The Plastics Problem

Part 1: Plastic Packaging and the Solid-Waste Crisis

by Stephen G. Puccini

From Bakelite, the first synthetic plastic produced in 1909, to everything from insulation to floor covering to beverage containers, plastics has emerged as one of the fastest-growing categories of materials used--and discarded--in the economy today.[1] The production and consumption of plastics is now greater than that for steel, aluminum and copper combined, with as many as 10,000 plastic varieties catalogued.[2] In 1970, plastics comprised less than 3 percent of the municipal solid-waste stream by weight; by 1986, its contribution doubled; today it is estimated that waste plastic comprises approximately 8 percent of the stream by weight and nearly 30 percent by volume.[3]

This increase in the use of plastics, however, has created problems for local governments attempting to manage solid-waste. With the capacity of landfills decreasing and many of the concerns surrounding the safety of mass-burn incineration still unanswered, increased expectations by solid-waste planners, legislators, and environmentalists have developed for recycling as a preferred waste-disposal option. At the same time, packaging materials, which comprise more than one-third of municipal waste, by volume, in the United States, has become the focus of attention. It is now widely recognized that if this country is to have an effective integrated waste management system, recycling must play a major role in reducing packaging in the waste stream.[4]

Plastics are proliferating in the packaging sector of the economy. In 1974, 6.7 billion pounds of plastics were consumed in the manufacture of packaging materials. By 1984, that usage roughly doubled. By 1995, projections indicate that 19.1 billion pounds of plastic packaging materials will be consumed in the United States, accounting for over one-third of all oplastic resin use annually.[5] Plastic packaging also accounts for more than half the plastics in the municipal waste stream making it the single largest source of waste plastic.[6] In contrast to the 25 to 50 year life span of plastics used in building and construction, plastics used in packaging materials have a life span of less than one year before entering the waste stream.[7]

The materials plastics are replacing in the packaging industry, however, have much higher recycling rates because well-secured recycling systems already exist for most of these traditional materials. In 1980, for example, approximately 14 percent of all discarded packaging was recycled, primarily paper and paperboard, with a recycling rate of 25 percent. Aluminum was recycled at a rate of approximately 29 percent. The recycling rate for plastic, however, was near zero.[8] Interestingly, because plastics require less energy to produce, the switch to plastics from glass and paper in the 1970s was promoted as part of an effort toward source reduction.[9]

"Plastic packaging accounts for more than half of the plastics in the municipal waste stream, making it the single largest source of waste plastic."

This trend is likely to continue. In 1987 a study conducted for the United States Department of the Interior found that plastics were displacing significant amounts of both glass and metals, as well as competing with paper and paperboard in the packaging industry.[10]

It is against this backdrop, where the increasing consumption of plastics in the packaging sector is changing the traditional composition of the waste stream and the mounting difficulties municipalities are facing in reducing their solid-waste have converged, that the impact the proliferation of plastics in the packaging sector may have on the nation's ability to meet local and state targets for waste reduction is examined. If the recyclability of the packaging-waste stream diminishes due to the influx of plastic packaging, it may become impossible to satisfy these goals.[11]

We begin the discussion by defining plastics and identifying the types of plastics commonly used in packaging. This is followed by an analysis of the disposal methods available to solid-waste planners in managing the waste stream, the merits and drawbacks of each option in handling plastic packaging waste, and some of the factors which favor the employment of some waste-disposal options over others. Finally, degradable plastics are examined to better understand what role, if any, they may serve in minimizing the impact of plastics on the solid-waste crisis.

I. Plastics

A. What Are Plastics?

Plastics are particularly valued in the packaging industry. They are lightweight, durable, and resistant to breakage. These attributes reduce handling costs and fuel consumption costs in shipping, thereby benefiting the consumer in the form of lower prices for the finished product.

What gives plastics these characteristics?

Modern plastic materials are almost universally derived from petroleum and natural gas. About 20 percent of all oil and natural gas consumed in the United States annually is used to produce petrochemical feedstocks for the plastics industry. It is from these fossil fuels that monomers are derived. Monomers, consisting of hydrocarbon molecules like ethylene, propylene, benzene, and styrene, are linked together by a chemical reaction called polymerization to create high-molecular-weight polymers, also called resins, the essential ingredient of every plastic.[12]

Once a polymer is formed, additives transform it into a plastic. Common additives are antioxidants to prevent or slow degradation, colorants to enhance the appearance of the finished product, heat stabilizers to aid in the manufacturing process of certain polymers, flame retardants, and plasticizers.[13] These non-polymeric components amount from less than one part per million to several percents.[14]

Plasticizers are added to resins to alter their processing and physical properties, making them more flexible and therefore more useful in a broad array of applications.

In addition to the additives and plasticizers that are incorporated during or after polymerization, the properties of plastics "are determined by the linkages between monomers and their structural arrangement, the length and types of molecules in the polymer chain, and the integration of differing types of monomers in the same chain."[15]

While designers classify the hundreds of different types and blends of polymers by their physical properties, chemists place them into two main groups, thermoplastics and thermosets.[16] Thermoplastics represent about 87 percent of resin sales in the United States. Heat softens thermoplastics, allowing them to be reshaped into different objects. Thermosets account for the remaining 13 percent of resin sales in the United States.[17] Molecules in thermosets form cross-links that once formed or molded cannot be reshaped by heat. As a result, although they are easy to reclaim, they are difficult to recycle.[18] Thus, concerning the recyclability of plastic packaging in the waste stream, thermoplastics are more desirable than thermosets.

