Plastic sorting

- An evaluation of the methods used in today's recycling business

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Abstract

This short report describes what a waste fraction of plastic packages may look like and what techniques there are to separate the distinct materials from each other. We present to you our six most common packaging plastics, there usage and properties. We have as well written about the methods used to sort them apart. Our first conclusion is that what the final product is to be used for is a key question before making up our minds about how to sort. As it comes to efficiency and accuracy different kinds of automatic sorting processes, which one depends on what materials that are to be separated from each other, are far better than any manual process. Furthermore, an advanced combination of techniques and processes is crucial if one wants to apply plastic sorting on a batch of household plastic waste. In the project we only discuss the six major plastic materials used for household packaging, we rarely describe the thousands of other plastics available on the market that may end up in our sorting processes as well.

Project description

One basic principle of plastics is that they all very well may be mixed with each other but that how they are mixed greatly will influence the outcome of the material. Another principle therefore tells us to try to get as pure plastic material as possible to avoid unwanted surprises about the new material. These issues are very important when we are dealing with plastic recycling, since the extent of sorting needed will impact how, why, and when we choose to sort the plastics and not.

Despite of similarities between different kinds of plastics, it is sometimes sufficient to add just a percent of incompatible plastics to spoil the batch. Everything depends on how the new material is supposed to be used and the composition of the plastic waste. Therefore, sorting owns a key position in the plastic recycling industry.

In this project we will find and describe technologies used to sort plastics. Following these descriptions, you will find a comparison of their advantages and disadvantages. The last step of the project will respectively include the discussion, which will probably answer the question or just give some hints, which technology is the best and which could be the most efficient combination of different separation methods.

Plastic waste sorting, an introduction

Plastic is not one single pure chemical product, but a multitude of different materials where some are widely used in numerous different applications and others are specialized for use in a few distinct contexts. Down the line all our bags, cans, barrels, computer chassis, toothbrushes etc becomes waste and needs to be taken care of in one way or another. According to national and European regulations concerning plastic recycling, plastic packages from households and industries are to be collected and recycled or used as fuel in district heating furnaces.

To enable plastic recycling, the batch of plastics that we want to recycle has to be as pure as possible. Some artificial materials that own very distinct properties or contain certain chemical substances might ruin the whole process even in extremely small quantities. One example often used to demonstrate how sensitive the chemical plastic structures actually are, is that one stray PVC-bottle among 10’000 PET-bottles ruins the whole batch. This implies a purity demand of more than 99.99% in a batch of PET and

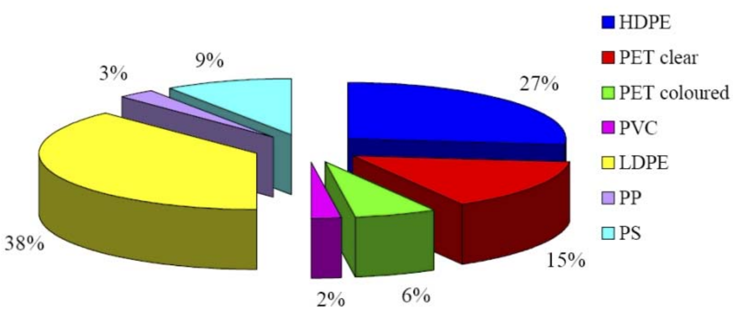
PVC-bottles that are to be separated from each other. Fortunately, not all plastic materials are as sensitive to alien materials as PET or as contaminating as PVC.

For household product packaging there are mainly six different plastic types used:

- Polyethylene Terephthalate (PET)
- High- Density Polyethylene (HDPE)
- Low-Density Polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene (PS)
- Polyvinylchloride (PVC)

Waste composition

The composition of the waste coming to the plastic sorting plant looks somewhat different depending on a few factors. Except for regulations about plastic, such as prohibition of the use of PVC in some countries, the choice of material used for packaging of distinct common products and separate recycling systems for some materials influences the composition. In the UK plastic bottling of milk is common, and these bottles constitutes one third of the plastic household waste. In the Scandinavian countries waxed paper cartoon is instead used for packaging of milk and similar dairy products. Separate recycling systems for PET bottles in the Scandinavia, Germany and a few other countries, decreases these bottles' contribution to the plastic waste predestined for sorting. Between 7 and 8 percent of the Swedish waste coming to a plastic sorting plant composes of PET bottles, in the UK that share is almost three times as big, 21 percent. All these factors will of course influence the composition of the plastic waste and greatly influence the economy of the different sorting processes available. Therefore, there will never be one universal solution to plastic sorting; different countries and even cities will find different ways of sorting suiting their specific needs and demands. In the end not only environment, but also economy, will play a great role in the decision about what sorting methods to implement.



