PROFILES

Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science

Are We Overusing Plastics?

A grade 10-11 science (chemistry) module on Thermoplastics and Thermoset plastics and their Recycling

Abstract

Plastics have invaded our lives to such an extent that it is almost impossible to think of life without them. Since plastics do not decompose as easily as other materials, their excessive use has created a problem of disposal of discarded products like plastics bags and bottles. As a result, plastics are slowly becoming a potential danger to the environment. There is thus the problem of plastic waste disposal or re-use.

Sections included		
1.	Student activities (for students)	Describes the scenario in more detail and the tasks the students should perform
2.	Teaching guide	Suggests a teaching approach
3.	Assessment	Gives suggested formative assessment strategies
4.	Teacher notes	Provides additional information about plastics and student worksheets

Acknowledgement

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Overall Competences: The students are expected to learn to be able to:

- Devise, carry out and interpret tests to distinguish between various plastics.
- Explain thermoplastic and thermosetting plastics and their preparation by addition and condensation polymerisation.
- Describe moulding processes for shaping plastics.
- Explain the recycling processes for plastic waste.
- Collaborate as a member of a group in devising and carrying out the investigations and in undertaking discussions on whether the public have a responsibility to discard plastics more wisely.
- Decide, based on sound arguments, whether the public have a social responsibility to discard plastics more wisely, or whether we should ban the use of certain types of plastics.
- Communicate orally and in writing to create a report on decisions made, based on sound scientific argumentation and making use of scientific evidence.

Curriculum content: Types of plastics, polymerisation, thermoplastics, thermoset plastics, formation of plastics, recycling of plastics,

Kind of activity: Devising and carry out experimental tests to distinguish between plastics; group work on making a justified decision after calculations have been successful performed.

Anticipated time: 4 lessons plus a visit to a recycling factory.

Prior knowledge: Recognising plastic materials, Covalent bonding using single, double and triple bonds.

This unique teaching-learning material is intended to guide the teacher towards promoting students' scientific literacy by recognising learning in 4 domains – intellectual development, the process and nature of science, personal development and social development.

Its uniqueness extends to an approach to science lessons which is designed to follow a 3 stage model. For this the approach is intentionally from society to science and attempts to specifically meet student learning needs.

This uniqueness is specifically exhibited by:

1. a motivational, society-related and issue-based title (supported in the student guide by a motivational, socio-scientific, real life scenario);
2. forming a bridge from the scenario to the scientific learning to be undertaken;
3. student-centred emphasis on scientific problem solving, encompassing the learning of a range of educational and scientific goals;
4. utilising the new science by including in socio-scientific decision making to relate the science acquired to societal needs for responsible citizenship.

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Are We Overusing Plastics?

