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how the chemical composition of different kinds of plastics affects the circular economy

Aayan Kabra

Different kinds of plastic, their ability to get recycled and their effect on the Circular economy

Plastics that can be easily recycled-

- Polyethylene Terephthalate (PET) – water bottles and plastic trays
- High Density Polyethylene (HDPE) – milk cartons and shampoo bottles
- Polypropylene (PP) – margarine tubs and ready-meal trays
- Polyvinyl Chloride (PVC) – piping
- Low Density Polyethylene (LDPE) – food bags
- Polystyrene (PS) – plastic cutlery

Plastics that don't get recycled-

- Bioplastics
- composite plastic
- plastic-coated wrapping paper
- Polycarbonate

The chemical industry has been interested in the transition to a system based on a circular economy with little waste. Due to their widespread manufacturing, one of the primary issues in the transition to a more environmentally friendly production system is the recycling and disposal of plastics.A common misconception is that when the common folks with restricted knowledge see the recycle symbol with a number in the middle of it, they assume that the specific plastic is recyclable, however each number has a different meaning which correlates to its chemical composition making it difficult to recycle.
Different types of plastic have varying properties that can affect their recyclability and overall impact on the circular economy. For example, PET (polyethylene terephthalate) and HDPE (high-density polyethylene) are widely recycled and have a relatively low environmental impact. On the other hand, PVC (polyvinyl chloride) is difficult to recycle and has a higher environmental impact due to the release of toxic chemicals during its production and disposal. Additionally, certain types of plastic like single use plastics, such as straws, are not easily recyclable and have a high environmental impact due to their disposal. Overall, it is important to consider the specific properties of different types of plastic when evaluating their impact on the circular economy

Out of the 7 plastics discussed here, numbers 3,6 and 7 are not recyclable under standard recyclable procedures.

WE LIVE IN A PLASTIC ERA.

From the clothes we wear to the food we eat, plastic has become a household staple for families and communities around the world. Given its prominence, and the fact that scientists estimate it takes

somewhere between 450 -1,000 years to decompose (some argue it will never decompose), it is essential for us to understand this material.

“Waste is only waste, if we waste it”

PET- POLYETHYLENE TEREPHTHALATE

PET, or polyethylene terephthalate, is a thermoplastic polymer that is used in a wide variety of applications, including packaging, textiles, and consumer goods. The structure of PET is composed of a repeating unit of two monomers, ethylene glycol and terephthalic acid.

This structure makes PET highly recyclable because it has a strong chemical bond and is able to withstand the high temperatures and pressures used in the recycling process. Additionally, PET is a clear, strong and lightweight material, it can be easily cleaned and sorted from other materials, making it easier to recycle.

The recycling process for PET involves the collection of used plastic, which is then sorted, cleaned, and shredded into small flakes. These flakes are then melted and formed into pellets, which can be used to make new plastic products, such as bottles and fibers for textiles.

Because of its chemical structure and the ease of recycling, PET is one of the most widely recycled plastics. The recycling of PET helps to conserve resources, reduce energy use, and decrease the amount of plastic waste in the environment. Thermoplastics such as PET are easy to recycle because they have a low melting and boiling point, and hence the polymer chain breaks down easily at low temperatures. The most adopted forms of recycling this plastic are chemically, through the process of hydrolysis alone or the process of mechanical blending. Hydrolysis is an effective strategy for the depolymerization of waste to terephthalic acid, also known as TPA. For this process, we propose TPA, the basic unit of PET, as an acid catalyst to promote the hydrolysis of PET. A catalyst lowers the activation energy of a reaction without getting used up in it. Conditions for hydrolysis-Under optimized conditions, i.e., 2.5 g of PET, a TPA concentration of 0.1 g/mL, mass ratio PET:H2O of 1:8, 220 °C of temperature, and 180 min of reaction time, a PET conversion of up to 100.0% and a TPA yield of 95.5% were achieved. The steps in mechanical recycling include separation of waste, washing to remove dirt and contaminants, crushing and grinding to decrease PET particle size, re-extrusion, and reprocessing for production of new PET goods

HDPE- HIGH DENSITY POLYETHYLENE

HDPE, or high-density polyethylene, is a thermoplastic polymer that is used in a wide variety of applications, including packaging, consumer goods, and industrial products like shampoo bottles and grocery bags. The structure of HDPE is composed of a repeating unit of one monomer, ethylene.

