The plastics are mechanically ground into smaller size to produce a plastic flake. The hard-granulated pieces are produced after having been treated with wind shifter to remove any impurities.

5.1.5 Compounding and Pelletizing

It is easier for some converters to process fine particles, as a result, granulated pieces are re-granulated into a finer particles or soft particles. Depending upon demand, this process is optional.

5.1.6 Targeted products

The processed fine particle is melted by treating with heat to give it a desired shape and sizes under a required pressure. In some cases, the same product as before is made with the help of a catalyst. In most cases, however, particles are downcycled to something else rather than the product it was before due to the breakage of the polymer chain.

PETE or PET are found in food containers and beverage bottles which are recycled into carpets, furniture and fibres for clothing. High density polyethylene (HDPE) are commonly found in products like milk jugs, body wash bottles which is downgraded to pens, plastic lumber, picnic tables, plastic fencing and bottles *(Talk, 2019)*. PVCs are downgraded to flooring, panelling and roadside gutters etc. LDPE is converted into, for example, garbage cans, flooring and furniture. PPs are recycled to products like battery cables, pallets, ice scrapers. PS is converted to items such as insulation and framing.

5.2 FUTURE AND EMERGING TECHNIQUES

Separation and sorting plays a key role in giving the product a desired shape and size after recycling. Polymer separation is an integral part when different plastics are mixed and is the main ingredient of the targeted product *(Ragaert, et al., 2017)*.

5.2.1 Tribo-electric (electrostatic) separation:

In this process, the polymer flakes are separated in a charging unit. One polymer flake becomes negatively charged while the other remain neutral causes the flakes to separate. Practically, two types of plastic polymers have been separated but in theory, it is supposed to work for more than two blends of polymers or a complex blend.

5.2.2 Froth floatation:

This technique is designed to separate two mixes of polymers that have densities heavier than water. Both polymers are dissolved in the water and one of the designated polymers is targeted with air bubbles so that it floats on the water surface separating from the other polymer. This technique is not yet implemented for mass scale separation in an industry, rather, a lab-based experiment.

5.2.3 Magnetic density separation:

A magnetic liquid is used as a medium to separate a mix of multiple polymers. This is an enhanced process of density-based separation. This technique is also quite effective for blends of multiple polymers, not only for mixes of two polymers.

5.2.4 X-ray detection:

This is a regular x-ray-based process where the blend is distinguished by shooting an x-ray. Its more effective with chlorine-based plastic blends.

6 CONCLUSION

With the 2016 European Union statistical data showing about 23% of plastic waste still being disposed of in a landfill, more sustainable and effective recycling method ought to be developed. The energy recovery rate of about 42% is heading to the proper direction. The recycling rate of about 24% is still considered to be poor performance and needs to be updated with the sustainable and effective future recycling model. Finland, on the other hand, is doing quite well with the landfilling rate of about only 5%. Obviously, the target must be 0% landfilling, and for that, a more effective recycling model is needed. Sorting and separating seems to be a tedious task during mechanical recycling as almost 28% plastics are still disposed of in landfills (EU). However, new methods are undergoing research and development, which is a step towards sustainability. Nevertheless, most of the research is based on theory or conducted in laboratory-scale, which makes the results difficult to implement practically in industry. Hence, more research and development is needed.

REFERENCES

Beckman, E., 2019.. *The world of plastics, in numbers*. [online] The Conversation. Available at: https://theconversation.com/the-world-of-plastics-in-numbers-100291 [Accessed 16 Sep. 2019].

Bellis, Mary. "A Brief History of the Invention of Plastics." ThoughtCo, Oct. 20, 2019, thoughtco.com/history-of-plastics-1992322.

Europe, P., 2017.. *Plastics – the Facts 2017 An analysis of European plastics production, demand and waste data*. [ebook] Brussels: PlasticsEurope. Available at: https://www.plasticseurope.org/application/files/5715/1717/4180/Plastics_the_facts_2017_FINAL_for_website_one_page.pdf [Accessed 5 Oct. 2019].

Fantastic Plastics!, 2014.. *Thermosets and Thermoplastics*. [video] Available at: https://www.youtube.com/watch?v=lNS7TwWmlrg [Accessed 26 Sep. 2019].

Gu, F., Guo, J., Zhang, W., Summers, P. and Hall, P., 2017.. *From waste plastics to industrial raw materials: A life cycle assessment of mechanical plastic recycling practice based on a real-world case study*. [ebook] leiden: Elsevier B.V. Available at: https://www.sciencedirect.com/science/article/pii/S0048969717313980?via%3Dihub [Accessed 20 Sep. 2019].

General Kinematics, 2014.. *The Different Types of Plastics and How they are Recycled*. [online] Available at: https://www.generalkinematics.com/blog/different-types-plastics-recycled/ [Accessed 7 Nov. 2019].