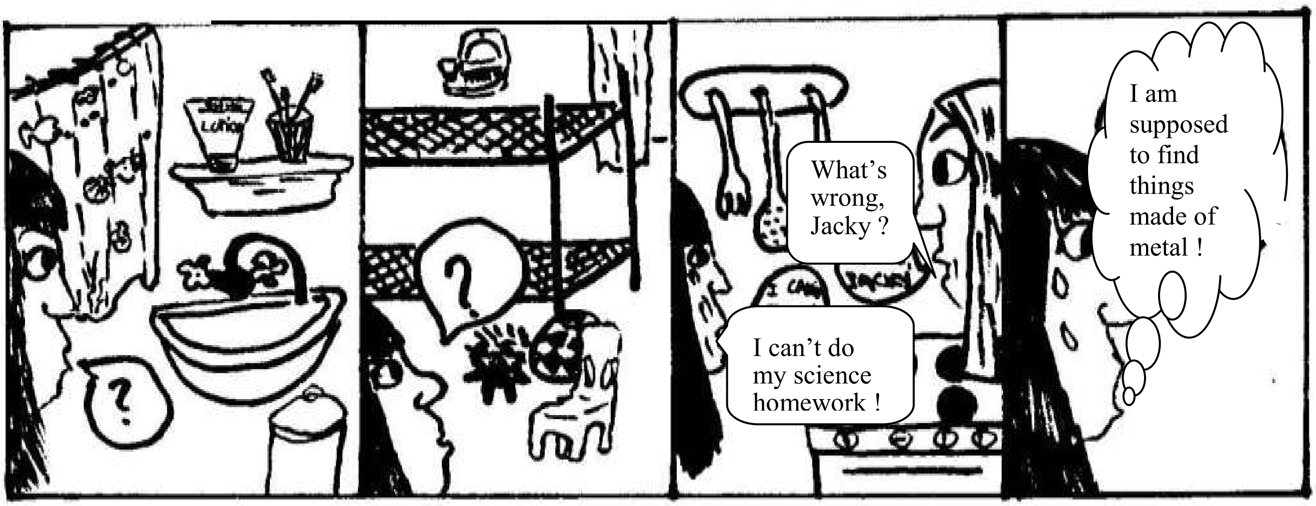
Student Activities

Scenario

It is almost as if plastics have become an integral part of our lives. Put to every possible and conceivable use from house doors to car parts, from clothes to various types of containers and bags, they have slowly replaced materials like metals, glass, wood, etc. This is especially true of packaging of materials used in our daily life, in which various types of plastics are used extensively.

But what happens to all the plastic materials once they have outlived their usefulness? How do we dispose of them in the home, or in the school? What happens to plastics after they are thrown on rubbish dumps along with household garbage, or simply thrown out on the streets by people who don't care? Why are people talking about the threat to the environment and human life posed by the excessive use of plastics and the way in which they are disposed of?

What do you do with plastic materials when you no longer have a use for them? Do you perceive alternative uses? Do you feel that knowing more about the starting process for producing plastics and the choice of different plastics could help in leading you to consider whether we are overusing plastics, whether recycling is a meaningful possibility or whether more regulation is need to ensure a sustainable future.



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Your Tasks

1. Look around your home and school. Note down the variety of uses of plastics. Discuss them with your classmates and prepare a detailed list of uses to which plastics are put.
2. Prepare a list of all plastic materials discarded from your home in a week. Divide the list into categories such as plastic bags, containers, wrappers, clothing, etc. Estimate the percentage of plastics in the total waste. Hence estimate the waste being generated by 100 households, and how much of it would be plastics.
3. Classify the collected (discarded) plastic materials from 2, based on criteria you specify.
4. Devise a range of tests to distinguish between different plastics in a scientific manner. When permitted by your teacher and with appropriate safety precautions, carry out an investigation to find out more about different plastics based on their strength, behaviour when heated, solubility, etc. Reclassify the collected plastic materials based on the results of the tests.
5. From an encyclopaedia, the internet, or any other source, try to find out the reasons why different plastics have different properties. Find out common or commercial names for plastics used for bottles, kitchenware, piping, electrical insulation, or other uses you identify.
6. Noting that an important property of plastics is their lack of reactivity, set up an experiment for finding out about the biodegradability of plastics.
7. Visit a plastic processing unit. Find out the common name, chemical name and structure of the plastics being processed. Try to find out what additives (colours, plasticiser, etc.) are being used and why,
8. Determine the complete chain of procedures utilised in the recycling of plastics.
9. Find out, from any available source, whether the additives being used are carcinogenic (i.e., cancer causing).
10. Write a brief report based on your visit detailing the processing of plastics. Also write a brief note about how the plastic recycling chain functions.
11. Based on the various facts and details collected during the above activities, debate in the class regarding various potential dangers to the environment and human life by excessive plastics usage and the social responsibility of the public towards the discarding and disposal of plastic waste.

Note: In case you are unable to visit a processing unit, collect the above information from various sources like petrochemical companies, reference books, internet, etc.

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Are We Overusing Plastics?

Teacher Guide

This script is intended to

a) draw attention to the problem of using plastics
b) gaining an awareness of thermoplastic and thermosetting materials
c) consider whether biodegradable plastics are a current reality.

Lesson Learning Outcomes

Lesson 1

At the end of this lesson, students are expected to be able to:

Make a list, and discuss uses and concerns, of plastics in daily life, especially in the home. Recognise that there are many different types of plastics.

Explain the meaning of the word plastics.

Lesson 2

At the end of this lesson, students are expected to be able to:

Categorise items collected, based on the suspected type of plastic.

