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Plastics Overview

Plastics are man-made polymers. A polymer is a large molecule that is made from the repetition of a single base unit. Polymers come in many different shapes with many different properties. (Though it is not, you might consider a brick wall to be a polymer made from bricks. Not all polymers are plastics; for example, protein and DNA are both polymers.) Most plastics are derived from oil, coal, natural gas and, more rarely, cellulose. In the past 15 years, commercial technology has emerged to make plastics from sugars or starches. Table 1 summarizes the raw material sources for plastics.

Table I Sources of Common Plastics

Raw Materials	Examples of Types of Plastic
Oil, Coal & Natural Gas	most plastics (like PP, PET, HDPE, PVC, PC, etc)
Cellulose from plants	cellulose acetates
Sugars, starches	PLA (Natureworks); PHA (Metabolix)

Plastic production generally uses oil & natural gas that have been refined (in a process called cracking) and processed into chemicals (hydrocarbons) that are ready for the chemical process of polymerization. In the USA about 4% of oil and natural gas consumption is for the production of plastics. For years, some plastics have been made from the renewable resource cellulose, which comes from plants. Recently a few biodegradable plastics have entered the marketplace. These are typically produced by using bacteria to prepare sugars for polymerization. With current commercial technology most biodegradable plastics are made from sugar or starches. However, there are commercial technologies that use carbon dioxide and catalysts to produce biodegradable plastics.[1] Scientists are also working to develop plastics from algae or from processes that rely on nanotechnology.[2] It is likely that the next 100 years of plastics will show even greater innovation than the first 100 years.

Though plastics were known by scientists during the mid 1800s, the discovery of synthetic plastics really started during the 1920s with a plastic called Bakelite. During the 1930s, the now common plastics polystyrene (PS), polyvinyl chloride (PVC), and nylon entered widespread production. In the early 1940s, polyethylene terephthalate (PET) was discovered and ten years later, polypropylene (PP) was discovered. Polycarbonate (PC) was introduced to the market in the 1970s. The usefulness of plastics and ease of synthesis from natural gas and oil have made them ubiquitous in the developed world.

With the increase in types of plastics and their widespread use, in 1988 the Society of the Plastics Industry (SPI) introduced a voluntary resin identification coding system to help with identification of plastics in products. Table 2 summarizes this system.

Table I Identification Codes for Plastics

SPI Code	Family of Plastic	Typical Use
#1	polyethylene terephthalate (PET, PETE)	Soft drink and single-use water bottles
#2	high density polyethylene (HDPE)	Milk bottles
#3	polyvinyl chloride (V, PVC)	Pipes
#4	Low density polyethylene (LDPE)	Wrapping films, grocery bags
#5	Polypropylene (PP)	Yogurt cups, ketchup bottles
#6	polystyrene (PS)	Single-use coffee cups
#7	Other e.g., polycarbonate (PC)	Various

In 1995 many states started requiring these codes on certain products (like bottles and containers over a certain size). These codes attempt to identify the family of plastic to which the product belongs. Please note that #7 is regarded as a "catch-all" category – any plastic not fitting into the 1-6 families can be labeled as #7. PLA, polycarbonate, and ABS are included in the #7 category. The recycling codes are not an attempt to categorize which plastics are more or less benign or recyclable. For more information on the SPI codes, see http://www.plasticsindustry.org/outreach/recycling/2124.htm.

It is important to note that the common names of plastics denote a family of plastics. For example, polypropylene (PP) refers to a family of plastics that all have the same single base unit. In the PP family there are several different types of PP depending on the arrangement of the base unit in the polymer. Further complicating matters, some plastics can be combined with other plastics and/or additives to produce different plastics, yet the resulting plastic may still be referred to by its common name.

Summary

For the health of our consumers and the environment, we aim to minimize the impact caused by our products. As scientific understanding develops, we must be on the cutting edge of understanding the affects of our products. We pledge to act only if we are reasonably convinced our actions will minimize harm to humans and the environment. Specifically, we only use:

- recycled plastics that are formed from benign building blocks,
- chalk, talc and a soap to change the properties of our plastic,
- safe, FDA-approved colors, and
- "source-controlled" recycled materials to make our recycled plastic, food-contact products.

We use recycled plastics to save energy and to reduce emissions and the waste that goes into landfills. We are conducting our own life-cycle assessment in order to quantify the benefits of using our recycled #5 PP.

