Are We Overusing Plastics?

Teacher Notes

The materials in use in the home are mainly of the thermoplastic type as this is much easier to generate through a continuous process. Thermosetting materials require a setting time and hence are generated through a batch process in which the plastics are polymerised in the mould and then the moulds are emptied. This process is slower and hence more costly. Luckily thermoplastic materials can be recycled, whereas thermosetting plastics cannot *they undergo a condensation polymerisation process in which a small molecule (often water) is eliminated during the creation of the polymer chain and form cross-linkages..

Student Handout 1

Using of plastics

Observe and note the usage of plastic in day to day life, at home and in the school

Record your observations in a list like this:

Usage (as basic material, layer, wrapper, bag)	Purpose of use (e.g. to carry vegetables)

Student Handout 2

Information on waste generation by a household

For one week or some other agreed time period, prepare a detailed list of the items and the quantity of plastics materials that are discarded from your home. List them in categories such as plastic bags, containers, wrappers, clothing, etc. Weigh the quantity of plastics in each category. Estimate the percentage of the total waste being disposed of by your home. If possible, collect together all the plastic waste for one week and create a pile. Take a photograph of the pile.

It is suggested that two separate containers may be kept in the house, out of which one could be

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exclusively for plastic waste. This will help you not to soil the plastic waste.

Day/date	Estimated weight of non-plastic waste generated	Estimated weight of plastic waste generated	Kind of plastic waste Bottle/wrapper/toy, etc
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			

Use another sheet if necessary. In case plastic waste generated in one day is too little to weigh, the weighing- should be done after a week. Your teacher will conduct a class discussion on how to calculate average waste generation. Complete the following after the discussion.

Weight of plastic waste generated in one week ____________

Weight of plastic waste generated by 100 households ____________

Weight of plastic waste generated in your city ____________

Is photographic evidence attached? Yes/No

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The Issue of Plastic Bags

Plastic bags not only litter the landscape, they pollute the soil and sea. They make for even more household refuse and fill up our rubbish bins. Since they're not biodegradable, they often end up caught in branches or, worse still, swallowed by mammals who choke on them. They are in fact among the most "non-sustainable" products around. Made in a second, used for 20 minutes, but they take 400 years to disappear ... Let's use fewer plastic bags and bring along our baskets, satchels and string bags when we shop instead!

Recycling of Plastics

When compared to glass or metallic materials, plastic poses some unique challenges from a recycling perspective. Chief among them is their low entropy of mixing, which is due to the high relative molecule mass of large polymer chains. Another way of stating this problem is that, since a macromolecule interacts with its environment along its entire length, its enthalpy of mixing is very, very large compared to that of a small organic molecule with a similar structure; thermal excitations are often not enough to drive such a huge molecule into solution on their own. Due to this uncommon influence of mixing enthalpy, polymers must often be of nearly identical composition in order to mix with one another. To take representative samples from beverage containers, the many aluminium-based alloys all melt into the same liquid phase, but the various copolymer blends of PET from different manufacturers do not dissolve into one another when heated. Instead, they tend to phase separation like oil and water. Phase boundaries weaken an item made from such a mixture considerably, meaning that most polymer blends are only useful in a few, very limited contexts.

Another barrier to recycling is the widespread use of dyes, fillers, and other additives in plastics. The polymer is generally too viscous to economically remove fillers, and would be damaged by many of the processes that could cheaply remove the added dyes. Additives are less widely used in beverage containers and plastici bags, allowing them to be recycled more frequently.

The use of biodegradable plastics is increasing. If some of these get mixed in the other plastics for recycling, the recycled plastic is less valuable.

Alternative processes

Many such problems can be solved by using a more elaborate monomer *recycling* process, in which a condensation polymer essentially undergoes the inverse of the polymerisation reaction used to manufacture it. This yields the same mix of chemicals that formed the original polymer, which can be purified and used to synthesize new polymer chains of the same type.