Put forward the scientific (inquiry) question 'in what way can we determine properties of different plastics?'

Lesson 3

At the end of this lesson, students are expected to be able to:

Devise tests for exploring the properties of different plastics.

Explain thermoplastic and thermosetting plastics.

Carry out tests and identify properties of different thermoplastic plastics.

Lesson 4

At the end of this lesson, students are expected to be able to:

Write a report on the conclusion of the experiments.

Discuss different processes for making/moulding plastics

Explain the economic disadvantage of using a batch rather than a continuous moulding process in producing plastic materials/items.

Explain the meaning of biodegradability.

Lesson 5

At the end of this lesson, students are expected to be able to:

Write a report on the operations of a plastics recycling plant.

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Suggested Teaching Strategy

1. Begin with a whole class discussion on how plastics have invaded our lives and how they are slowly replacing traditional materials like glass, porcelain, wood, paper, etc. in day-to- day use. The discussion can lead to an assignment for students - to observe and note the variety of uses plastics are put to, and to prepare a detailed list. Student Handout I could be used for the purpose.
2. After students have come back with their individual lists, there can be a further discussion, guided by the teacher, about the possible uses of plastics, ending up with an exhaustive list of plastic usage. The teacher may ask the students to prepare, collectively, an exhaustive list of plastic usage and display it in the class. This could be done by pooling together lists prepared individually by each student, as well as by small groups.
3. Ask students to collect discarded waste plastic materials from home for one week, or some other suitable period of time. Help them to make categories based on usage, such as plastic bags, wrappers, etc. See Student Handout 2.
4. Guide students in estimating the percentage of plastic waste vis-a-vis the total waste generated by a household (the % is probably best based on volume rather than mass/weight). Show how different techniques can be used to estimate waste generation. For example:
   (a) Multiply the waste generated by one household by one hundred to get an estimate about 100 households. It may be better, however, to get an average based on the data provided by the whole class and multiply it by 100.
   (b) For estimating the waste generation by a city, the number of households can be calculated by dividing the total population by the average number of members in a household (4-5 for example).
   Then total waste generation can be calculated based on the above data. The result should be recorded in Student Handout 2. Emphasis may be laid on the enormity of disposal of such a huge quantity of waste.
5. Students should be encouraged to create equivalent samples of various types of plastic waste and design tests for finding out:
   (a) pliability/strength (e.g. how much weight a sample can take without stretching)
   (b) effect of heating (small samples in a test tube could be taken)
   (c) effect of water, cooking oil, methylated spirits, petrol, etc. on plastics.
   The presence of the teacher is necessary when students conduct these experiments. *The teacher must ensure students do not inhale fumes created by heating/burning of plastics.*

6.The teacher could make suggestions regarding reclassification based on the results of the experiments. Also if felt necessary the teacher may encourage students to find out

(a) common names of various types of plastic
(b) chemical names and formulas of the above
(c) reasons for varied properties of the plastics.

In case students are unable to get the above information, the teacher can demonstrate to them how to use various sources like encyclopaedias, the Internet, etc.

7. Facilities for conducting the experiment on biodegradability should be planned in advance so as to avoid last-minute confusion. Advance planning may include:
   (a) demarcation of sites for pits
   (b) tools for digging
   (c) availability of varied waste materials including plastic waste
   (d) availability of common salt
   (e) dating of the pits.

   The question of the use of common salt to aid decomposition could be discussed and reasons could be inferred. The effort should be to let students discover for themselves that plastics are not biodegradable. Also a discussion could be held on how non-biodegradability is threatening the environment and human life.
8. When visiting the plastics processing or recycling plant, the emphasis should be on:
   (a) collecting information regarding additives like colours, plasticisers, resins and their carcinogenic nature
   (b) the plastic recycling process - the various links in the chain - rag-pickers and plastic granule makers; and also the fact that only a fraction of the total plastic waste being generated is recycled
   (c) drawing diagrams of plastic processing and how different kinds of plastics are processed differently.
9. After the students' written report and drawn conclusions, small groups could be formed to focus on a particular aspect of the problem and come up with solutions. This may help in a focussed brainstorming and debate on the issue of social responsibility for the excessive usage of plastics and their disposal. The points that are thrown up by the debate could be summarised by the teacher and then attached to each student's report as a recommendation of the group.