There are somewhere between 500 and 1,000 different kinds of thermoplastics. We will be focusing only on the major types found in packaging: polyethylene terephthalate (PET); high-density polyethylene (HDPE); polyvinyl chloride (PVC); low-density polyethylene (LDPE); polypropylene (PP); and polystyrene (PS). Each of these thermoplastic polymers, in combination with various additives and plasticizers, have unique attributes which make them useful for certain applications in the packaging industry.

B. Identifying Plastics

In 1984, when the idea of imprinting codes on plastic items was first brought to the Society of Plastics Industry (SPI), a trade organization, SPI strongly resisted the measure. Without codes to identify the type of resin used in any given plastic item, however, it is almost impossible to recycle plastic packaging materials. The only exception is usually PET beverage containers where common knowledge allows identification.[19]

In 1988, however, SPI finally responded and offered the "Voluntary Plastic Container Coding System" (SPI coding system), a seven-code listing that proposes to cover almost all plastic packages (see Tables 1 and 2).

Table 1

Plastics in Packaging and Disposable Consumer Goods

PET	Soft-drink containers; dual ovenable trays.
HDPE	Containers for milk, dairy products, and ice cream; laundry detergent, bleach, and household cleansers; motor oil; paint; bottled water; base cups of PET soft-drink containers.
HDPE (film)	Grocery sacks and merchandise bags; bag and box liners of food products.
PVC (Rigid)	Containers for cooking oil and bottled water.
PVC (Film)	Meat and poultry wrapping; shrink wrapping.
LDPE	Wrapping for baked goods, candy, dairy, meat, poultry, seafood, produce; grocery sacks; dry-cleaners' bags; shrink wrapping; trash bags.
PP	Food lids, containers.
PS (Solid)	Produce baskets; tumblers and cocktail glasses; disposable cutlery; disposable lids; dairy containers.
PS (Foam)	Clamshell containers; hot-drink cups; disposable plates; egg cartons; meat and poultry trays; packaging beads.
Mixed Resins	Squeezable condiment containers; aseptic juice cartons; bags for snack foods (potato chips); toothpaste tubes.

Source: Wolf, Nancy and Feldman, Ellen, Environmental Action Coalition, Plastics: America's Packaging Dilemma, (Washington, D.C., Island Press, 1991)

SPI and its newly formed association, the Council for Solid Waste Solutions, are promoting the voluntary system. This should result in the coding of more and more plastic items and prove to be a very important development toward the goal of collecting, separating and recycling plastics.[20]

In creating the new coding system, however, the industry also created a new controversy. By using the conventional recycling symbol--arrows-chasing-arrows in a triangular loop--the SPI coding system suggests that plastic packages are completely recyclable.[21] Currently, however, from the standpoint of economic viability, most plastic packages are not "recyclable." Since the word has gotten around that plastics are recyclable, and the arrows indicate to some that they are, many well-intentioned consumers deposit their used plastic bottles and containers, regardless of resin type, with recycling operations. Most operations, however, will accept only PET or HDPE, if any, bottles and containers. As a result, recycling operators must spend time sorting among plastic bottles and containers for ones they can process.

While some states have rejected the use of the arrows in the codes that have been suggested, other states have made it mandatory that the SPI coding system be used on all plastic packages that are distributed within the state. California, for example, now requires that labels

Table 2

Classification of Thermoplastics Based on the SPI Coding System

Resin	Number Code	Abbreviation
PET	1	PET, PETE (Cal.)
HDPE	2	HDPE
PVC	3	PV, V (Cal.)
LDPE	4	LDPE
PP	5	PP
PS	6	PS
Mixed Resins	7	OTHER (Cal.)

Source: "Selling Green," *Consumer Reports*, October 1991

in accordance with the SPI coding system be molded into the bottom of all rigid plastic bottles and rigid plastic containers sold within its borders.[22]

If we wish to allow the separation and collection of those few plastics that are developing a recycling infrastructure to move forward, for example, PET and HDPE, the "arrow controversy" regarding the SPI coding system must be resolved, perhaps, as some have suggested, at the federal level.

II. Plastics Disposal

A. Landfilling

With over 80 percent of the solid-waste stream being landfilled today, the availability of cheap landfill sites has been declining, and proposals for new sites or the expansion of existing ones have encountered growing opposition from NIMBY-minded community groups concerned about increased truck traffic, lower property values, and nagging questions about environmental safety. The result has been dramatic. In 1979, the Environmental Protection Agency (EPA) reported that approximately 18,500 landfills were operating across the country. In 1989, that number had fallen to 6,000. By 1993, there may be as few as 4,800 landfills in operation, representing a 76 percent decrease in operating landfills in just over a decade. Among plastics, the record is much worse: 96 percent of all waste plastic is landfilled.[23] Although plastics are increasingly prevalent in landfills, there remain important unanswered questions regarding their overall impact.