Another potential option is the conversion of assorted polymers into petroleum by a much less precise thermal depolymerisation process. Such a process would be able to accept almost any polymer or mix

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of polymers, including thermoset materials such as vulcanized rubber tyres and the biopolymers in feathers and other agricultural waste. Like natural petroleum, the chemicals produced can be made into fuels as well as polymers.

Recently, a process has also been developed in which many kinds of plastic can be used as a carbon source in the recycling of scrap steel.

Yet another process is Heat Compression. The heat compression process takes all unsorted, cleaned plastic in all forms, from soft plastic bags to hard industrial waste, and mixes the load in tumblers (large rotating drums resembling giant clothes dryers). The process generates heat from the friction of the plastic materials rubbing against each other inside the drum, eventually melting all, or most of the material. The materials are then pumped out of the drum through heated pipes into casting moulds. The most obvious benefit to this method is the fact that all plastic is recyclable, not just matching forms. But criticism arises from the energy costs of rotating the drums, and heating the post-melt pipes.

The environmental benefits of recycling plastic are that it produces less sulphur dioxide, less waste and less carbon dioxide.

Plastic recycling rates lag far behind those of other items, such as newspaper (about 80%) and cardboard (about 70%). One reason is that consumers often don't understand the types of plastics that can be recycled in their area. Types of plastics are assigned a number, which is usually stamped or printed on the bottom of containers and surrounded by a pyramid of arrows. Numbers 1, 2, and 6 are the most-often recycled plastics in the United States. Many programs exist in the United States and the reduction of weight in numerous packaging applications has been significant over the last 25 years. Consumers can find out which plastics are accepted in their local area and how to prepare and transfer them by contacting their local recycling hauler (usually the local city or county solid waste or public works department, or a private company). Generally, paper labels do not need to be removed from plastic bottles or containers, but lids should be thrown away because they typically are made from a type of plastic that is not recyclable. Plastic bottles and containers must be rinsed, squashed, and placed in recycle bins for collection. Plastic grocery bags are often accepted by stores in recycling containers placed near the entranceways.

In the UK, not very much plastic is currently recycled due to a lack of recycling facilities for plastic and many other materials. Only a few exist in the whole country and many people do not know what plastics can be recycled. Furthermore, most of the plastic that is re-used is sent to China to be recycled, raising ethical questions as well as concern that such recycling costs more CO_2 emissions than simply burying in landfill. This is not a valid claim and many recycling programs exist in the UK, and landfill is not an option if there are no sites to fill. One of the largest recyclers of PET bottles is based there and also has initiated one of the first "bottle to bottle" recycling businesses in the world. Many other 'waste' products are sent to China for recycling, using the often empty containers that are used for delivering goods to the UK and that are sent back for re-use. In fact one of China's new 'multimillionaires' has

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made her fortune by this process, and recyling of plastic, if it reduces the requirement landfill in the UK, has got to be a positive action for as long as western civilisation uses the Far East as a cheap source of consumer goods and the container ships are making their run back to China virtually empty.... For local councils and recyling centres to say that plastic cannot be recycled is unacceptable. However, perhaps consumers should first be looking at the Reduce and Reuse options to lower the quantities of plastic being used in the first place, so reducing the strain on Recycle - wooden clothes pegs, brown paper carrier bags, wood pulp egg cartons, timber doors and windows - the list is virtually endless... 90% of household waste into black bins in those areas where recycling is carried out is discarded (usually plastic) packaging.

Types of Plastics

ABS - Acrylonitrile Butadiene Styrene Plastic

Introduction

ABS is an ideal material wherever superlative surface quality, colorfastness and luster are required. ABS is a two phase polymer blend. A continuous phase of styrene-acrylonitrile copolymer (SAN) gives the materials rigidity, hardness and heat resistance. The toughness of ABS is the result of submicroscopically fine polybutadiene rubber particles uniformly distributed in the SAN matrix.