Achieving the Competences

Competence	This is achieved by
1. Decide, based on sound arguments, whether the public has a social responsibility to discard plastics more wisely, or whether we should ban certain types of plastics.	*participating in a debate or if a member of the audience, voting for or against the motion.*
2. Devise tests to distinguish between various plastics.	*devising additional tests to those given on the worksheet and using them to distinguish between different plastics.*
3. Co-operate as a member of a group.	*actively participating in group work.*
4. Communicate orally and in written form.	*discussing within the group and giving written descriptions of the manufacture of plastics and the recycling of plastics.*
5. Explain the recycling process for plastic waste.	*creating a written explanation for the recycling of different plastics.*

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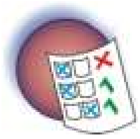

Suggested Assessment

This guide to assessment strategies is put forward from different perspectives (only one approach is expected - chosen by the teacher - but of course the teacher can use different approaches in different lessons if seen by the teacher to be appropriate). Importantly, the assessment ideas are **only** suggestions. Undertaking student assessment on all the components indicated, or in all categories, is emphatically not intended - the teacher chooses those considered to be meaningful).

In part A the assessment is based on the skill to be developed in the student. Part B is based on the assessment strategies to use in each lesson, whereas part C illustrates the assessment by the 3 different approaches which a teacher may use for formative assessment – observation, by oral communication, or by marking of written work.

Please note – the use of x, √ or √√ is arbitrary. The teacher can use whatever scale is appropriate. In the scale chosen, x = not able; √= achieved the learning and √√ = achieved more than intended/ expected (For example - being creative, independent thinking/reasoning, showing initiative, etc)

Summative assessment strategies are not shown, but these could relate to viva type oral communication and/or to the marking of written tests/examination questions.

Part A Assessment based on Skills Acquired

Award of social value grade

Teachers listens to the debate

x Not able to contribute to the debate

√ Participates in the debate and puts forward a point of view with justification

√√ Not only participates in the debate and puts forward a point of view but is able to do this with persuasion and can offer counter-arguments to points made by others.

Award scientific method grade

The teacher marks the student record during the lesson before allowing the students to carry out additional experiments

x Not able to suggest additional tests of any kind.

√ Able to suggest additional tests but not able to suggest how they should be carried out without the help of the teachers.

√√ Able to suggest additional tests which are suitable and appropriate and be able to suggest how to carry them out.

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Award of a personal skill grade
Teacher observes the students during the group work

x Does not cooperate with others during the group discussions and activities.

√ Participates in group work meaningfully, in the discussions and in the recording of work in written form.

√√ Not only participates in the group work and in the discussions and written work, but takes on a leadership role helping others to participate.

Award a science concept acquisition grade
Teacher marks the written work of students

x Not able to explain the manner of recycling plastics and non-biodegradability in a meaningful way

√ Able to explain recycling and the non biodegradability of plastics

√√ Able to fully understand and record in a meaningful way, different methods by which polymers are formed, the lack of bio-degradability of plastics and the manner in which plastics can be recycled.

Part B Assessment by Lesson (not all dimensions may be possible)

Lesson 1

	Dimension	**Suggested criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Create a list	Able to make an extensive list of plastics in daily use.	
2	Answers questions	Able to explain the meaning of the word plastics	
		Able to discuss the plastics used in daily life	
3	Draws tables.	Able to provide a suitable table for the list of plastic materials.	

Lesson 2

	Dimension	**Suggested criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Categorise plastics	Able to group plastic items made of the same material	
		Able to group different types of plastics	

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2	Write a report	Able to write a report on the categorisation and the difficulties for reasons such as (a) mixture of plastics (b) plastic has specific properties.	

Lesson 3

	Dimension	Suggested criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Devises tests	Puts forward suggested tests to carry out on testing the properties of plastics	
		Indicates the procedures for carry out the tests in a safe manner.	
		Puts forward an appropriate prediction/hypotheses	
2	Carries out test and Records experimental data collected	Makes and Records appropriate observations. Draws appropriate conclusions.	

