Plastics Can Be Good for the Environment

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The Popular View

Many have a negative view of plastics. With their increased use, there is concern that their production and use will detract from the environment, and their disposal will contribute to the increasing accumulation of trash. There is over-emphasis on these aspects; in consideration of the many positive contributions of plastics, they may add to the quality of the environment.

Do Plastics Use Up Petroleum?

Ninety percent of petroleum is used for fuel. Only about 5% is used by the petrochemical industry, and 3-5% is used to make plastics. These plastics serve to make our cars and planes lighter, and in doing so, save more oil than needed to make them. If we increased car fuel consumption efficiency only 5%, a readily achievable goal using present-day technology, we would save more oil than the entire plastics industry uses.

Petroleum is a resource resulting produced over millions of years from vegetable matter, which originally got its energy from the sun through photosynthesis. Thus, we are using up this accumulated storehouse of energy in a relatively short period of time. It will run out, sooner or later. Just when this will happen is controversial. However, in the long run, petroleum will become more scarce and its cost will rise. As this happens, industry will divert its efforts to using a greater fraction for plastics and less for fuel, since such is more profitable. As a result, the use of petroleum as a source for plastics will be less sensitive to the forthcoming shortage of petroleum than will be its use for fuel.

Even if petroleum for making plastics becomes more scarce and expensive, there are alternatives. Plastics can be made from natural gas, coal, or biomass. Technology for this exists today, but it is not widely employed. Currently, it is still cheaper to make plastics from petroleum, and it will probably be so for quite a while. Some day it may not be, and we should be and are thinking about these alternatives.

Do Plastics Pollute?

Plastic factories are considered undesirable neighbors because of concerns with pollution. This has merit as many remember the disaster in Bhopal, India in December 1984 when many were killed in an accident leading to the release of a toxic intermediate, methyl isocyanate, used in plastic manufacture.

The situation is rapidly improving in this country, with strict regulations by the EPA and a government encouraged effort for "green chemistry". This involves replacing older processes by newer, more environmentally friendly, ones. For example, the former process for making the plastic, polycarbonate, involved the use of phosgene, a poisonous gas that was used in WW-I. This process has now been replaced by one not requiring phosgene. Modern technology employs computer control of processes using the "just-in-time" approach, in which only small amounts of intermediates are present at any time, since they are generated only as rapidly as they are needed. Thus, even if undesirable intermediates are used, there is never enough present at any time to have appreciable environmental impact.

There are concerns about toxic consequences of plastic use. Plastics are made by joining together small molecules called monomers. As chemical reactions are never complete, traces of these monomers may remain in the plastic. Some of these monomers are toxic. However, increasingly sensitive techniques for their detection have been developed, leading to regulations limiting the amount that can be present. These have led to the banning of some products and to the improvement of processes leading to less residual monomer. For example, several years ago, there was an industrial effort to make soft drink bottles from the polymer, poly(acrylonitrile) (PAN) which has some properties superior to the commonly used poly(ethylene terephthalate) (PET). However, processes at the time for making the PAN resulted in traces of its monomer, acrylonitrile, being present. This led to the EPA banning the product. Today, improvement of processes could produce PAN that would be acceptable for bottles, but the psychological damage arising from the earlier ban has discouraged its use.

There have been other concerns about toxicity in use, much of which is controversial. There has been concern about residual monomer in polycarbonate used for baby bottles, of possible hormonal activity of plasticizers in polyvinyl chloride, and of decomposition products that might arise from overheating teflon frying

pans. These have led to extensive studies, some of which have cast doubt on their dangers. However, care is certainly indicated, and increasing strict standards have developed.

Problems with Disposal

There is awareness that there is a problem in finding economical means for disposal of discarded articles, and plastics have been of prominent concern. The public view of rubbish probably places too much of the blame on the role of plastics in that they only amount to about eight percent of the total weight. However, their contribution is a visible one, particularly in that plastics are long lasting.

The long lifetime of plastics arises by design, in that, for many applications, this is a desirable attribute. However, it is not necessary; it is possible to design plastics so that their lifetime may be varied depending on their intended use. Thus, for an underwater cable or a buried sewer pipe, long life is very desirable, since repair would be difficult and expensive. However, for some uses such as for candy wrappers, where careless disposal is possible, there may be justification for using plastics of more limited lifetime.

There are economic barriers to employing limited life plastics. It would require the development of a greater variety of plastics of varying lifetimes dependent upon their use. There would be need to keep track of the age of the plastics, so that their failure would not occur prematurely. As a result, use of such limited life plastics has not been great; encouragement through regulation may be necessary to overcome these economic barriers.

