The Product Test Method on the example of evaluating different sorts of plastics

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All students receive the introduction to the product test method, the sheet with facts and figures about plastics and one out of the three texts on the individual plastics PVC, PET or TPS.

Sequence of the product-testing method

- I Setting (or introducing) relevant dimensions of an evaluation
- I Individual weighting of the separate dimensions
- I Agreeing on the weighting of the separate dimensions in small groups, then in the whole class
- I Individual evaluation of one plastic using suitable sources
- I Exchange of considerations and comparison of the evaluations for one plastic in small groups
- I Constructing new groups using the jigsaw classroom method, exchange of information about the results and the argumentation behind the evaluations
- I Calculation of the weighted evaluation for the three different plastics
- I Reflection on the results and the process of evaluation

References and further details:

Burmeister, M., & Eilks, I. (2012). An example of learning about plastics and their evaluation as a contribution to Education for Sustainable Development in secondary school chemistry teaching. *Chemistry Education Research and Practice*, 13 (2), 93-102.

Burmeister, M., von Döhlen, J., & Eilks, I. (2014). Learning about the different dimensions of sustainability by applying the product test method in science classes. In K. D. Thomas & H. E. Muga (eds.), *Handbook of pedagogical innovations for sustainable development* (pp. 154-169). Hershey: IGI Global.

Burmeister, M., & Eilks, I. (2014). Learning about sustainability and the evaluation of different plastics by the product testing method. *School Science Review,* 95(353), 49-56.

Different parts of a product test and their weighting factors

Below you can find an example from the German product testing agency “Stfitung Warentest”. The test is about Nordic Walking Sticks.

In the test of Nordic Walking Sticks we can see that various areas are constructed for the evaluation. These include function, material and function on different grounds. But not all of the areas are equally important. The suitability profile isn't even considered (0% in the weighting), whereas function makes up 60% of the emphasis in this particular case.

Nordic Walking Sticks		**Sticks with a fixed length**			
		Leki Flash Carbon	Fizan NW Trail x-Lite	Komperdell Spirit Composite	Swix NW 033 CT 4
Average price in Euro		79	50	50	80
Available length and range in cm		105-135	100-135	105-135	100-140
Weight of each stick in g		195	175	193	206
Material of the tube		Carbon	Carbon	Carbon	Carbon
Material of the handle		KS/cork	Plastic like rubber	Plastic like leather	plastic
Test- Overall Result		good (2,0)	good (2,1)	good (2,2)	good (2,2)
	weighting				
Nordic Walking	60%	good (1,8)	good (1,8)	good (2,2)	good (1,9)
Comfort of loop and handle		+	+	+	+
Vibration, absorption, balance		+	+	+	+
Noise while walking		+	+	+	+
Changing the pad		o	++	++	++
Lengthwise adjustment		n.a.	n.a.	n.a.	n.a.
Material	40%	good (2,2)	satisf. (2,6)	good (2,3)	satisf. (2,6)
Equality of the sticks		++	+	++	o
Slip resistance of tip and pad (grip)		o	o	o	o
Supporting loop and handle		+	o	+	+
Durability and reliability		+	+	+	+
Function	0%				
Asphalt and pavement		+	+	+	+
Ways and broken stone		+	+	+	+
Forrest floor		+	+	+	+
++ = very good (1,0-1,5), + = good (1,6-2,5), o = satisfactory (2,6-3,5), ⊖ = barely sufficient (3,6-4,5), inadequate (4,6-5,5)					

(source Stiftung Warentest)

In the next lessons you will perform a similar product test on different plastics: PVC, PET and TPS. Your own plastic evaluation also requires different criteria and similar weighting, which you will have to work out among yourselves at the beginning. The following four areas are important in the test:

Green Chemistry

This portion of the tests has to do with environmental and energy questions. There are guidelines for sustainable "green chemistry" that are valid for all of Europe. Many companies in the chemical branch seriously attempt to fulfill these regulations, which are aimed at optimizing production. The goals are to use nonpoisonous, harmless starting materials and to make the production process as effective and energy-saving as possible. Also, waste by-products should be minimized. All products should be harmless and easy to dispose of, e.g. via recycling or simple biological decomposition.

Consumer and Social Interests

Consumer interests are the focus of this area. Is the use of a given material safe for humans and animals. Is the danger represented by a product also minimal under accidental circumstances, e.g. in a house fire? Is the product produced under acceptable social conditions, or in Third World sweat shops, possibly with the employment of child labor? It is also important to the consumer whether plastic products are available under reasonable pricing conditions of supply and demand.