Since the moisture and oxygen that encourages degradation of waste materials are not present in most landfills, nothing fully degrades in them, including food and newspaper waste. This is illustrated by landfill digs that have unearthed newspapers decades old which are still largely readable. It would be more accurate to state, however, that the practice of compacting waste at modern landfills delays, rather than halts, degradation. Nonetheless, some landfill engineers and planners point out that the decomposition is not rapid enough to extend the useful life span of a landfill.[24]

Recent figures indicate that waste plastic accounts for about 8 percent of the waste stream by weight, but almost 30 percent by volume.[25] With the decreasing availability of landfill space an issue, volume, rather than weight, is the more important measure. This is illustrated by foamed PS, used widely in food packaging as meat and produce trays and as "fast-food" containers. The 725 million pounds of foamed PS waste generated annually in the United States is equivalent to an uncompressed bulk of 13 to 20 million cubic yards, most of which is landfilled.[26] The plastics industry maintains that this concern is overstated. They point to a series of digs conducted by Dr. William Rathje of the University of Arizona which revealed plastics' share on a per-volume basis at roughly 16 percent of the solid-waste mass.[27] Furthermore, some landfill engineers and planners point to other types of waste, such as construction/demolition wastes, and newspapers which also occupy enormous amounts of space, to downplay this concern.

Issues surrounding the degradability and volume of plastics materials in landfills, however, largely depend upon the management of each particular landfill. Landfill engineers and planners may not be "managing a landfill as a composter or digester, and they are not seeking to maximize breakdown for space maximization or methane recovery." If these were their goals, and some suggest that they should be, the fact that waste plastic does not degrade and takes up large amounts of space could be critical issues concerning landfills.[28] (See the discussion of "degradable" plastics, infra part III.)

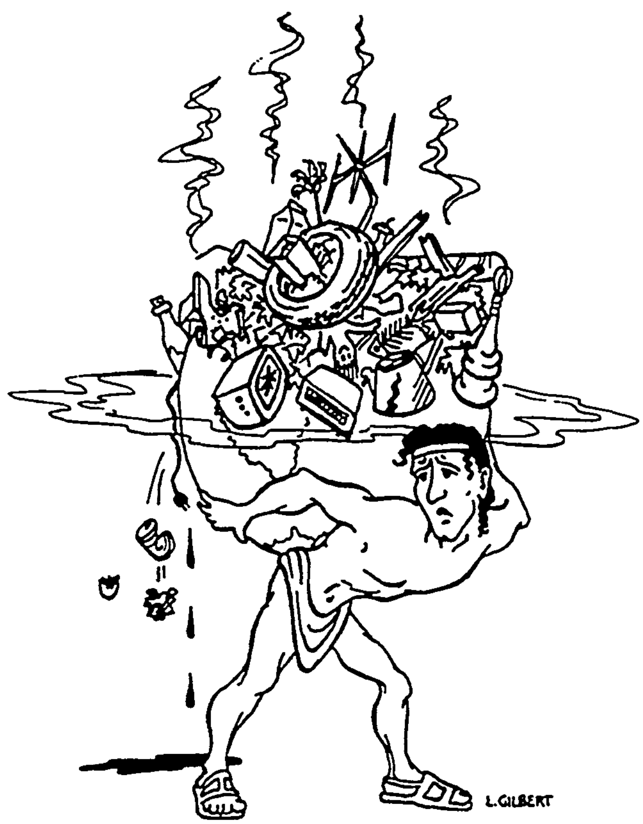
Another concern that has been raised regarding the increasing amounts of waste plastic that is entering landfills is the role they play in groundwater contamination. There is some speculation that plasticizers, such as lead, and additives, such as cadmium, leach from plastics in landfills and pollute groundwater. However, no conclusive evidence that plasticizers or additives do or do not leach has been presented.[29] Some additive manufacturers are nonetheless removing cadmium from resins in response to California's Proposition 65 which requires "the inclusion of any hazardous material in the labeling of any product, no matter the amount."[30]

B. Resource Recovery Through Mass-Burn Incineration

As landfills close and new sites become more difficult to find, more attention has been focused on resource-recovery through mass-burn incineration. There are approximately 135 waste incineration plants operating in the United States, processing about 13 percent of the solid waste in the United States. An additional 93 plants are under construction, and as many as 200 more are under consideration. One industry expert has estimated that in twenty years, the United States will be incinerating half its municipal solid waste.[31]

As we have seen, plastics are largely derived from fossil fuels. As a result, they raise the total energy content of the waste stream. Thus when a waste stream containing plastics is incinerated, more heat can be recovered from the combustion process to create steam, which in turn can be used to generate electricity. The Council for Solid Waste Solutions found that PET, for example, contained roughly 20,000 BTUs/lb. By contrast newspaper contains less than 8000 BTUs/lb.[32] From this perspective, operators of mass-burn facilities find plastics in the waste stream desirable.

Others concerned about the emission of carbon dioxide, a "greenhouse gas," from the burning of fossil fuels, sharply criticize this position contending that "Plastic is a fossil fuel once removed; on that basis alone, burning it is a bad idea."[33] On the other hand, Bill Moffitt, the British Plastics Federation's recycling consultant, feels that "the public has a mental block about recovering energy by



© Linda S. Gilbert

incineration...Why is it that 93 percent of oil can get burnt straight away yet the 4 percent used for plastics production cannot have a second life as energy?"[34]

Mass-burn incineration, however, is not without other controversies regarding its potential environmental costs.

Residue, trapped by pollution control equipment, and bottom ash contain toxics and heavy metals. The metals may leach in landfills and dust may be released in transporting ash and residue.[35] In addition to the impact these releases have on the environment and human health, how to properly dispose of the residues is also widely debated.