Grades available

ABS standard grades have been developed specifically to meet the requirements of major customers. ABS is readily modified both by the addition of additives and by variation of the ratio of the three monomers Acrylonitrile, Butadiene and Styrene: hence grades available include high and medium impact, high heat resistance, and electroplatable. Fibre reinforcement can be incorporated to increase stiffness and dimensional stability. ABS is readily blended or alloyed with other polymers further increasing the range of properties available. Fire retardancy may be obtained either by the inclusion of fire retardant additives or by blending with PVC. The natural material is an opaque ivory colour and is readily coloured with pigments or dyes. Transparent grades are also available.

Physical properties

Tensile Strength	40-50	Mpa
Notched Impact Strength	10 - 20	Kj/m^2
Thermal Coefficient of expansion	70 - 90	$x\ 10^{-6}$
Max Cont Use Temp	80 - 95	^oC
Density	1.0 - 1.05	g/cm^3

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Resistance to chemicals

Dilute Acid	Very good
Dilute Alkalis	Very good
Oils and Greases	Very good
Aliphatic Hydrocarbons	Moderate
Aromatic Hydrocarbons	Poor
Halogenated Hydrocarbons	Poor
Alcohols	Poor (variable)

Applications

Because of its good balance of properties, toughness/strength/temperature resistance coupled with its ease of moulding and high quality surface finish, ABS has a very wide range of applications. These include domestic appliances, telephone handsets computer and other office equipment housings, lawn mower covers, safety helmets, luggage shells, pipes and fittings. Because of the ability to tailor grades to the property requirements of the application and the availability of electroplatable grades ABS is often found as automotive interior and exterior trim components

History of ABS

Styrene Acrylonitrile copolymers have been available since the 1940's and while its increased toughness over styrene made it suitable for many applications, its limitations led to the introduction of a rubber (butadiene) as a third monomer and hence was born the range of materials popularly referred to as ABS plastics. These became available in the 1950's and the variability of these copolymers and ease of processing has led to ABS becoming the most popular of the engineering polymers.

Polystyrene (General Purpose) GPPS

Applications

Toys and novelties, rigid packaging, refrigerator trays and boxes, cosmetic packs and costume jewellery, lighting diffusers, audio cassette and CD cases.

Properties

Brittle, rigid, transparent, low shrinkage, low cost, excellent X-ray resistance, free from odour and taste, easy to process

Physical properties

Tensile Strength	2.30 - 3.60	N/mm²
Notched Impact Strength	2.0 - 2.5	Kj/m²
Thermal Coefficient of expansion	80	x 10^{-6}
Max Cont Use Temp	70 - 85	^{o}C
Density	1.05	g/cm^3

Resistance to chemicals

Dilute Acid	Good (variable)
Dilute Alkalis	Very good
Oils and Greases	Good (variable)
Aliphatic Hydrocarbons	Very good
Aromatic Hydrocarbons	Poor
Halogenated Hydrocarbons	Poor
Alcohols	Moderate (variable)

PVC

Introduction

Polyvinyl chloride (PVC) is a major thermoplastic material finding use in a very wide variety of applications and products.

The essential raw materials for PVC are derived from salt and oil. The electrolysis of salt water produces chlorine, which is combined with ethylene, obtained from oil, to form vinyl chloride monomer (VCM). Molecules of VCM are polymerised to form PVC resin, to which appropriate additives are incorporated to make a customised PVC compound.

Properties

PVC's major benefit is its compatibility with many different kinds of additives, making it a highly versatile polymer. PVC can be plasticised to make it flexible for use in flooring and medical products. Rigid PVC, also known as PVC-U (The U stands for "unplasticised") is used extensively in building applications such as window frames.

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Its compatibility with additives allows for the possible addition of flame retardants although PVC is intrinsically fire retardant because of the presence of chlorine in the polymer matrix.