Economy and Industry

Industrial factors must also be taken onto account. Production of plastics must be profitable for companies and the State alike and production costs must be in the correct relationship to final marketing profits. Here it is important to know if the group of potential customers is large enough and whether the plastic is highly marketable. Recyclability is also important, since marketability is also influenced by resale value of spent products.

Material characteristics

The use of plastics is naturally influenced by the suitability of a given substance as a raw material for manufacturing end products. Can the plastic be easily produced and formed into goods? Can its characteristics be employed to produce a broad spectrum of various products, or is the material especially suited for special uses. Such properties as durability and the ability to be produced in various colors is also rated in this area.

Product test plastics **Evaluation criteria**	My weighting factor	Weighting factor of the group	Weighting factor of the class	My assessment	Assessment of the expert group	Assessment of the mixed group		
Plastic						PVC	TPS	PET
Green Chemistry	%	%	%					
Production and use without dangers for humans and environment								
No problems for disposal or recycling								
Production primarily from renewable resources								
Low energy costs for production								
Consumer and social interests	%	%	%					
Production, use and reuse take place according to West European social standards								
Safe usage for humans and animals also in the case of improper use (burning, swallowing, etc.)								
Products available cheaply everywhere								
Economy and industry	%	%	%					
Industrial production possible without subsidies								
Good marketability								
Recycling possible								
Material characteristics	%	%	%					
Good durability and long lifespan								
Good material properties and a broad area of usage								
Decision			**100%**					
Decision from the entire class								

Evaluation key: **++** = very good (1) **+** = good (2) **o** = satisfactory (3) **⊖** = barely sufficient (4) **–** = inadequate (5)

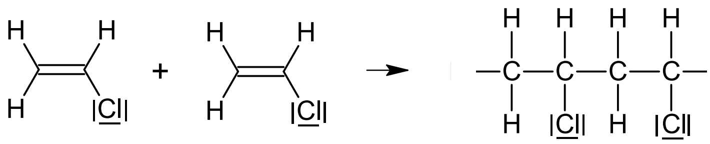
Aids:

Take another look at the consumer protection report in order to understand how the evaluation sheet is supposed to be filled out.
In order to calculate the overall grade you must first calculate the average grades for the plastics in the individual parts. These grades are then multiplied by the weighting factor, then the result divided by 100. These values for a plastic yield the end result when added together.
Example for Leki Flash carbon: $(60 \cdot 1{,}8 + 40 \cdot 2{,}2)/100 = 2{,}0$

A. PVC

PVC (polyvinyl chloride) is a thermoplastic material which is produced from petroleum via ethene extraction. Additionally, chlorine is necessary, which is won from sodium chloride at a high energy cost. Older methods of chlorine production which are sometimes still employed overseas remain environmentally risky, since they employ poisonous mercury in the production process. The final step is the polymerization of vinyl chlorid into PVC (a compound made out of ethene and chlorine) with the help of catalysts:

Corrosive HCl (hydrochloric acid) and the carcinogenic intermediate vinyl chloride (VC) can also be produced during the production of PVC. Frequent accidents involving vinyl chloride used to be a constant problem until current safety measures curbed this tendency. Dealing with the HCl produced during the procedure remains a problem.



Reaction of vinyl chlorid to polyvinyl chlorid

PVC is very easy to work with and the areas in which it is used are legion. Most PVC is used in the building industry: window frames, wastewater pipes, cable coverings, roof seals or floor coverings. PVC is often cheaper than other plastics. Additionally, PVC is also used for packaging materials, hospital equipment and toys.

Different additives are mixed into PVC in order to give it various properties. These substances make the resulting products soft, colored or durable. Softeners remain highly contested, since they are suspected carcinogens.

PVC pipes www.maerz-industriebedarf.de

Window frames made out of PVC

PVC is a very durable substance. It is resistant to UV rays and the effects of the weather. Cleaning agents like alcohol, acids or bases have almost no effect on it.

But this high durability means that PVC is also not decomposed by natural processes. PVC waste is therefore often simply stockpiled in dumps. This solution is cheaper than recycling, however, it has also been illegal in Germany since 2005, if it is technically and industrially possible to recycle such waste products. This is why storing PVC only happens in foreign lands. And part of Germany's PVC waste is exported and stored in other countries.