The Human Benefits of Our Recycled Plastic

A plastic is made from a base chemical, called a monomer, that is linked together to create a long chain that is called a polymer. Furthermore, most every plastic contains additional chemicals (called additives) to give them properties such as flame resistance, a certain color, or added flexibility or softness. It is possible, though very unlikely, for these monomers and additives to leach out of plastics. Leaching of chemicals from plastics depends on the specific type of plastic and the conditions of its use (e.g., high levels of heat and strong acids and bases, like coffee or bleach). Table 3 presents Recycline's ranking of common plastics. Not enough research has been conducted on biodegradable plastics for us to rank these plastics.

Table 2 Our Plastics Rankings for Human Health Impacts

Our Rating	Family of Plastic	SPI Code
Favorable	HDPE, LDPE, PP	#2, #4, #5
Less Favorable	PET	#1
Least Favorable	PVC, PS, PC	#3, #6, some #7 (PC is marked as an other, #7)

When we choose to work in a certain plastic, we choose ones with non-harmful, non-leaching monomers. We use #5 plastic (PP, polypropylene) because the single base unit (or monomer) of the plastic is a benign chemical and is not known to leach. Some plastics contain monomers that we think it is best to avoid:

- Polystyrene (#6, PS): The base monomer, styrene, has been implicated as a suspected carcinogen by the EPA, can form into a possible endocrine disrupter (see more below), and is suspected to leach.
- Polycarbonate (sometimes marked as #7, PC): The base monomer is often harmful bisphenol A (discussed more below).
- Polyvinyl chloride (#3, PVC): The base monomer, vinyl chloride, is a carcinogen and can produce dangerous dioxins (discussed more below).

We do not use additives except for talc, chalk, and soap. We add talc and chalk (calcium carbonate) to our recycled plastics to adjust their properties (e.g., to make our cutting boards harder). While talc (magnesium silicate) has been shown to have preliminary links to lung disease and several types of cancer, these effects are only evident at extremely exposure high levels, like those found in mining and milling activities where talc is present in large quantities as a dust particle.[3] The US Food and Drug Administration (FDA) lists talc as an acceptable food additive. Chalk is an extremely abundant mineral in the Earth's crust and has no known side effects. We use a type of soap, zinc stearate, to help our manufacturing process. This compound ensures that our plastic parts are released from our metal molding tools. (This is similar to greasing your baking pan before making a cake.) The FDA has approved zinc for a number of topical applications, including lip balms and sun protection lotion. Zinc is often combined with stearic acid to produce zinc stearate. Stearic acid is derived from animal and/or vegetable sources. Although long-term exposure to extremely high levels of zinc stearate can lead to lung disease, the US Occupational Safety and Health Administration (OSHA) reports that there have been no reports of lung disease due to zinc stearate in the U.S.[4]

The colors that we use to make our products are compliant with FDA standards. We also specially formulate our colors to be more environment friendly by avoiding the ingredient titanium dioxide because the mining of this mineral has a high environmental impact.

For our food contact products, we apply "source control" methods to the plastic products we recycle to ensure that they do not contain additives that may be harmful to human health. We are working with companies and universities to stay abreast of the latest scientific research on additives that may have possible effects on the endocrine system and, if needed, to eliminate these additives. To-date we have not had to eliminate any additives.

More about Additives

We believe that there is not enough scientific understanding of many of the additives commonly added to plastics. Furthermore, the complex scientific nature of the debate has led to confusion. Below is an outline of Recycline's position on these issues.

Some additives in plastics seem to be able to mimic the action of hormones (often estrogen) making these additives endocrine disruptors. These additives are dispersed within the bulk of the plastic and are generally not leachable or extractable to any significant extent. But understanding the risk from endocrine disrupters, especially of their reproductive, neuronal and/or immunological effects, is extremely complex and more research needs to be done. We pledge to be on the cutting edge of understanding these scientific developments as they pertain to plastics for the health of you, our consumers, and the Earth.

Endocrine Disrupters

Some additives in plastics are increasingly being shown to have interactions with the body's hormone system (a.k.a., the endocrine system). The issue is that there are a lot of small molecules that seem to be able to mimic the action of hormones (often estrogen) to some extent, making the molecules
endocrine disruptors. Essentially, these endocrine disrupter molecules "fit" into the same spaces that normal hormones do. (A good visual here would be two puzzle pieces.)