This structure makes HDPE highly recyclable because it has a strong chemical bond and is able to withstand the high temperatures and pressures used in the recycling process. Additionally, HDPE is tough, durable, and resistant to many chemicals, it can be easily cleaned and sorted from other materials, making it easier to recycle.

The recycling process for HDPE involves the collection of used plastic, which is then sorted, cleaned, and shredded into small flakes. These flakes are then melted and formed into pellets, which can be used to make new plastic products, such as bottles, containers, and pipes.

Because of its chemical structure and the ease of recycling, HDPE is one of the most widely recycled plastics. The recycling of HDPE helps to conserve resources, reduce energy use, and decrease the amount of plastic waste in the environment.This type of plastic is very easy to recycle as it is easy to remove any foreign substance like debris from the plastic making it easy to homogenize and recycle the plastic.Recycling HDPE is a three step process. The three stages are sorting and cleaning, homogenization and granulation respectively. Sorting and cleaning helps the plastic get rid of residual substances, preventing it from negatively impacting the composition of recycled plastic.Homogenization is a process of reducing a substance, such as the fat globules in milk, to extremely small particles and distributing it uniformly throughout a fluid, such as milk. When milk is properly

homogenized, the cream will not rise to the top. The process involves forcing the milk through small openings under high pressure, thus breaking up the fat globules. Homogenization separates out the HDPE products and pieces so that any other plastics that they were mixed with do not inhibit HDPE-specific recycling. There are multiple ways to homogenize HDPE;they can isolate PET plastic from HDPE through sink-float separation, where the different densities of these materials will have them float at different levels in a liquid. They could also differentiate between HDPE and other plastic items by hitting them with infrared radiation and finding their unique near-infrared (NIR) signatures

PVC- POLYVINYL CHLORIDE

PVC, or polyvinyl chloride, is a thermoplastic polymer that is used in a wide variety of applications, including pipes, siding, and flooring and cleaning products. The structure of PVC is composed of a repeating unit of one monomer, vinyl chloride.PVC is generally not considered as easily recyclable as other plastics such as PET and HDPE, due to its chemical structure and the addition of plasticizers and other additives that make it more difficult to recycle. PVC is also more difficult to sort and clean, which makes it harder to recycle.The recycling process for PVC is not as common as other plastics and is not as efficient, it requires a more complex process, which is not always economically viable. PVC must be mechanically recycled, which means it needs to be ground into small pieces, cleaned, and then melted and formed into new products.

PVC's recycling process is limited, and it is not widely recycled, this is mainly due to its lack of demand, and the fact that it is less environmentally friendly, as it can release toxic chemicals during the production and disposal.PVC is made up of 57% sea salt and 43% petroleum derivatives.PVC although being recyclable, there is a limit to how many times it can be recycled.PVC sheets and their scraps are easy to recycle as long as they are made from a single thermoplastic material. When PVC is recycled it reduces the carbon footprint when compared to the footprint in the production of fresh materials.Hence PVC is usually not considered recyclable. PVC is the worst offender, it is considered as the least recyclable of all plastics.This is mainly because PVC contains so many additives that recycling it is considered impractical and expensive.Some additives include stabilizers and lubricants.Heat stabilizers are used to prevent degradation of plastics by heat, especially during processing, but also in applications. For example, they are widely used in PVC compounds. Heat stabilizers act by stopping thermal oxidation or by attacking the decomposed products of oxidation.lubricants are used to reduce shear and frictional heating during the processing of PVC. At low temperatures, this involves regula- tion of energy transfer between PVC particles or at the PVC/metal interfaces. In addition, by impeding PVC intergrain diffusion, lubricants will delay the fusion process of PVC.