However, there is an increasing number of PVC reuse processes. there is thermal recycling, which burns PVC in order to win energy. This was impossible for a long time, since the combustion of PVC produces poisonous dioxins. But modern plants can burn PVC without dioxins as by-products. This, however, is not the case when PVC combusts under uncontrolled conditions like house fires, etc. In poorer Third World countries PVC and other plastics are often illegally disposed of by burning them in the open. This is usually by children or young people seeking to harvest metallic remains to sell on the open market. Large amounts of poisonous gases are released during the process, which lead to health problems.

The recycling of PVC wastes into new products is actually more profitable economically than simply burning waste. In this case, very pure PVC wastes are melted and combined at low temperatures in order to form new products.

B. TPS

Symbol for compostability

The term TPS represents bioplastic products called „thermoplastic starches“. Bioplastics include a large group of substances and are widely known. The name can refer to biologically decomposable plastics which are not won from renewable resources. It can also indicate plastics stemming from plant-based raw materials, but are not decomposable under normal biological conditions. TPS itself is not only biologically decomposable, but also produced from renewable plant materials.

TPS is manufactured from starches, which come from potatoes, corn, rice or grain, which are easy to win and safe to handle. Starch is composed of two substances: amylose and amylopectin. The latter is of special interest for the plastic manufacturing industry. However, normal breeding experiments cannot raise the amylopectin content of corn plants, for example, to any appreciable degree. This is why many countries have begun experiments with genetic engineering. In Germany the use of genetic manipulation is forbidden due to the risks represented for humans and animals alike. In the USA and a few other lands, large quantities of genetically-altered crops are planted and harvested every year.

Starch can absorb water and expand. Therefore, it must be processed and other materials added to the mix. The result is a durable plastic which remains biologically decomposable. However, TPS is not very stable for exactly this reason. It is quickly split into its components by outside factors such as moisture, light rays or the effects of microorganisms.

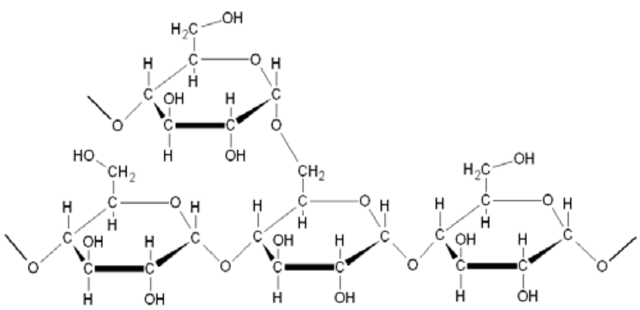
Producing large quantities of starch-based plastics entails intensive agricultural practices. Additionally, many chemical steps are necessary in order to get from raw material to final product. Taken as a whole, these aspects do not make TPS much more attractive than normal plastics when it comes to environmental protection. Another disadvantage is that starch-based plastics cannot currently be recycled.

TPS as packaging material

The only choices are combustion or biological decomposition, whereby burning is the economically more viable solution due to the energy won out of the process.

TPS is also used as packaging material, e.g. for fruit and vegetables. Other uses include agricultural applications such as plastic sheeting which can simply be plowed under after use. Supermarkets have also sold decomposable trash bags for quite some time. However, research has shown that these bags only break down quickly under specific conditions. For this reason, normal composter heaps cannot handle these bags and plastic foils, which can be easily separated out of compost wastes.

Although areas of bioplastic use have been limited, the demand is growing. Bioplastics are supported by the State, since they are paid for by the waste fees in the dual system of plastic disposal (the "yellow dot" symbol in German). But bioplastics cannot compete in price with normal plastic foils. Despite this, bioplastic may become increasingly more competitive and important in the face of rising oils prices and shrinking oil reserves.



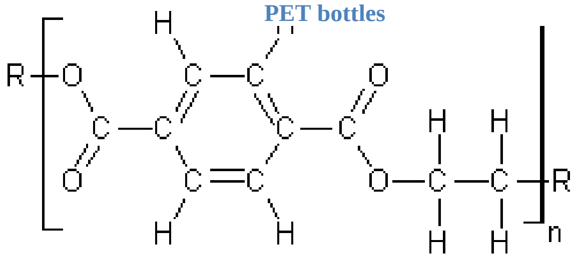
Amylopectin structure

C. PET

Polyethylene terephthalate (PET) is a thermoplastic substance belonging to the polyester family. PET is easy to work with and is used in large quantities in the manufacture of drinking bottles. PET is very transparent, lighter than glass and resistant to environmental weathering. However, PET is porous and allows gases to move through container walls. Because of this, carbonated drinks may lose their CO_2 after a period of time.