Because bottom ash is less toxic than fly ash, industry favors mixing the two to reduce the overall toxicity by dilution; environmentalists and others argue that the ashes should be kept separated so they may be tested for toxicity.[36] Toxic ash would be sent to a hazardous waste landfill. Critics argue that this is unnecessary and would only serve to increase the cost of incineration.

"What are the effects of adding increasingly large mixtures of different plastic resins, plasticizers, and additives to the burn-stream?"

Disagreements are also evident regarding the dangers of gas emissions from mass-burning unsorted waste. Emissions may include hydrochloric acid gases, nitrogen oxides, particulates, heavy metals, and trace elements of organic compounds.[37] Industry maintains that state-of-the-art incinerators in good working order neutralize acid gases with scrubbers and filters and that high temperatures destroy organics.[38] As many as 15 percent of these incinerators, however, are shut down for various reasons, including alleged noncompliance with state or local emission requirements.[39]

The pollutants of greatest concern are dioxins and furans, extremely hazardous organic compounds. Many parts of the burn stream contribute to their formation, but waste plastics has been the most controversial. What are the effects of adding increasingly large mixtures of different plastic resins, plasticizers, and additives to the burn stream?

Chlorinated plastics, such as PVC, for example, are known to contribute to the formation of hydrochloric acid gases. Because these plastics include chlorine, they may also provide precursors to dioxins and furans, although other sources, for example, paper, form precursors as well.[40] One study showed that plastics accounted for about one-third of the chlorine generated in trash; paper accounted for 56 percent of the chlorine produced. Professor Richard S. Magee of the Hazardous Substance Management Research Center at the New Jersey Institute of Technology concluded: "[This study] and many others clearly establish the multiple sources of chlorine in municipal solid waste and seriously challenge the hypotheses that a reduction in [dioxin and furan] emissions can be based on an overall strategy of lowering the content of municipal solid waste by separating chlorinated plastics [such as PVC]...from the refuse."[41]

Others conclude that more studies of burning need to be done to determine if "isolated plastics" contribute to the "formation of any particular pollutants [in gas emissions and ash] in the combustion process" and contend that "...responsible policy decisions must be based on the realization that nothing in the municipal solid-waste stream is 'entirely safe' to burn, nor is any one material solely responsible for the emission of toxic substances."[42]

Finally, there are those who believe incineration is incompatible with other options in the waste management hierarchy, namely recycling, source reduction and reuse. As Barry Commoner explains, "the only insurmountable hindrance to recycling is building an incinerator." Plant operators, however, disagree. They argue that removal of some recyclable materials from the waste stream makes the facilities burn more efficiently.[43]

If this is true, then one might reasonably expect the incentive to remove recyclables to extend only to those materials that are noncombustible, such as glass and aluminum, and not to plastics, whose high energy content makes them a desirable component of the burn stream. As one observer notes, because "[resource-recovery] incinerators depend on revenue generated from energy sales, they must run near capacity to stay profitable. Effective recycling and waste reduction programs can cut the amount of waste flowing to such facilities enough to put them in the red." In 1989, for example, waste disposal officials in Warren County, New Jersey pointed to the enactment of a state law mandating a 25 percent recycling rate as largely responsible for a local incinerator's declining revenues--estimated at $59,000 a week. The community was later forced to reimburse the builder and operator of the incinerator for their losses.[44]

C. Recycling

Summary

One of the most tangible benefits derived from recycling plastics is resource conservation. As one observer explains, "since most of the energy required to produce a plastic product goes into the production of feedstock materials, not the manufacturing process, waste plastics retain most of their original energy content. Thus, producing a plastic product from scrap plastic instead of virgin resin saves approximately 85 to 90 percent of the energy otherwise used." When the BTU energy in waste plastics is converted to heat through burning, some of the energy is recovered, but recycling conserves more energy. Landfilling, of course, squanders all of the potential energy.[45]

For this and other reasons recycling has been proposed by many as the solution to plastic-waste disposal. The plastics recycling business in the United States, however, is still in its infancy and where plastic packaging is being recycled, the types of plastic being recovered, primarily PET and HDPE, fall far short of their market potential.

Plastics makers were slow to embrace the idea of recycling plastics. However, in response to pressure from environmental groups and community leaders, improvements in the technology of processing waste plastic, and escalating costs for raw materials, more and more companies have committed themselves toward recycling postconsumer waste plastic.[46] Last year, for example, the Council for Solid Waste Solutions announced a plan by large companies in the plastics industry to recycle 25 percent of all plastic bottles and containers by 1995.[47] Other 1995 goals include increasing the number of plastics recycling programs to make them accessible to one-half of the population in the United States and an increase in the number of communities with curbside recycling programs to 4,000.[48]

As one observer explains, "The plastics industry is waking up to the fact that consumers are very frustrated with packaging that goes straight from the grocery bag to their trash can."[49] The trend toward recycling helps to defuse the criticism that nonrecyclable, nondegradable plastic products are straining efforts to manage solid-waste in this country.