LDPE- LOW DENSITY POLYETHYLENE

LDPE, or low-density polyethylene, is a thermoplastic polymer that is used in a wide variety of applications, including packaging, consumer goods, and industrial products such as bread bags and plastic films. The structure of LDPE is composed of a repeating unit of one monomer, ethylene.This structure makes LDPE recyclable, although not as easily as HDPE. LDPE is a flexible, lightweight and resistant to impact, it can be easily cleaned and sorted from other materials, but it needs to be properly sorted and cleaned before it can be recycled.

The recycling process for LDPE involves the collection of used plastic, which is then sorted, cleaned, and shredded into small flakes. These flakes are then melted and formed into pellets, which can be used to make new plastic products, such as bags, films, and sheets.

Because of its chemical structure and the ease of recycling, LDPE is one of the most widely recycled plastics. The recycling of LDPE helps to conserve resources, reduce energy use, and decrease the amount of plastic waste in the environment.

It's worth noting that the recycling rate of LDPE is lower than HDPE, as it's a less common plastic, and it's more difficult to recycle. Also, some LDPE products may not be recyclable because of the presence of contaminants, additives for coatings, which make it difficult to recycle.Due to the absence of toxins when being recycled, it becomes an eco-friendly alternative.LDPE can be recycled but with a few minor complications. The plastic bags get tangled in the recycling machine and therefore require workers to constantly open machines and check whether the machine

is fully operational and functional which can be a tedious job. Hence many municipal corporations prefer not to recycle LDPE.After being separated, LDPE film gets shredded into flakes with grinders. Once in flake form, the plastic gets cleaned to remove dirt, contaminants and other debris. The cleaned flakes are then dried, melted and turned into pellets for ease of handling.This process is fairly simple, however just 5% of what LDPE is produced gets recycled in real time

PP- POLYPROPYLENE

PP, or polypropylene, is a thermoplastic polymer that is used in a wide variety of applications, including packaging, consumer goods, and industrial products such as yogurt cups, straws and plastics. The structure of PP is composed of a repeating unit of one monomer, propylene.

This structure makes PP recyclable, although not as easily as PET and HDPE. PP is a strong and flexible plastic, it can be easily cleaned and sorted from other materials, but it needs to be properly sorted and cleaned before it can be recycled.

The recycling process for PP involves the collection of used plastic, which is then sorted, cleaned, and shredded into small flakes. These flakes are then melted and formed into pellets, which can be used to make new plastic products, such as bottles, containers, and fibers.

PP can be recycled into a variety of new products, although its recycling rate is lower than other plastics like PET and HDPE. This is due to a lack of demand for recycled PP and the fact that it can be more difficult to recycle than other plastics.

It's worth noting that some PP products may not be recyclable because of the presence of contaminants, additives for coatings, which make it difficult to recycle. Also, PP is not always easily distinguishable from other plastics visually, therefore, it should be properly labeled, and sorted before recycling.Principally, PP is also well suited for recycling. It can either be processed as a recyclate for reuse or re-melted directly into new products. Since polypropylene bags are made entirely using fabric fibers, they are typically made entirely of plastic which means they are fully recyclable and reusable. By mechanical recycling, the PP wastes are separated from other resin types, washed to remove dirt and contaminants, and grinded and crushed to reduce the plastics' particle size, followed by extrusion by heat and reprocessing into new plastic goods.Polypropylene generates lesser waste when it is disposed and therefore contributes to a more healthy and sustainable living.No toxic chemicals are released in the recycling process of polypropylene, and it also does not generate toxic gasses when burned.

PS- POLYSTYRENE

PS, or polystyrene, is a thermoplastic polymer that is used in a wide variety of applications, including packaging, consumer goods, and industrial products like take away and hard packaging toys. The structure of PS is composed of a repeating unit of one monomer, styrene. PS is a brittle and lightweight plastic that can be easily cleaned and sorted from other materials, but it needs to be properly sorted and cleaned before it can be recycled.

The recycling process for PS involves the collection of used plastic, which is then sorted, cleaned, and shredded into small flakes. These flakes are then melted and formed into pellets, which can be used to make new plastic products, such as plastic trays, and disposable cups.