Plastic waste composition for the UK

Some materials are easier to sort out than others. For instance, PET as a material owns some distinguished qualities and is excellent for bottling of soft drinks, which is where most of the PET produced is utilized. PET is therefore easily sorted out in an automated or manual sorting plant from the

plastic waste composition. Other materials such as plastic films that often stick to other plastic products are much trickier to sort out and will therefore demand a different kind of sorting process[1] [2].
In the following table different properties of most common plastics are presented. (0 – good; triangle – average; x – bad).

Characteristics / Resin	Transparency	Luster	Alkali resistance	Acid resistance	Alcohol resistance	Oil resistance	Water vapor permeability	Oxygen permeability	Carbon dioxide permeability	Aroma permeability	Heat resistance
HDPE	×	×	○	○	△	△	○	△	×	×	80-100°C
LDPE	△	△	○	○	△	×	△	×	×	×	70-100°C
PP	△	△	○	○	○	○	○	△	×	×	90-110°C
PET	○	○	△	△	○	○	△	○	○	○	50-60°C
PS	○	○	○	○	×	×	×	×	×	×	60-80°C
AS	○	○	○	○	×	○	×	△	△	△	70-90°C
PVC	○	○	○	○	○	○	△	○	○	△	60-70°C

Characteristics for different plastic materials

PET – polyethylene terephthalate

PET stands for polyethylene terephthalate, a plastic resin and a form of polyester. Polyethylene terephthalate is a polymer that is formed by combining two monomers called modified ethylene glycol and purified terephthalic acid. PET is a popular package for food and non-food products. Manufacturers use PET plastic to package products because of its strength, thermo-stability and transparency. Customers choose PET because it is inexpensive, lightweight, reseal able, shatter-resistant and recyclable.[3]

HDPE – high-density polyethylene

A linear polymer, High Density Polyethylene (HDPE) is prepared from ethylene by a catalytic process. The absence of branching results in a more closely packed structure with a higher density and somewhat higher chemical resistance than LDPE. HDPE is also somewhat harder and more opaque and it can withstand rather higher temperatures (120° C for short periods, 110° C continuously). High-density polyethylene lends itself particularly well to blow moulding, e.g., for bottles and containers. Its main

[1] *WERG Household Plastic*
[2] *Marcus Ihre, spokesman for "Plastkretsen"*
[3] *National association for PET Container resources*

advantages are low cost high chemical and moisture resistance. That is why it is used for a wide range of purposes.[4]

LDPE – low-density polyethylene

It is a squeezable resin superior to HDPE in transparency and lustre, inferior in chemical resistance. The first of the polyolefins were originally prepared some fifty years ago by the high-pressure polymerisation of ethylene. Its comparatively low density arises from the presence of a small amount of branching in the chain (on about 2% of the carbon atoms). This gives a more open structure. LDPE is a most useful and widely used plastic. It is translucent to opaque, robust enough to be virtually unbreakable and at the same time quite flexible. Chemically LDPE is non-reactive at room temperature although it is slowly attacked by strong oxidising agents and some solvents will cause softening or swelling. It may be used at temperatures up to 95º C for short periods and at 80º C continuously. LDPE is ideally suited for a wide range of laboratory apparatus including wash bottles, pipette washing equipment and tanks.[5]

[4] Dynalab
[5] Physical science information gateway

PP – polypropylene

Structurally, it is a vinyl polymer, and is similar to polyethylene, only that on every other carbon atom in the backbone chain has a methyl group attached to it. Polypropylene can be made from the monomer propylene by Ziegler-Natta polymerisation and by metallocene catalysis polymerisation. Polypropylene is one of those rather versatile polymers out there. It serves double duty, both as a plastic and as a fibre.[6] As a plastic it is used to make things like dishwasher safe food containers. It can do this because it does not melt below 160º C. Polyethylene, a more common plastic, will anneal at around 100º C, which means that polyethylene dishes will warp in the dishwasher. As a fibre, polypropylene is used to make indoor-outdoor carpeting around swimming pools and miniature golf courses. It works well for outdoor carpet because it is easy to make coloured polypropylene, and because polypropylene doesn't absorb water, like nylon does.

PS – polystyrene

Polystyrene is a vinyl polymer. Structurally, it is a long hydrocarbon chain, with a phenyl group attached to every other carbon atom. Polystyrene is produced by free radical vinyl polymerisation from the monomer styrene. Polystyrene is an inexpensive and hard plastic and probably only polyethylene is more common in our everyday life. Here are the areas of it’s use: outside housing of the computers, model cars and airplanes, clear plastic drinking cups, moulded parts on the inside of cars (like the radio knobs), toys, things like hairdryers and kitchen appliances.[6]