In 1989, approximately 800 solid-waste bills involving plastics were being considered by state and local governments. Some were calling for severe restrictions or bans, others for mandatory recycling or degradability. Only a few years before, about 10 bills were being considered.[50] The plastics industry wants to prevent more bans or other

"In response to pressure from environmental groups and community leaders,... more and more companies have committed themselves toward recycling post-consumer waste plastic."

legislative restrictions which curb the use of plastic packaging in state and local economies. This is apparently the impetus behind plans by the National Polystyrene Recycling Company, a consortium of eight major PS resin producers, to establish a total of five PS recycling plants across the country. The industry has set a goal of recycling 25 percent of food service PS, [51] or roughly 5 percent of PS production in the United States by 1995.[52]

Scrap materials inside plastics factories have long been recycled. In 1988, for example, between 3.5 and 5 billion pounds of industrial plastic was recycled.[53] The advent of new cleaning and reprocessing technologies, however, has dramatically improved the quality of postconsumer recycled plastic to levels comparable with virgin plastic.[54] As a result, recycled plastic is no longer strictly confined to preconsumer waste or to materials where purity of resin was not a concern, such as building and construction materials.

Increases in the price of ethylene, a principal ingredient in virgin plastic, and rising demand for plastic resin has spurred many manufacturers to include recycled plastic in their products. As one industry representative noted, "It appears that you can collect plastic, sort it, reprocess it, and still be able to sell a pure high-density plastic at two-thirds to one-half the cost of virgin resin. If you're a user of virgin resin, you almost have to use [recycled plastic] because of the economic incentive."[55]

Despite these and other major efforts by manufacturers, however, plastics recycling, with the exception of PET bottles and containers, has not yet reached rates close to those now achieved for paper, glass or metals.

As Environmental Action explains, there are a number of obstacles to expanding plastics recycling including "the lack of economically feasible collection, separation, and transportation mechanisms; the small number of large-scale commercial recycling operations capable of handling a heterogeneous mix of contaminated postconsumer materials; and the lack of steady and demanding markets for recycled plastic products."[56] Because many processors require a "consistent, homogenous resin supply," plastic products made from different resins must be sorted from each other before they can be recycled. In the packaging waste stream, however, it is difficult to separate resins unless they can be identified by common knowledge, for example, if the person knows that milk jugs are made from HDPE, or by its code, if it has one.[57] Separation is further complicated by the increasing number of composite containers, usually composed of different non-plastic materials and two or three resins, in the waste stream. (Composite packaging is discussed in Part 2.) Although the plastics industry will be a key player in improving this situation, the public must also be educated in identifying and preparing their waste plastic for collection if recycling goals are to be met.

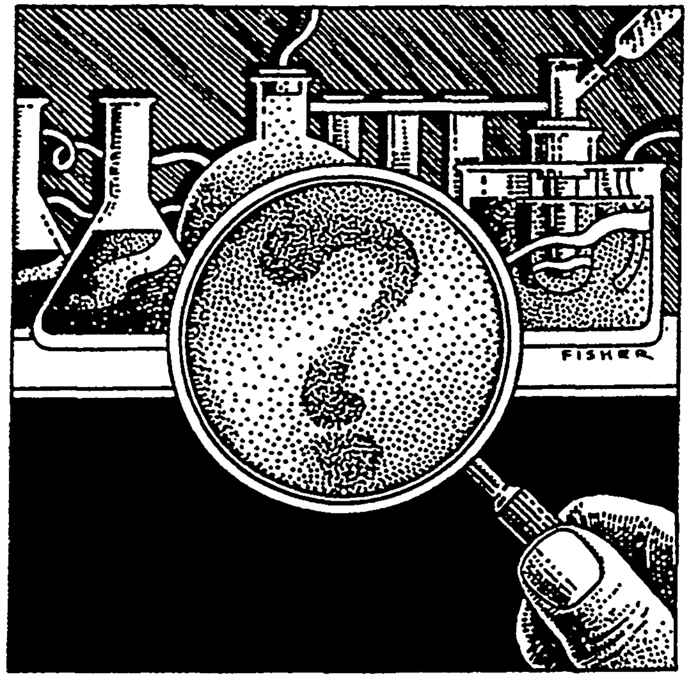
Because empty plastic packages occupy a large volume of space, collecting and transporting plastics greatly increases the costs of recycling waste plastic. Grinders and other equipment, perhaps financed in part by plastics manufacturers, could be used by communities to reduce their waste plastic into a denser form, thereby making it more cost-effective to transport.[58]

> *"The market potential for recycled PET exceeds 1.3 billion pounds a year, ten times the amount currently collected for recycling..."*

Most efforts in recycling waste plastic have been focused on PET and HDPE bottles. In fact, in regard to plastic packaging, "there is virtually no recycling of resins other than PET or HDPE."[59] Of all plastic resins, PET enjoys the highest recycling rate. The recycling of soft-drink bottles made from PET, for example, "soared from 8 million pounds in 1979 to 175 million pounds in 1989 and could reach 600 million pounds by the mid-1990s."[60] The main sources of recycled PET are states with returnable beverage-container laws, which make PET easier to recycle than other plastics.[61] In 1991, for example, 33 percent of PET soft-drink bottles were recycled.[62] In California, the number was closer to 60 percent. Absent such bottle-deposit legislation, however, the amount of PET collected and recycled would be drastically reduced. This suggests there is a "lack of effective collection mechanisms" for this widely used resin.[63]

While some PET processors feel that there are "abundant" end markets for recycled PET products, some smaller processors disagree and believe that end markets would need to be developed to accommodate an increase in PET recycling. Industry observers estimate "the market potential for recycled PET in the United States exceeds 1.3 billion pounds a year, ten times the amount currently collected for recycling, and almost twice the amount of PET used by the beverage-bottle industry." [64]