PET is tear-resistant, light and does not absorb water, so that it is suitable for sports clothing. Fleece pullovers are made of PET. Plastic foils are also produced using PET, e.g. tarps for tractor trailers or farm equipment. Overall, PET-products cover a broad, varied field of uses.

PET bottles



The structural formula of PET

PET manufacture includes many different steps and is therefore very energy intensive. All raw materials for PET production are won from petroleum. There are two different paths of PET manufacture. Older factories still use the reaction of dimethyl terephthalate with health-damaging ethanediol, which releases poisonous and highly flammable methanol as a by-product. More modern facilities use terephthalic acid and ethanediol, so that methanol can be avoided as a product. PET itself is not poisonous. However, it is also not biologically decomposable and has to be disposed of by other means. Stockpiling PET waste has been illegal in Germany since 2005. Therefore, PET used to be recycled using thermal processes. In 1999 approximately 96% of all PET wastes were burnt in order to reclaim energy, since no poisonous by-products result during combustion.

PET recycling symbol

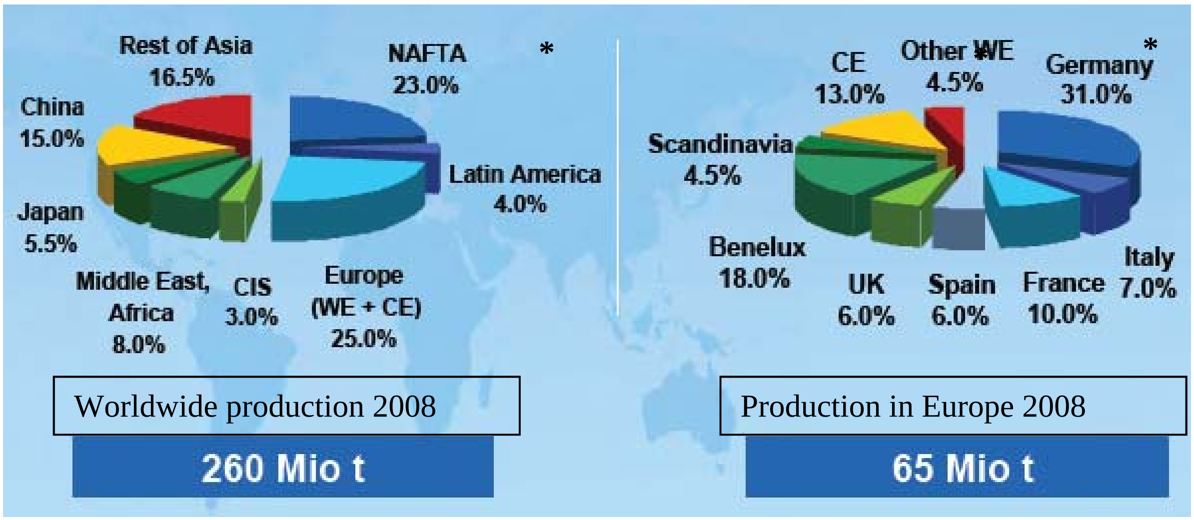
A good alternative for recycling PET wastes into new products, bottles or fleece cloth exists. Unlike in the past, however, the majority of recycling does not take place in Germany. Most German PET waste is shipped to China, where it is separated by color, washed and freed from impurities, then ground up into tiny flakes. These flakes can later be melted and used to manufacture new products. China produces fleece jackets out of old PET bottles, then ships them back to Germany to sell.

Exporting the waste to China is economically profitable, because China pays more per ton of PET waste than German firms can earn recycling it. Of course, this also is due to China's environmental laws are almost nonexistent and recycling is therefore much cheaper. Wastewater produced during the recycling process does not have to be clarified at the factory, as is the case in Germany. Additionally, personnel and company costs are lower in China due to lower wages and much lower social standards as compared to Europe.