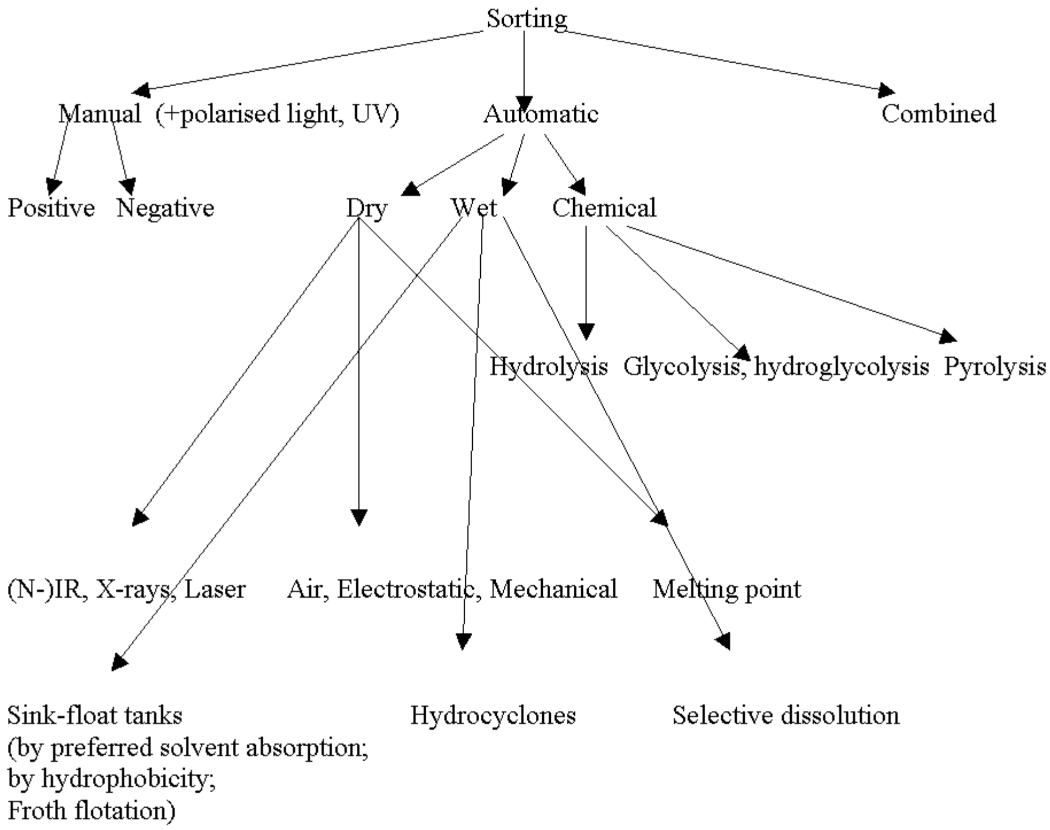
PVC – Poly Vinyl Chloride

Structurally, PVC is a vinyl polymer. It is similar to polyethylene, but on every other carbon in the backbone chain, one of the hydrogen atoms is replaced with a chlorine atom. It is produced by the free radical polymerisation of vinyl chloride. PVC is useful because it resists two things that hate each other: fire and water. Because of its water resistance it is used to make raincoats and shower curtains, and of course, water pipes. It has flame resistance, too, because it contains chlorine. When you try to burn PVC, chlorine atoms are released, and chlorine atoms inhibit combustion. Poly vinyl chloride is the plastic known at the hardware store as PVC. This is the PVC from which pipes are made, and PVC pipe is everywhere. The plumbing in your house is probably PVC pipe, unless it's an older house. PVC pipe is what rural high schools with small budgets use to make goal posts for their football fields. But there's more to PVC than just pipe. The "vinyl" siding used on houses is made of poly (vinyl chloride). Inside the house, PVC is used to make linoleum for the floor. In the seventies, PVC was often used to make vinyl car tops[6].

Plastic sorting methods

[6] Polymer science leaning center

We should be aware of feeling competence, that consumption waste contains just these kinds of plastics. Many other plastics can appear there because of various reasons. We would like to continue with detailed description of various methods used for plastic sorting in modern society.
The following scheme (Sorting methods' scheme) includes all the results of our findings, grouped in the order of technologies used.



Sorting methods' scheme

There is no enterprise, using automatic sorting separately without following manual control. Different combinations of methods are used in the world. Manual sorting is still rather common. Even though its productivity and efficiency may be questioned, it has a great advantage in price since it is a relatively cheap method. Due to efficiency issues, large attention is nowadays drawn to automatic technologies.

NIR, IR, X-Ray, laser detectors

These methods come from the properties of atom groups to vibrate with sharply determined frequencies that are predictable and unique for different substances. The first commercial sensor (1991) had very narrow field of use: just for PVC recognition. The one was based on absorption of X-rays by chlorine atoms in PVC. In 1994 the first NIR sensor was created: it had capability of identifying most of the majority consumer plastic packaging resins (codes one through seven). In 1996 new multi-frequency sensor appeared. That one could identify plastics both by colour and resin.