About four times more HDPE resin is produced than PET and in packaging HDPE resin is used more than twice as often.[65] Until communities incorporate HDPE, as well as PET, in their (mandated) recycling programs, HDPE collection will continue to depend on the efforts of organized community recycling programs for HDPE.[66] Absent a vital recycling infrastructure, however, HDPE will be unable to realize its enormous recycling and end market potential. Since the end products of reclaimed PET resin are mostly polyester fibers, many end uses include fiber fill products, such as garments, strapping bands, engineering plastics, textiles, and carpeting.[67] Recycled HDPE is used in a number of products including plastic lumber for boat piers, animal pens, fence posts, and garden furniture; base cups for soft-drink bottles; flowerpots; pipe and drainage tiles; toys; traffic barrier cones; trash cans; and packaging for nonfood products such as laundry detergent.[68]



© Mark S. Fisher

PET and HDPE cannot recycled back into the food or beverage containers from which they were originally derived. Some plastics tend to absorb small quantities of what they contain. If someone used a milk jug to store motor oil, for example, and "that jug were later recycled into a new milk jug, traces of the motor oil might conceivably leach back into the milk."[69] Since PET and HDPE resin cannot be sterilized at high enough temperatures without being destroyed, the FDA has not allowed recycled PET or HDPE to be used in applications where they come into contact with food.[70]

The fact that new bottles and containers cannot be produced from old ones have led some people to question the whole notion of recycling plastics. As one critic puts it, "This may be a metamorphosis, but it is not recycling. Or, in the unintentional oxymoron coined by the plastics industry, it's linear recycling."[71] Others pointing to the lack of an extensive infrastructure for collecting, sorting and recycling plastics caution, "If we let these people [in the plastics industry] use recycling as a means of saying that there is nothing wrong with plastic bottles, we're doing a great deal of harm to the environment."[72]

Ann Leonard, a campaigner for the Greenpeace Toxic Trade Project, alleges that plastics recycling is largely a "sham" by the waste management industry promoted in response to the deteriorating image of plastics among consumers. According to Leonard, rather than being collected, sorted and reprocessed in recycling facilities in the United States, most of our plastic waste is being shipped to Asia and other Third World destinations in order to "...avoid domestic regulations, avoid community opposition to waste handling facilities, pay their workers pennies a day, and maintain a ''green' image at home." Leonard estimates that in 1991 alone, over 200 million pounds of plastic waste were exported abroad from the United States, and only some of it was recycled. One Indonesian importer, for example, claims that he dumps up to 40 percent of the plastic waste he receives in a local landfill because it is "worthless." Leonard concludes that this "waste trade" has allowed industry to "seduce its consumers into the belief that plastic packaging can be environmentally-benign."[73]

Regulations and Proposed Bills

The first comprehensive recycling legislation (H.R. 500) introduced by Representative George Hochbrueckner (D-N.Y.) in Congress in 1988 addresses these issues. The bill, the Recyclable Materials Science and Technology Development Act, among other things, "attempts to encourage the plastics industry to consider recycling as a basic design goal, and calls for scientific research into development of plastics recycling methods and systems, including collection, sorting, reclamation, and end-use manufacturing."[74]

California legislators passed S. 235, introduced by Gary Hart (D-Santa Barbara) in 1991. S. 235 established recycling standards for rigid plastic containers. Beginning on January 1, 1995 all rigid plastic containers between eight ounces and five gallons sold or offered for sale in the state must meet one of the following criteria:

1) Be made from 25 percent postconsumer material.
2) Have a recycling rate of 25 percent if its primary material is not PET.
3) Have a recycling rate of 25 percent if its primary material is PET.
4) Be reusable or refillable.
4) Be a 10 percent source reduced container by weight or volume.

These requirements are waived if one of the two criteria listed below are satisfied:

1) Less than 60 percent of the single-family homes in the state beginning January 1, 1994 have curbside collection programs which include recycling of beverage containers.

2) At least 50 percent of the manufacturer's rigid plastic containers sold or offered for sale in the state in 1991 were made from 25 percent postconsumer material and the containers will otherwise comply with the requirements above on or before January 1, 1996.

Some states have mandated that their agencies procure products which contain postconsumer recycled plastic in order to encourage markets for them. California, for example, requires the Office of Procurement to purchase "recycled secondary and postconsumer plastic products" where the cost is "equal to or less than the virgin resin product." Bid awards are extended to those products which contain the highest percentage of secondary and postconsumer plastic.[75]

Successful recycling programs are built from many pieces, and while legislation certainly has an important role to play, changing the mindset of individuals is also important. As one observer commented, "People are not used to thinking of plastics as having an economic value or being recyclable."[76]

It is also important to remember that recycling is a means, not an end..."[It] is but one piece of a strategy--which also must include strong efforts to reduce waste at the source and directly reuse products--to build a society that consumes and discards a bare minimum of materials."[77]

III. Degradability

A. The Non-Solution to the Solid-Waste Crisis?

At a press-conference in 1989, six-leading environmental groups urged consumers not to purchase degradable plastic products insisting that they are "a feel good smokescreen that obscures the real goals of source reduction and recycling."[78] In June 1990, attorneys general from seven states filed individual suits against Mobil Corporation alleging that it made false and deceptive claims on its Hefty Degradable® plastic trash bags.