PET flakes

Plastics – Facts and Figures

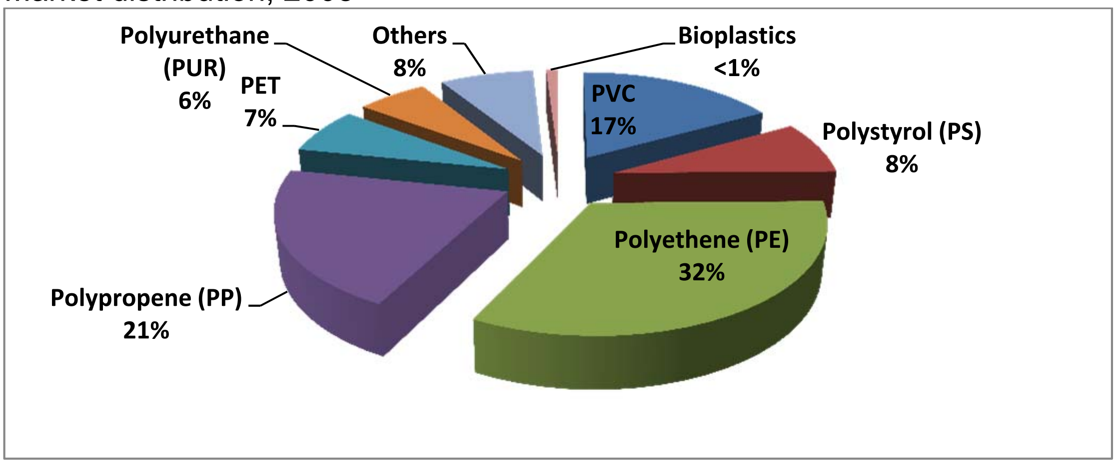
Producers



Quelle: PlasticsEurope Market Research Group (PEMRG)

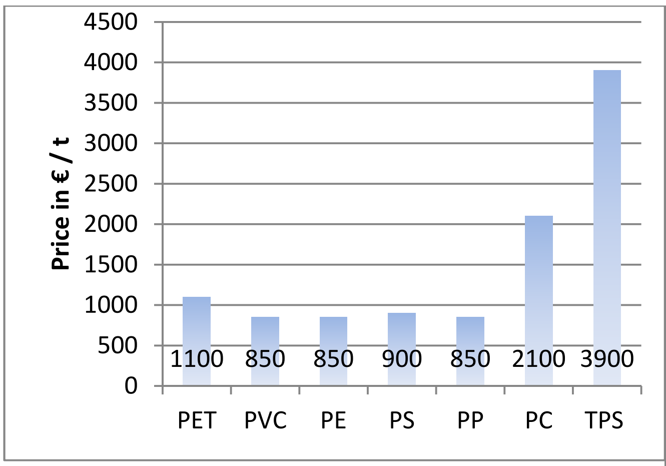
* NAFTA = USA, Kanada, Mexico, CE= Central Europe (Estonia Latvia, Lithuania, Poland, Slovakia, Czeck Rep., Bulgaria, Hungary, Slovenia), WE= Western Europe

Market distribution, 2008



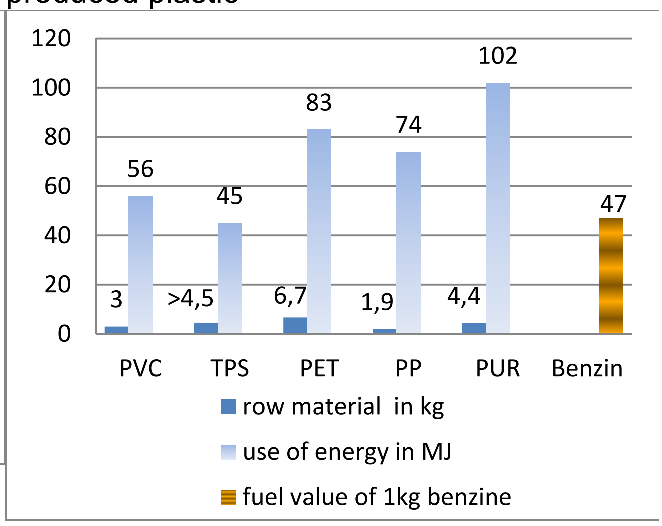
Source: PlasticsEurope Market Research Group (PEMRG)

Price per ton



Source: bvse - Bundesverband Sekundärrohstoffe und Entsorgung e.V

Consumption of raw materials per kg produced plastic



Source: http://www.lca.plasticseurope.org/index.htm