Plastic trash can be reduced, of course, by using less. There has been effort to do this through marketing products in larger containers and/or more concentrated solutions. Such is often less convenient for the consumer, and it is necessary to achieve a balance between this and the environmental advantage.

A disadvantage of degradable plastics is that degradation involves the loss of valuable materials, often made from non-renewable resources. It is much better practice to reuse them where possible, and this often involves changes in consumer habits. It might be desirable, for example, to encourage the European practice of reusing shopping bags rather than giving shoppers a new bag each time.

In some cases, one finds apparently excessive packaging used for small objects so as to prevent theft. Here, it is necessary to balance the cost of this against that of alternative theft-reduction practices.

The adopting of plastic packaging has increased both to reduce spoilage and to improve sanitation. Again, there is the balance to consider between the cost of doing this (with the resulting environmental clean-up) and the environmental consequences of spoilage or contamination of products.

Recycling

Recycling is another way of preventing discarded plastics form entering the landfill and retain some of their value. Many plastics have the attribute of being meltable, so that discarded objects can be reformed to make others. This is certainly desirable, but again, there are economic barriers. Costs involve those for collecting, cleaning, and processing the waste plastic so as to produce the starting material to make new objects. Also, it has been shown that the properties of the objects made from mixed plastics are inferior to those made from a plastic of a single kind. Therefore, it is desirable to separate the discarded plastics before recycling, an often costly process. The result is that recycling has proved economically viable for only a fraction of discarded plastic, perhaps presently 20 - 30%. This percentage could increase with improvement in recycling infrastructure, with advances in separation and sorting technology and with increases in the cost of petroleum, rendering fabrication from new starting material more expensive. A consequence is that recycling, while desirable, can only be appropriate for a portion of waste plastic, and other means for dealing with the rest must be considered.

Trash to Energy

In a sense, by making plastics from petroleum, we are just borrowing its energy. Most of this can be recovered by burning the plastics and using the heat produced to generate useful energy. Such burning has been done in incinerators, which has not met with public acceptance because of polluting. Such pollution may arise from the plastic, itself, or from other things mixed with it. Pollution from the plastic is often in the form of organic compounds arising from incomplete combustion of plastics. This may occur in "old fashioned" incinerators commonly encountered but can be substantially reduced using "state-of-the-art" facilities operating at proper temperatures and with adequate air supply. The second source might be from materials associated with the plastics such as pigments, fillers, and catalyst residues. Changes in practice can appreciable reduce this. Similarly, substances such as mercury from thermometers and relays, preservatives from treated lumber, and lead and cadmium from discarded batteries can lead to the production of polluting fumes and ash n the incinerator. The best way to avoid this, of course, is prevent such material from being mixed with the plastics, either by regulation or by some crude separation technique.

These solutions also have economic consequences. Building modern facilities with separation techniques for their feedstock and scrubbing of fumes can be costly. However, much of this cost is the initial

one for construction; cost effectiveness increases with time. Thus, while trash-to-energy might be initially uneconomical, it may become more favorable with time as the facility is used.

Suppose burning was not done and the alternative of disposing of the trash in the landfill was adopted. What would happen to the potential pollutants that it might contain? These would eventually be released into the environment in an uncontrolled way. In the incinerator, the volume of the trash is considerably reduced, and many of the pollutants would end up in the ash. One then has a reduced volume of material to dispose of, an easier task. Furthermore, material such as lime can be added to convert the ash into a cement-like material of reduced solubility, so that escape of the pollutants from the ash at its disposal site is limited.

Overview of Problems

It is evident that the use of plastics can lead to problems, particularly if use is improper. However, such problems may be reduced if proper measures are taken. Doing so may be costly; one must balance this against the advantages ensuing from plastic use.

Why Is So Much Plastic Used?

It is evident that plastic use is increasing, exceeding that of all metals. This happens because plastics have advantages, serving our needs better and being cheaper. They may replace other substances that are more polluting. They may save energy, the generation of which is also polluting and consuming of resources. They may provide properties that cannot be achieved with other materials.

What Might Plastics Replace?

Let us consider a few cases where plastic has replaced other materials. A principal reason is that of weight saving since plastic bottles are much lighter than glass ones. This leads to fuel saving in shipment. Furthermore, breakage is reduced, saving on the loss of product and of injuries arising from broken glass. While glass bottles can be reused, the cost of doing so has increased because of the cost of collecting, shipping, sorting, and cleaning. This is compensated, in part, by the effective reuse of the plastic bottles by recycling.