According to Consumer Reports, "the illustration on the [Hefty Degradable®] package, showing the sun filtering into a forest glen, reinforced the implied message: You could buy this plastic bag with a clear conscience because, in no time at all, it would return to the soil."[79] According to Roger Wynne, writing in the University of Michigan Journal of Law on environmental marketing claims, Mobil also printed the following claims on their Hefty Degradable® boxes to further promote their trash bags as environmentally benign:

> *"...before introducing its Hefty Degradable® trash bags, Mobil knew that the alleged environmental benefits of degradable plastic materials were a myth."*

"New Hefty Degradable Bags contain a special ingredient that promotes their breakdown after exposure to elements like sun, wind and rain."

"This ingredient promotes degradation without harming the environment."

"Once the elements have triggered the process, these bags will continue to breakdown [sic] into harmless particles even after they are buried in a landfill."[80] That same month, Mobil settled the lawsuit by paying $150,000 in fines and agreeing to stop making degradability claims; it did not admit or deny its guilt.[81] The irony regarding the action taken against Mobil is that before introducing its Hefty Degradable® trash bags, Mobil knew that the alleged environmental benefits of degradable plastic materials were a myth. In a pamphlet it had published, entitled "Plastics and the Environment," Mobil had "concluded that the solution to the solid waste management does not lie in degradable materials, but in a combination of source reduction, recycling, incineration, and landfilling." [82]

Wynne contends that Mobil's decision to promote its degradable bags, despite clear evidence that they would "be of little or no value to landfill problems," was largely "market driven" and was made for "its public relations value...as opposed to real solutions to the [landfill] problem."[83] The "smokescreen" was apparently effective. In a poll taken in by Abt Associates three months after the settlement, "eighteen percent of the respondents reported they'd switched to 'degradable' bags for environmental reasons."[84]

The controversy over degradability, however, actually arose before any lawsuit was filed against Mobil, and has not really been resolved since then. Degradability became an issue after many state and local initiatives mandated biodegradable six-pack ring holders in response to litter problems, including their effect on animals, especially marine species, which would starve when they ingested the plastic ring holders or would strangle after becoming entangled in them. The General Accounting Office reported that floating in every one square mile of ocean are 46,000 pieces of plastic.[85]

The mandates were intended to encourage a return to cardboard beverage-container holders, as opposed to ones made from plastic, since cardboard was advanced as being more degradable. However, because these laws did not specify the particular type of material to be used, such as cardboard, but rather focused on degradability, the plastics industry responded by introducing a photodegradable (plastic) six-pack ring holder. These claims of photodegradability, however, were never examined because six-pack ring holders comprised such a small part of the total waste-stream. Eventually, as people became increasingly concerned about the proliferation of plastic packaging, including the switch from paper to plastic (LDPE) grocery bags, and began relying on the promise of recycling as an alternative to more landfills and resource-recovery plants, "degradability...became part of the debate between consumers and the industry in the controversies over packaging in general."[86]

What are some of the environmental problems associated with degradable plastics?

Biodegradable plastics are formed by means of incorporating starch molecules into the inert plastic mix which chemically link or bond the chain of polymers together. When microorganisms, usually bacteria or fungi, break down the starch, these "links" are broken and the plastic polymers are released into the environment as plastic "dust". As one expert explains, however, because sanitary landfills are kept relatively dry "to minimize the amount of toxic leachate generated" and "biodegradation proceeds fastest in a moist, oxygen-rich environment, the degradation process is slow for everything.[87]

"The General Accounting Office reported that floating in every one square mile of ocean are 46,000 pieces of plastic."

To create photodegradable plastics, various percentages of chemical additives which break down in reaction to ultraviolet (UV) light are added to the polymers. UV light "energizes" the "links" holding the polymer chain together and breaks it into smaller fragments and eventually into plastic "dust."[88] However, once the photodegradable plastic is removed from natural sunlight, as it is when buried in a landfill, the degradation process is halted.

In both bio- and photodegradation, the end products are inert plastic "shards" or "dust." One EPA official, however, cautions that "there are no field data to support the claim that a starch-based plastic bag will be reduced to dust in four or five years."[89] Degradable plastics, however, pose other possible threats. There is some speculation that toxic substances in the plastics, for example, various heavy metal additives used to color the product, may be released into the ground and groundwater when they do break down. A Lincoln, Nebraska "composting study," for example, found that "the amount of cadmium leached from degradable plastic bags rendered the compost unusable."[90]

In addition to these concerns, degradable plastics may hamper efforts to reduce and recycle plastics. Some observers worry that consumers will conclude that their waste plastic will "degrade and simply disappear" and not "be inclined to recycle [plastic] in the first place."[91] Furthermore, those most vocal in their opposition to degradable plastics argue, "The smallest amount of degradable plastic could contaminate the recycle feedstock, with dire consequences."[92] Products derived from such mixed waste plastic may be vulnerable to bio- or photodegradation during their second useful life cycle. Others feel that degradables should be used only in cases where recycling proves to be impractical, and argue, "The issue is not to get the waste to degrade. It should be to get the product out of the landfill. The way to do it is recycling."[93]

Manufacturers of degradable plastics insist that these concerns are overstated. Some simply contend that the small percentage of degradable plastic typical mixed plastics recycling would contain "would have little impact on overall performance." A spokesperson for Plastigone Technologies (Plastigone), for example, points out that their product uses "degradability additives" which "require a certain minimum triggering concentration in the final plastic." Because the degradable plastic would be diluted in the mixed plastic feedstock, the "triggering mechanism" would be rendered ineffective. Other suppliers note that their products stop degrading when removed from sunlight and that "UV stabilizers" added to the recycle feedstock will stop degradation.[94] Beyond these concerns are the "unknown effects of those millions of [petroleum-based] particles of degraded plastic dust blowing around the earth and entering the groundwater" where they will persist "as long as sand on the beach."[95] At the present time no one really has a clear understanding regarding their impact.