PVC has excellent electrical insulation properties, making it ideal for cabling applications. Its good impact strength and weatherproof attributes make it ideal for construction products. PVC can be clear or coloured, rigid or flexible, formulation of the compound is key to PVC's "added value".

Physical properties

Tensile Strength	2.60	N/mm²
Notched Impact Strength	2.0 – 45	Kj/m²
Thermal Coefficient of expansion	80	x 10^{-6}
Max Cont Use Temp	60	^{o}C
Density	1.38	g/cm^3

Resistance to chemicals

Dilute Acid	Very good
Dilute Alkalis	Very good
Oils and Greases	Good (variable)
Aliphatic Hydrocarbons	Very good
Aromatic Hydrocarbons	Poor
Halogenated Hydrocarbons	Moderate (variable)
Alcohols	Good (variable)

Applications

Window frames, drainage pipe, water service pipe, medical devices, blood storage bags, cable and wire insulation, resilient flooring, roofing membranes, stationary, automotive interiors and seat coverings, fashion and footwear, packaging, cling film, credit cards, synthetic leather and other coated fabrics.

Construction

PVC has been used extensively in a wide range of construction products for over half a century. PVC's strong, lightweight, durable and versatile characteristics make it ideal for window profiles. PVC's inherent flame retardant and excellent electrical insulation properties make it ideal for cabling applications.

Typical example of PVC construction products include:

- Architectual glazing systems
- Pipes and fittings
- Power, data and telecoms wiring and cables
- Internal and external cladding
- Roofing and ceiling systems and membranes
- Rainwater, soil and waste systems
- Flooring
- Window and door profiles
- Wallcoverings

Healthcare

PVC has been used for hundreds of life-saving and healthcare products for almost 50 years being used in surgery, pharmaceuticals, drug delivery and medical packaging.

Typical examples of PVC healthcare products include:

- "Artificial skin" in emergency burns treatment
- Blood and plasma transfusion sets
- Blood vessels for artificial kidneys
- Catheters and cannulae
- Blood bags
- Containers for intravenous solution giving sets
- Drip chamber components
- Feeding and pressure monitoring tubing
- Heart and lung bypass sets
- Inflatable splints
- Inhalation masks
- Surgical and examination gloves
- Shatter-proof bottles and jars
- Overshoes
- Wall and floor coverings
- Blister and dosage packs for pharmaceuticals and medicines

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Automotive

PVC brings both high performance qualities and important cost benefits to the automotive industry.

Typical examples of PVC automotive components include:

- Instrument panels and associated mouldings
- Interior Door Panels and Pockets
- Sun Visors
- Seat Coverings
- Security Covers
- Seals
- Mud Flaps
- Underbody Coating
- Floor Coverings
- Anti-Stone Damage Protection
- Auto Harness Wiring

High Density Polyethylene HDPE

Properties

Flexible, translucent/waxy, weatherproof, good low temperature toughness (to -60'C), easy to process by most methods, low cost, good chemical resistance.

Physical properties

Tensile Strength	0.20 - 0.40	N/mm^2
Notched Impact Strength	no break	Kj/m^2
Thermal Coefficient of expansion	100 - 220	$x\ 10^{-6}$
Max Cont Use Temp	65	^oC
Density	0.944 - 0.965	g/cm^3

Resistance to chemicals

Dilute Acid	Very good
Dilute Alkalis	Very good
Oils and Greases	Moderate (variable)

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Aliphatic Hydrocarbons	Poor
Aromatic Hydrocarbons	Poor
Halogenated Hydrocarbons	Poor
Alcohols	Very good

Nylons (Polyamides) PA

Introduction

The name "nylons" refers to the group of plastics known as polyamides. Nylons are typified by amide groups (CONH) and encompass a range of material types (e.g. Nylon 6,6; Nylon 6,12; Nylon 4,6; Nylon 6; Nylon 12 etc.), providing an extremely broad range of available properties. Nylon is used in the production of film and fibre, but is also available as a moulding compound.