It's worth noting that PS is often not widely recycled, mainly because of its low density, which makes it difficult and expensive to transport and recycle. Also, some PS products may not be recyclable because of the presence of contaminants, additives or coatings, which make it difficult to recycle. Additionally, PS products are often not easily distinguishable from other plastics visually, therefore, it should be properly labeled, and sorted before recycling.

It is recommended that people should not put such plastic in a recycling bin because of two major reasons- its density and contamination.Polystyrene foam is 95% air so it is not cost-effective to store or ship. It is often contaminated with food or drink, and it is difficult to clean because it is so porous. Hence such plastic is not easily recycled. Polystyrene is not recyclable due to its unique molecular structure. Polystyrene is a plastic formed from styrene, a liquid hydrocarbon. However expanded polystyrene is recyclable. It is produced from solid beads of polystyrene which is polymerised from styrene monomer, and contains pentane, an expanding gas, which is dissolved within the polystyrene beads.Each solid polystyrene bead contains small amounts of gas which expand when heat (in the form

of steam) is applied, thus forming closed cells of EPS. These expanded cells occupy approximately 40 times the volume of the original polystyrene bead, and so with a second heat treatment using a mold, large EPS blocks can be molded into specific customized shapes.While EPS is highly recyclable, it's tough to recycle at the consumer level. It has to be shipped to facilities where it can be compressed. Once it's compressed, it can then be recycled and then used again.

OTHER

Examples of this include baby bottles, nylon, cd's.This kind of plastic is not recyclable.

Plastic number 7 is a catch-all category for "other" types of plastic that do not fit into the first six categories. Because of this, the structure of plastic #7 can vary greatly depending on the specific type of plastic it is made from. However, many types of plastic #7 are not recyclable due to the fact that they are made from a combination of different types of plastic, which makes it difficult to separate the materials and recycle them. Additionally, some types of plastic #7 contain additives or chemicals that can make them difficult or impossible to recycle.Products stamped with grade 7 plastic are usually not recyclable as they are made out of multiple plastic types, in short they are multilayered, and hence plastics that are grouped in this category are not recyclable. The different layers are chemically incompatible with each other and are hence not recyclable. Plastics labeled under this category cannot be reused unless they have a PLA compost coding. This indicates that these plastic materials have a plant based resin that will degrade under certain conditions.

Circular economy is an economic system based on the reuse and regeneration of materials or products, especially as a means of continuing production in a sustainable or environmentally friendly way. Therefore now we know that plastic number 3,6 and 7 cannot be a part of the circular economy due to its integrated chemical composition.

The largest Plastic manufacturer is Eastman Chemical Company and the company itself is estimated to invest upto 1 billion dollars to promote a circular economy.Consistent with Eastman's holistic sustainability strategy, the LCA team has evaluated programs being implemented in 2020 and beyond related to the circular economy. The studies have shown that in terms of carbon footprint, Eastman's carbon renewal technology is 20%-50% advantaged over conventional production of syngas in Kingsport and that polyester renewal technology is 20%-30% advantaged for production of monomers compared to conventional production.

Tata company has launched a recyclable salt packaging method by challenging conventional knowledge by combining two plastic types- HDPE and LDPE.LDPE is a branched structure and HDPE is a linear structure. HDPE, as seen in its name, has a higher density relative to LDPE, and HDPE has a greater crystalline structure when compared to LDPE.SInce LDPE and HDPE are members of the same family, they can be blended together. When this HDPE and LDPE blend together, its crystallinity increases which makes the film stiffer by its increase in its modulus of resistance, and forms LLDPE, which stands for linear low density polyethylene. This offers puncture resistance.LLDPE is better than LDPE and HDPE, as its short branches can slide against each other, and it has more flexibility. HDPE can withstand heat temperature more than 100 degrees Celsius while LLDPE density decreases when exposed to a temperature more than 20 degrees, as it has the least heat resistance.Because LLDPE has shorter branches than LDPE, its chains have lesser probability to get entangled. Rather, the chains are able to slide against each other upon elongation, without becoming much entangled like LDPE. This gives LLDPE higher tensile strength and higher impact and puncture resistance than the LDPE. LLDPE is therefore used in stretch film.Thus, the characteristics of shrink and stretch film are opposite.

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