If degradability is not a panacea to our solid-waste crisis, should degradable plastics be used in special applications?

As we have seen, degradable plastics are being used in six-pack ring holders to mitigate their deadly effect on animals, especially marine species. Whether these six-pack rings actually degrade in the marine environment, however, remains an open question. Preliminary evidence indicates that when these ring holders float on the surface at sea where they are exposed to UV light they eventually degrade. UV radiation is blocked, however, when ring holders become covered with algae or sink below the surface of the water. Researchers have similarly found that biodegradable plastics in marine applications have only limited benefit. New developments in "selectively soluble" plastics which "break down under controlled conditions, including exposure to water or aqueous bases," may prove more promising in mitigating the harsh effects of plastics in the marine environment.[96]

Other applications for degradable plastics have been in "biodegradable sutures," which can be absorbed by the body, and agricultural mulch film. A mulch film produced by Plastigone incorporates a "trigger" mechanism which allows plastic to 'degrade' on a timed basis ranging from three weeks to twelve or eighteen months; once the mechanism is "tripped" by exposure to UV light, the plastic begins an "irreversible degradation."[97]

In 1988, Plastigone studied the long-term effect repeated degradation of their black photodegradable film would have on particular agricultural crops. Of special concern was the build-up of nickel in the soil. Nickel is classified as a hazardous metal and is known to inhibit the growth of, or be poisonous to, plants. Plastigone "found little if any evidence of plants uptake of nickel from the plastic film" and using EPA rulings regarding the allowable levels of heavy metals, concluded that "Using Plastigone film for 50 years would only amount to about 0.8 lb/acre," well below the 7 lb/acre standard set by EPA.[98]

"Beyond these concerns are the 'unknown effects of those millions of particles of degraded plastic dust blowing around the earth and entering the groundwater.'"

As the debate regarding degradability continues, some researchers are studying the promise of "natural plastics," which they argue are biodegradable in the true biological sense of the word. *BioCycle* reported that in a few laboratories around the world, "bacteria-produced polyesters," or "natural plastics," are being examined.[99] Genetic engineering techniques are used to "'trick' *E. coli* bacteria into making a plastic of their own" which share properties of their petroleum-based counterparts."[100] According to some scientists, unlike petroleum-based plastic which does not truly biodegrade, but instead disintegrates into plastic "dust," these bacteria produced polyesters biodegrade into water and carbon dioxide. Notwithstanding this new development, claims of "biodegradability" or "photodegradability" will continue to be made by the plastics industry absent a "generally accepted, or legal, definition of these words."[101] Without such definitions, industry will continue to make degradability claims for their products.

IV. Conclusions

The growth of plastics in the packaging sector has been explosive. At the same time, the question of how to best manage the solid-waste stream has become the topic of lively debate. Most solid-waste planners, government officials, environmentalists and others involved with this issue concur with the EPA that the waste management hierarchy of landfilling, incineration, and recycling must be reversed if we are to "close the loop."

In the United States, packaging, being readily disposable, is a large component of the waste stream. As plastic displaces more and more conventional packaging materials--paper, glass and metals--it follows that plastic waste will invariably become a larger segment of the solid-waste stream. As a result, plastic packaging has been thrust into the spotlight where it has received mixed reviews.

It is unlikely that paper, glass and metals will be able to regain the market share they enjoyed previous to the rise of plastics. It is also apparent that petroleum-based plastics, like other packaging materials, have an economic value that should not be "squandered" in landfills and incinerators.

Recycling infrastructures, however, are generally not as well-secured for plastics as the paper, glass and metals they replace. Where plastics recycling does enjoy some limited success, however, it is largely confined to the recovery of PET and HDPE bottles and containers in the handful of states which have passed returnable beverage container laws.

Degradable plastic packaging has been condemned by some as a "smokescreen" that sabotages recycling efforts and hailed by others as the solution to litter problems and the solid-waste crisis. If anything, the controversy of degradability has been a clarion call to legislators and others that green marketing terms (discussed in Part 2) need to be clearly defined to protect the public from misleading claims and to give industry guidelines in advertising the environmental "goods" of their products. So far, only a few states have responded in drafting green marketing legislation.

It is clear that plastic packaging in the waste stream has diminished its recyclability, and therefore may further frustrate the present and future efforts of local and state authorities to meet their targets for waste reduction. Opportunities to reverse this trend, however, are also evident.

Many observers agree that plastics recycling would be boosted by the adoption of uniform recycling policies mandated by the federal government and a greater commitment by industry in developing recovery technologies, recycling infrastructures and end markets for reclaimed plastics. There also seems to be an increasing recognition on the part of government, industry, environmentalists and other interested parties of the pivotal role the consumer must play in drastically reducing the solid-waste stream in the United States. This is more fully discussed in Part 2.