Nylon is formed by two methods. Dual numbers arise from the first, a condensation reaction between diamines and dibasic acids produces a nylon salt. The first number of the nylon type refers to the number of carbon atoms in the diamine, the second number is the quantity in the acid (e.g. nylon 6,12 or nylon 6,6). The second process involves opening up a monomer containing both amine and acid groups known as a lactam ring. The nylon identity is based on the number of atoms in the lactam monomer (e.g. nylon 6 or nylon 12 etc).

Properties

The majority of nylons tend to be semi-crystalline and are generally very tough materials with good thermal and chemical resistance. The different types give a wide range of properties with specific gravity, melting point and moisture content tending to reduce as the nylon number increases.

Nylons tend to absorb moisture from their surroundings. This absorption continues until equilibrium is reached and can have a negative effect on dimensional stability. In general, the impact resistance and flexibility of nylon tends to increase with moisture content, while the strength and stiffness below the glass transition temperature (< 50-80^oC) decrease. The extent of moisture content is dependent on temperature, crystallinity and part thickness. Preconditioning can be adopted to prevent negative effects of moisture absorption during service.

Nylons tend to provide good resistance to most chemicals, however can be attacked by strong acids, alcohol's and alkalis.

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Nylons can be used in high temperature environments. Heat stabilised systems allow sustained performance at temperatures up to 185°C (for reinforced systems).

Grades Available (Suggest TYPES rather than Grades.)

There are many types of nylon available (e.g. Nylon 6 nylon 66, nylon 6/6-6, nylon 6/9, nylon 6/10, nylon 6/12, nylon 11, nylon 12). The material is available as a homopolymer, co-polymer or reinforced. Nylons may also be blended with other engineering plastics to improve certain aspects of performance. Nylon is available for processing via injection moulding, rotational moulding, casting or extrusion into film or fibre.

Physical Properties: NB The lower figure is typical for unreinforced Nylon, and the higher figure typical for 30% glass filled.

Physical properties

Tensile Strength	90 - 185	N/mm²
Notched Impact Strength	5.0 - 13	Kj/m²
Thermal Coefficient of expansion	90 - 20/70	x 10^{-6}
Max Cont Use Temp	150 - 185	°C
Density	1.13 - 1.35/1.41	g/cm³

Resistance to chemicals

Dilute Acid	Poor
Dilute Alkalis	Good
Oils and Greases	Very good
Aliphatic Hydrocarbons	Very good
Aromatic Hydrocarbons	Very good
Halogenated Hydrocarbons	Good (variable)
Alcohols	Poor

Application

Nylon fibres are used in textiles, fishing line and carpets. Nylon films is used for food packaging, offering toughness and low gas permeability, and coupled with its temperature resistance, for boil-in-the-bag food packaging.

Moulding and extrusion compounds find many applications as replacements for metal parts, for instance in car engine components. Intake manifolds in nylon are tough, corrosion resistant, lighter and cheaper than aluminium (once tooling costs are covered) and offer better air flow due to a smooth internal bore instead of a rough cast one. Its self-lubricating properties make it useful for gears and bearings.

Electrical insulation, corrosion resistance and toughness make nylon a good choice for high load parts in electrical applications as insulators, switch housings and the ubiquitous cable ties. Another major application is for power tool housings.

History

Carothers discovered polyamides in 1931. On the 28th October 1938 commercial production of nylon 6,6 began. Polyamides were first introduced as fibre forming polymers). The first commercial application was the Bristles on Dr West's Miracle Tuft toothbrush. In the following year nylon stockings became available and, in 1941, nylon moulding powders began commercial production. Nylon 6 was developed in the 1940's (largely as a consequence of the patent that existed on Nylon 6,6). Nylon mouldings were not widely used until the 1950's.

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