We are confronted with the choice of "paper or plastic?" when shopping. The choice of paper might seem to be environmentally better, but this idea might be challenged. While some pollution arises from plastic production, there is also considerable pollution (as well as energy consumption) in paper making. There is also the view that paper is more recyclable or degradable. Recycling paper also involves expense, since it, too, must be collected and sorted, and cleaning processes like de-inking must sometime be employed. The volume of paper in landfills exceeds that of plastics, and its decomposition is slower than commonly thought. There is considerable weight saving in shipping of plastic bags as compared with paper ones of similar carrying capacity. Plastic bags enjoy some performance benefits. Their wet strength is much superior to that of paper. They may be made transparent or opaque, depending on the desirability of viewing contents. They are relatively impermeable to vapors, liquids, fungi, and bacteria and may be sealed, rendering them desirable for the preservation and protection of their contents. They are often made with handles, permitting carrying a greater amount of material than possible with paper bags.

Paper is principally made from wood, so its use consumes another resource, our forests. The forested area of the world has decreased as a result of the need for wood as fuel, building material and paper production. Such loss of forests affects the climate, in that carbon dioxide absorption is decreased, partially leading to the "greenhouse effect".

Wood, when exposed to the climate or marine environment, will decay due to attack by fungi or bacteria. This may be retarded by introducing preservatives (often under pressure) that frequently contain toxic materials such as compounds of arsenic and chromium. When the wood is disposed of or burned, these components are released to the environment. This problem may be avoided through the use of "plastic lumber", often made from recycled feedstock. Such is now common for park benches and boat docks.

Formerly, telephone cables were sheathed with lead. Now lead is replaced by plastic, with consequent reduction in pollution, weight and cost. Most electrical insulation is plastic, and the very low dielectric constant of some plastics like polyethylene has made high frequency applications such as radar and high pulse rate communication possible.

Paint pigments were formerly primarily metal oxides dispersed in an organic liquid, both of which offered heath hazards. Today, use of such paints is restricted and they have largely been replaced by polymeric lattices, frequently in an aqueous vehicle.

Flexible hoses are essential in liquid handling, fire fighting, and in medical application. Polymeric elastomers are vastly superior to other materials for these.

Plastics Can Save Energy

Energy saving arising from the use of plastic bottles has been mentioned. Such saving by weight reduction has led to increasing use of plastics to replace metallic components of vehicles and aircraft. The use of reverse osmoses with polymeric membranes in water purification is much more energy saving than is distillation. Alternative energy sources such as wind turbines

use blades usually fabricated from plastic composites. Solar cells, involving plastic in fabrication, are now used to furnish electricity to remote locations, and their decreasing cost and improved efficiency are making them more competitive with fossil fuel generated electricity. Polymer based light emitting diodes are currently used for display devices, and there is promise that they may eventually serve as sources of illumination, using half as much electricity as present-day sources. Fuel cells and batteries, many employing plastic-based membranes, are expected to serve as energy sources in the future, possibly replacing internal combustion engines in cars. Water soluble plastics can be used in oil well drilling fluids, permitting obtaining oil from lower grade wells.

Plastics Can Reduce Pollution

Industrial and domestic waste water treatment involves separating impurities from water. Plastics can aid water cleaning in two ways. One is, that by adding soluble polymers to aqueous suspensions' the dispersed impurities can be coagulated, allowing separation by settling or filtering. Also, polymeric membranes can serve to separate impurities from waste water. Run-off of fertilizers and pesticides from agricultural facilities can be reduced by using polymer-based slow release techniques. These residues from run-offs find their way into lakes, causing eutrophication, or into drinking water supplies where they may cause heath problems.

Plastics Are Important in Electronics

In addition to their use as insulators and dielectrics, plastics make possible the fabrication of microelectronics by photolithography. This is carried out by covering the circuit chip material (usually silicon) with a photosensitive plastic layer. An image of the circuit, reduced in size, is projected on this, leading to crosslinking of the plastic portion exposed to light. The uncrosslinked plastic is then dissolved away, leaving a plastic replica of the circuit. The chip is then exposed to an etchant which attacks the uncovered portion, leaving an etched circuit imprint. ***

This technique has led to ever smaller circuit elements, leading to more compact electronics that are faster and cheaper. The technique is limited by the optical resolution of size comparable with the wavelength of the radiation employed. Current efforts are to use shorter wavelengths in the ultraviolet or even x-rays, but limits will soon be reached. An alternate approach, certain to be developed, is the fabrication of circuits by self-assembly whereby, instead of making microcircuits by size reduction, one builds them up from the molecular level. The task is to find ways to make molecules assemble to form patterns having the desired electrical (or optical) function. Already, simple molecular logic circuits have been made and there is optimism regarding future possibilities.