Lesson 4

	Dimension	Suggested criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Answers questions	Explain thermoplastic and thermosetting plastics and how these are produced in industry	
		Explain the meaning of biodegradability and why this is considered important. How toxic are the products of biodegradability.	
2	Writes a report	Records understanding of plastics, polymerisation and the differences between thermoplastics and thermosetting plastics.	
3	Socio-scientific decision making	Decide, with justification, whether we are overusing plastics.	

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Lesson 5

	Dimension	**Suggested criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
2	Writes a report	Records the processes undertaken in the plastics recycling factory and the variability related to cost, demand and other factors.	

Part C Assessment based on Teacher Strategy

Assessment Tool based on the Teacher's Marking of Written Material

	Dimension	Suggested criteria for evaluation The student:	Mark/grade given (x,√,√√)
1	Writes a plan or report of an investigation	Puts forward an appropriate research/ scientific question and/or knows the purpose of the investigation/ experiment	
		Creates an appropriate investigation or experimental plan to the level of detail required by the teacher	
		Puts forward an appropriate prediction	
		Develops an appropriate procedure (including apparatus/chemicals required and safety procedures required) and indicates variables to control	
2	Record experimental data collected	Makes and Records observations/data collected appropriately (in terms of no. of observations deemed acceptable/ accuracy recorded/errors given)	
3	Interpret or calculate from data collected and making conclusions	Interprets data collected in a justifiable manner including the use of appropriate graphs, tables and symbols	
		Draws appropriate conclusions related to the research/scientific question	
4	Answers questions	Provides correct written answers to questions given orally or in written format	
		Provides answers in sufficient detail especially when called upon to give an opinion or decision	

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5	Draws charts/ diagrams/tables/ models/symbolic representations.	Able to provide graphical representation as required	
		Able to present graphical representations of a suitable size and in suitable detail	
		Able to provide full and appropriate headings for diagrams, figures, tables	
6	Scientific or socio-scientific reasoning	Illustrates creative thinking/procedures in solving problems	
		Gives a justified socio-scientific decision to an issue or concern, correctly highlighting the scientific component	

Assessment Tool based on the Teacher Observations

	Dimension	**Suggested criteria for evaluation** **The student:**	**Mark/grade given (x,√,√√)**
1	Functioning in the group during activities and discussions	Contributes to the group work during the listing of plastics materials used and the discussion on the use of plastics.	
		Cooperates with others in a group and fully participates in the work of the group.	
		Illustrates leadership skills – guiding the group by thinking creatively and helping those needing assistance (cognitive or psychomotor); summarising outcomes.	
		Shows tolerance with, and gives encouragement to, the group members.	
2	Performing the investigation or experiment	Understands the objectives of the investigation/experimental work and knows which tests and measurements to perform.	
		Performs the investigation/experiment according to the instructions/plan created.	
		Uses lab tools and the measurement equipment in a safe manner.	
		Behaves in a safe manner with respect to him/herself and to others.	
		Maintains an orderly and clean work table.	

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

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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 that 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 plastic 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 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 made her fortune by this process, and recycling 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 recycling 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, colourfastness and lustre 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 sub microscopically fine poly-butadiene 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 electroplate-able. 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 retarding 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/m²
Thermal Coefficient of expansion	70 - 90	x 10^{-6}
Max Cont Use Temp	80 - 95	^{o}C
Density	1.0 - 1.05	g/cm^3

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 electro-plating 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

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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)

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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. 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)

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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:

- Architectural 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

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- 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

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/mm²
Notched Impact Strength	no break	Kj/m²
Thermal Coefficient of expansion	100 - 220	x 10^{-6}

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Max Cont Use Temp	65	°C
Density	0.944 - 0.965	g/cm^3

Resistance to chemicals

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

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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.
Nylons can be used in high temperature environments. Heat stabilised systems allow sustained performance at temperatures up to 185^oC (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 homo-polymer, 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	^oC
Density	1.13 - 1.35/1.41	g/cm^3

Resistance to chemicals

Dilute Acid	Poor
Dilute Alkalis	Good
Oils and Greases	Very good

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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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