Scientists categorize the risk from endocrine disrupters as reproductive, neuronal and/or immunological. Understanding the risk from endocrine disrupters, especially of neuronal and/or immunological effects, is extremely complex and more research needs to be done. In particular, exposure, dosage and response levels are not well understood, especially as they relate to mixtures of different endocrine disrupters. For example, phytoestrogens are a class of naturally occurring chemicals (found in plants like soy beans, apples, carrots, etc.) that are known to affect the endocrine system. (Please note that phytoestrogens demonstrate that there are naturally occurring chemicals that are endocrine disrupters.) The concern is that these chemicals in conjunction with man-made endocrine disrupters may result in hormonal imbalances. For more information, please see http://www.sph.emory.edu/PEHSU/html/exposures/endocrine.htm

At Recycline, as we have followed the scientific research and debate closely, we think the precautionary principle should apply. Thus we do not introduce any possible endocrine disrupters into our plastics. Furthermore, our systems are designed to make all of our Preserve plastics from recycled products and packaging that have not had these chemicals introduced to them.

Some of the more commonly known additives to plastics that are possible or confirmed endocrine disrupters[5]:

- Phenols are a large class of chemicals that are being investigated for possible endocrine disruption. We think some specific phenols have had enough study to warrant their ban, such as nonylphenol, which is banned in Europe.
- Another specific phenol is bisphenol A (BPA), the building block of the most common type of polycarbonate and many types of epoxy resins; it is also an additive to PVC. Low doses of BPA can leach from polycarbonate, especially with heat or in the presence of strongly "basic" cleaners (like bleach).
- Phthalates are a class of chemicals that are typically added to a plastic to make it more flexible, as in plastic films and wraps. Phthalates are often added to polyvinyl chloride (PVC, #3) to make it more flexible.
- Styrene is the monomer of the plastic polystyrene, so it is not technically an additive. It can combine together to form short molecules called styrene oligomers. These chemicals are not well researched, but it is believed that they may be endocrine disrupters.

Other Additives Not Found in Our Plastics

Dioxin is commonly used to refer to a specific family of chemicals called polychlorinated dibenzodioxins (PCDDs). PCDDs are environmental pollutants that are carcinogenic and that accumulate in living systems. PCDDs can be created in large amounts during paper manufacturing that uses chlorine, and when plastics that contain chlorine are exposed to very high levels of heat – typically these high levels of heat are only found in the manufacturing or incineration process. We do not use plastics containing chlorine.

Antimony and many of its compounds are highly toxic but found in extremely small amounts throughout the environment. A compound of antimony (a suspected carcinogen called antimony trioxide) is a catalyst used in the production of PET bottles. Small levels of the catalyst are not recovered during PET production and can be found in PET bottles. Studies have shown that extremely small amounts (3% of tolerable daily intake) can leach from those bottles.[6] There seem to be little available alternative technologies to remove this use of antimony catalysts for PET production.

Proper use of plastics

The impacts on humans from plastics are often dependent on the manner in which these plastics are used. When exposed to heat most plastics begin to degrade. When this happens, additives and monomers from the plastics are more likely to leach out of the plastics, and/or even combine with other available chemicals. The amount of heat, type of plastic, duration of heating and other things contacting the plastic are the factors that impact this process. Most of the concern around heating plastics is related to the production of PCDDs; however there are concerns that heating any plastic in a microwave or oven can release volatile organic compounds. While there remains research to be done, we advise that you not heat any plastics in the microwave or oven.

Dishwashers represent a condition of a low-level heat for a long duration. The addition of strong cleaners in the dishwasher presents opportunities for leaching of additives and monomers from plastics. We recommend that you only put plastics marked as dishwasher safe in your dishwasher. All of our Preserve plastics are dishwasher safe.

Storing food in plastics requires that the plastics meet certain conditions set by the FDA. Plastic items specifically designed for single use should not be used to store food or water. Specifically, there are a small number of conflicting studies that show the possibility that a phthalate, DEHP, may leach into water from single use PET containers. We recommend that you not reuse your single-use PET container.

Since we use plastics that do not contain possibly harmful additives or that are made from possibly harmful monomers, we believe that exposing Preserve recycled plastics to high heat for brief amounts of time or low heat for longer periods is safe.

The Environmental Benefits of Our Recycled Plastic

At Recycline we make our products from recycled plastics to reduce our use of limited natural resources, to reduce the amount of waste entering landfills, and to decrease the amount of carbon dioxide and other sources of pollution in making our products. The US EPA has shown that using recycled plastics instead of virgin plastics (normally made from the non-renewable resources of natural gas and oil) decreases the amount of carbon dioxide entering the atmosphere (the leading, but not only, cause of global warming).

In brief, the environmental benefits of our recycled plastics are:

- decreased waste in our landfills,
- reduced use of non-renewable resources, like natural gas and oil,
- decreased energy use, and
- decreased emissions of carbon dioxide.