Knight, L., 2014.. *A brief history of plastic*. [online] BBC News. Available at: https://www.bbc.com/news/magazine-27442625 [Accessed 14 Sep. 2019].

Ragaert, K., Delva, L. and Geem, K., 2017.. *Mechanical and chemical recycling of solid plastic waste*. [ebook] leiden: Elsevier Ltd, pp.25-34. Available at: https://www.sciencedirect.com/science/article/pii/S0956053X17305354?via%3Dihub [Accessed 11 Sep. 2019].

Talk, E., 2019.. *How to Recycle Different Types of Plastic*. [online] ThoughtCo. Available at: https://www.thoughtco.com/recycling-different-types-of-plastic-1203667 [Accessed 7 Nov. 2019].

Thakur, S., Verma, A., Sharma, B., Chaudhary, J., Tamulevicius, S. and Thakur, V., 2018.. *Recent developments in recycling of polystyrene based plastics*. [ebook] leiden: Elsevier B.V. Available at: http://www.sciencedirect.com [Accessed 7 Nov. 2019].

West, L., 2019.. *Why Recycle Plastics?*. [online] ThoughtCo. Available at: https://www.thoughtco.com/benefits-of-plastic-recycling-1204142 [Accessed 7 Nov. 2019].

Appendix 1.

Tiiriskankaantie 7	A-kassi Ky
Paluksentie 120	Alfaplast Oy
Lounaisväylä 3	Aqvacomp Oy
Aakkulantie 46	Artekno Oy
Vehmaantie 111	Arvo-Putki Oy
Teollisuuskuja 11	ASV-Jarex Oy
Kymenrannantie 8	Atplast Oy
.Teknikonkatu 2	Biaxis Oy Ltd
Kyläsuutarinkatu 8	Cathodex Oy
Kangastie 2	EC-Engineering Oy
Virtasalmentie 7	Ekin Muovi Oy
Pieni Teollisuuskatu 9	Europak Oy
Tiilitie 1	Finera Aitateollisuus Oy
Varastokatu 5	Finn-Valve Oy
Inkereentie 566	Hella Lighting Finland Oy
Lakarintie 8	Kiiltoplast Oy
Valimotie 27	Lassila and Tikanoja Oy
Schaumanintie 2	Leomuovi Oy
Luuta-Kreetantie 8	Li-Plast Oy
Niemenkatu 73	Muovipoli Oy
Painotie	Muovitekniikka Oy
Siivikkalantie 53	Muovitekniikka V. Riittinen and Co
Kynttilätie 12	Muoviura Oy
Harjulantie 125	Muovi-Ässä Oy
Kirkkarintie 7	Nerostep Oy
Leipurinkatu 5	Okartek Oy
Muovilaaksontie 6	Oy All-Plast Ab
Keilaranta 19	Oy Fibox Ab
Pohjanlahdentie 54	Oy Fluid-Bag Ab
Kivipyykintie 4	Oy Fluorotech Ltd
Ahventie 4 B	Oy G.W.Sohlberg Ab
Immulantie 166	Oy Orthex Finland Ab
Sysilahden teollisuus-alue 5	Oy Parlok Ab
Venteläntie 12	Oy Plastex Ab
Jakobstadsvägen 31	Oy Prevex Ab
Tiilismäki 9	Oy Toppi Ab

Fennokatu 10	Parkanon Muovituote Oy
Lentiläntie 6	Piiplast Oy
Kiviharjunlenkki 1 C	Pipelife Finland Oy
Kutomakuja 2	Plastep Oy
Vanha Vaasantie 13	Plastiroll Oy
Uotilantie 3	Plastiset Oy
Ilvestie 5	Plastone Oy
Muurlantie 438	Pohjoismainen Solumuovi Oy
Ritaalantie 3	Polyno Oy
Ilvesjoentie 1060	Pramia Plastic Oy
Vanha Tampereentie 260	Promens Oy
Valtakatu 6	RPC Superfos Pori Oy
Vanha Rajamäentie 173	S.Punkki Oy
Sirrikuja 4 C	Saintex Oy
Askonkatu 9 E	Schoeller Allibert Oy
Keskustie 23	Serres Oy
Saarentie 90	Suomen Käyttömuovi Oy
Alasniitynkatu 14	Tampereen Tiivisteteollisuus Oy
Huhdantie 6	TerhiTec Oy
Sorakatu 1	Treston Oy
Toivelintie 46	Ulvilan Lasikuitu Oy
Vipusenkatu 26	Uusiomateriaalit Recycling Osa-keyhtiö Ltd
Visiokatu 1	Wavin-Labko Oy
Tehtaankatu 21	Vepro Oy
Keskustie 23	Vieser Oy
Keinukankaantie 1	Wiitta Oy