Plastics for Music and Art

Plastics have helped bridge the dichotomy of the arts vs. the sciences. Most music recording techniques, records, tapes, and CD-ROMs involve plastic media. Modern photography would not be possible without plastic film, and this is now giving way to electronic digital photography. Through the internet, made possible by microelectronics, music and pictures can be electronically sent to distant locations and users can enjoy viewing art works in distantly located museums.

Plastics for Specialized Mechanical Applications

Plastics are usually thought of as being weak as compared with metals, but this occurs because of the usual random arrangement of the chain molecules in unoriented plastics. These molecules are very anisotropic in mechanical properties (different in different directions), being extremely strong in the chain direction but weak perpendicular to this. If the chains are all aligned, the resulting material can be extremely strong in the alignment direction. This has been done, leading to fibers such as those of Kevlar and Spectra that can be much stronger than steel and which have application for tow ropes, tennis racquets, golf clubs, bullet proof vests, and reinforcing fibers for high performance composites.

Aligning the molecules to a lesser degree can impart anisotropic mechanical properties for cheaper and more low-technology applications. There are many applications for which one desires differences in strength in different directions. For example, such is desirable for garbage bags, sealing tape, and bottles. Tire cord involves oriented polymer molecules where it is desired that the cord be very strong in the fiber direction. Tires consist of rubber reinforced by such cords, which accounts for their strength. Early tires used cotton cord and were very inferior to those today, which are reinforced by oriented synthetic polymers.

Plastics have the property that they can be molded into very complex shapes which would be difficult to make by conventional machining techniques. While such techniques are required to make a mold, once it is done, it may be used to fabricate large numbers of plastic parts. For example, large lenses or those having special shapes are usually made by such methods rather than by the tedious and expensive process of grinding glass.

Plastics in Sports

We have referred to the use of plastics for items such as tennis racquets. There are many other applications for plastics in sports such as for protective gear such as helmets and knee pads, for skis, snowmobiles, ski boots jogging shoes, baseballs, footballs, basketballs, and golf balls, mostly made from plastic. Mountain bikes, scooters, and roller blades employ plastic parts. Plastics

have helped hiking and camping in their use for fabricating backpacks, sleeping bags, and tents. Those of us who sail bless the use of fiberglass for boats, replacing difficult to maintain wood, and polyester and nylon for sails, replacing canvas.

Plastic for Clothing and Carpeting

The synthetic fiber industry got its start with Wallace Carothers's invention of nylon which has essentially replaced silk for women's stockings and fine garments. Dacron (PET) has had its impact and has been fabricated in ways to replace natural fibers such as wool (in carpeting as well as clothing). The strength of textile fibers is dependent on their fabrication from oriented polymer molecules. Special designs have resulted in fabrics of superior insulating value, better moisture resistance, and easier maintenance. It would be difficult today to replace such materials with natural fibers like wool and cotton, the production of which would place a severe burden on agriculture and have negative environmental consequences, as their production involves fuel for farm equipment, fertilizer or animal feed, and the disposal of agricultural or animal waste. Furthermore, the maintenance of synthetic fabrics has less environmental impact, since most are more resistant to biological attack and may be cleaned by simpler methods. Of course, their resistance to the environment leads to concern about their disposal, so considerations of means such as recycling are important.

Plastic in Medicine

The use of plastics for tubing as in catheters has been mentioned. Many medical articles are offered in plastic, sterilizable packages. Disposable gowns, sheeting, and sponges, as well as bags for intravenous fluid administration and membranes for blood dialysis are of plastic origin. More "high-tech" applications involve the use of fibers of controlled degradability for sutures for which removal is not necessary. Such degradable plastics can also serve as carriers for drugs which have controlled release rates or which can be implanted so as to offer high drug concentrations at a desirable site in the body. Such have proved effective in cancer chemotherapy.

The construction of prosthetics from plastics is common practice, the art of which is improving so as to allow their use for internal body parts, such as bone screws, joints, arteries, and even more complex structures such as hearts. Plastic based artificial skin enables serious burn victims to survive.

An exciting recent development is that of tissue engineering in which replacement body parts consisting of cells from the recipient are cultured in a degradable porous replica of the part. As the cells grow in an incubator guided by the plastic replica, the plastic degrades, and one ends up with a part composed of the cells of the recipient. Such parts are not rejected since they are composed of cells of the recipient This has already been done for simple parts such as ears and noses, and there is promise that growth of more complex parts like livers, might eventually become possible, eliminating the need for donors.

An Overview

This accounting of some of the virtues of plastics is incomplete, but it is apparent that they now affect our lives in many ways and will continue to do so. Our lives would be very different without them, and we believe that their advantages and benefits to the environment far outweigh the problems. They can improve the quality of life. We must recognize their properties and limitations and use them with these in mind and be concerned about employing proper techniques for their reuse or disposal which do not negatively impact the environment.