Laser diodes technology has similar principle, but cheaper and win NIR method in several important properties: response time, sensor size and illumination life. But the method is a new one and consequently is not wide spread [7].

Air sorting

By first mincing the plastic waste into plastic flakes hat has a size of ¼” to ½”, the waste might be air sorted. The flake is fed into the air classifier where it falls against a rising column of air. The air stream removes the lighter paper and debris, while the heavier plastic flake falls into a float/sink tank. There, the material is sorted based on the specific gravity. In the case of whole, shredded pop bottles, the HDPE bottle cap would sink, while the PET bottle would float[8].

Melting/softening point

The sense of this technique is that plastics reach their melting points at different temperatures. It seems that the method is not widely used. It works next way: it's normally used to sort two polymers by means of an hot conveyor belt or a hot roll working on a conveyor belt where a mono-layer of flakes is laying down. One kind will stick while the other falls down by gravity. The disadvantage “melting point” method is that it can sort only two plastic kinds at the time.[14]

Sink-float tanks

This equipment is based on the density differences of plastics. When the material is put into the water, the lightest fraction (with higher density, than water) will float, and the rest will sediment. The density of water can be changed, depending on the plastic, which is to be separated. Low throughput was found to be disadvantage of sink-float tanks.

Hydrocyclones

Often used to enhance the effectiveness of density separations from both a throughput and purity standpoint. They can provide a greater driving force (centrifugal verses gravity) to the separation, enhance material wetness and increase throughput.

When compared with two other separation technologies (centrifuge systems and sink-float tanks) — hydrocyclones were found to have the biggest throughput at a reasonable cost — two factors paramount to making recycling economically sustainable.[9]

[7] Idec Corporation fact sheet
[8] American recycler

[9] The American Plastic Council

Centrifugation

Typically centrifuges consist of a horizontal or vertical cylinder, which is continuously turned at high velocities. The technique subjects the particles to even higher forces than hydrocyclones, which can lead to more effective separations. But the equipment is expensive. The price and lower efficiency are main disadvantages of the method [10].

Selective dissolution

The process makes use of the different solubility, relevant for different plastics. Using different solvents under different temperatures polymers are separated. It is a new and very expensive solution, consequently not very popular. The method is considered to be wet one, but it is very close to chemical[11].

Hydrolysis, glycolysis and hydroglycolysis

These are chemical sorting methods, which refer even more to separating methods, because during this chemical processes polymer molecules are converted back to raw monomers. The ones can be reused in the manufacture of new polymers. Pyrolysis is a process in which plastic wastes are heated in the absence of oxygen in a closed chamber. The chemicals, which were received in the process, can be used both as a fuel or raw materials.

Efficiency analysis

Each next method of plastic identification - IR, NIR, X-Ray, optic – has two sub-methods, which are divided due to the feeding system (conveyor). One is singulated belt format: plastic parts go through the identification machine in a thin stream. The other one is a non-singulated belt format, which allows plastic parts to go in a wide stream through the detector.

The first ones are usually more efficient (98-99% purity) in comparison with the second ones (90-95), but the output ability is different: higher for non-singulated systems. It normally varies from 1500 up to 5000 kg/hour. One more difficulty is that wide belt systems require usually one sensor for each kind of plastics to be sorted. For single belt systems one sensor is enough[12 13].

[10] Mechanical Solid-Liquid Separation
[11] Recovery of plastics using solvents
[12] Canadian Plastics Industry Association
[13] Society of Plastic Engineers

The price of sorting equipment can vary. It depends mainly on the output rate and the quantity of sensors, which are the most expensive part. According to calculations the whole complex of equipment can cost up to $500.000[14].

Let us compare manual and automatic sorting. Two variants of manual sorting are known as “positive” and “negative”. “Positive” one means picking out from the belt everything, which is not the X. Positive one means picking out everything, what is X. Effectiveness of this methods actually depends on the type of plastics to be sorted. If we sort two plastics, such as PVC and PET, they are very similar, so that manual sorting is not efficient in general. But “negative” one is less effective than “positive” in this case. During the “positive” sorting people are obliged to pay more attention on sorting, which becomes more accurate this way. It is possible to improve the quality of sorting through installation of polarized light or UV light.

Conclusion

Automatic sorting techniques seems to be better alternatives than manual ones. The best solution to keep PVC away from other plastics is x-ray detector, which guaranties 99% PVC separation, but careless about other plastics. The second stage could be NIR detector, which recognises all kinds of plastics. But none of these automatic separators can work without manual supervision. Therefore it is really important to establish manual control as a following step after x-ray and NIR detectors[15].

[14] Centro panamericano de Ingeniería Sanitaria y Ciencias del Ambiente
[15] Separation of plastic waste in flake form

Internet sources as of May 2005:

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