We are currently studying our specific recycling system with life-cycle assessment in order to quantify the specific benefits to the environment.

The Recycled Plastics in Our Products

We use different sources of recycled plastic depending on what product we are making:

- Tableware & Kitchen Products – we use source-controlled, post-industrial collection of food grade material. These are clear lids from food storage containers that you typically see as to-go containers in a restaurant.
- Personal Care Products – we use post-consumer and post-industrial collection of food packaging containers. These are the containers that are the packaging for yogurt, hummus, cottage cheese, sour cream, etc.

Preserve Recycled Plastics Process

Our recycling process collects a stream of recyclables (packaging or products), grinds these recyclables into flakes, and then extrudes these flakes into pellets. The extremely high temperatures and pressures of our extruding process remove any biological contamination. We test our recycled plastics for heavy metals to ensure they have not been contaminated during collection and re-processing. We use an aggressive leaching test that ensures that the level of heavy metals possibly leached from our plastics is below what the EPA allows in drinking water.

Our source-controlled collection process for Preserve food contact products ensures that we meet FDA standards that regulate the materials that come into contact with food. Also we have received the consent of the FDA to include recycled plastics in the handle of our toothbrush.

Post-Industrial (PI) & Post-Consumer (PC) refer, broadly, to two methods to collect recyclables.

- Post-Consumer Collection – Post-consumer collection refers to the collection of recyclables after they have had their intended use in the marketplace. We use post-consumer material from retailer collection programs (such as the Park Slope Food Coop in Brooklyn, NY) and manufacturer takeback programs (such as Stonyfield Farm). We are opening more retailer collection programs as #5 is often not collected in town collection programs.
- Post-Industrial Collection – Post-industrial collection refers to the collection of recyclables before they have had their intended use in the marketplace. We use post-industrial material from manufacturers that cannot grind & reuse the material at their site. This can be waste from the manufacturing process, material from businesses that change or discontinue their packaging or product, or from manufacturers that produce a product that can not include recycled plastic.

With municipalities and interested organizations, we are working to increase the amount of post-consumer collection we are doing. There are limits to this with FDA standards and lack of processes to separate #5 plastics in most curbside collection programs. For our food contact applications we only source plastics where we can be assured that the plastic meets FDA standards. This limits our collection programs. We are working with materials reprocessors to develop a process whereby we transform some "regular" plastics into food grade plastics. This project will significantly increase our ability to source post-consumer plastics.

Our collection of post-consumer plastics is aimed at developing an environment-friendly recycling infrastructure for #5 plastic. We are working with materials recovery facilities (MRFs) to source #5 plastic from their municipal collection programs. Our business can be the impetus for these MRFs to install equipment to efficiently, effectively sort #5 plastic. (Thus saving these materials from being grouped together into a low value mixed-plastics stream that is often sent abroad or incinerated.) For areas that have not implemented municipal collection of #5 plastic, we are working with retailers to develop community-based recycling initiatives for #5 plastic. We use life-cycle assessments to ensure that our transportation and processing of these materials is as low impact as possible.

Recycling our Products

Among other reasons, we use #5 PP in order to increase the demand for this recyclable material and to help develop its recycling infrastructure. #5 plastic is one of the most used plastics and is one of the most easily reprocessed, yet it is one of the least recycled. In many areas the recycling infrastructure does not collect #5 plastic. Thus we have developed a takeback program for our more disposable personal care products. For our kitchenware and tableware products, we have designed them to be durable, reusable products. We will take back any of our products for recycling, but we encourage our product users to recycle locally if facilities exist. Recycle our products with us as follows:

- Toothbrushes and tongue cleaners – send them back to us with our postage-paid label.
- Razor – send the razor handles back to us with our postage-paid label.
- Razor blades – in the future we hope to offer a recycling program for these products.
- Tableware – if you send these products back to us, we will recycle them. But we encourage to you reuse these durable products.
- Kitchenware – like our tableware we will recycle these products if you send them back to us. However these products are designed to last for many years.

Our takeback program is currently being developed further with input from a life-cycle assessment to determine its most efficient, practical design. We encourage consumers to send our products back to us in bulk and in reused packaging, in order to minimize the environmental impact of this recycling step.

Steps to Improve

At Recycline we believe that providing safe, environment-friendly products requires us to be dedicated to continuous improvement and transparent in our efforts to do so. While we have many initiatives to this end we would like to highlight a few:

- Preserve Gimme 5 Program – this program is aimed at increasing awareness of the feasibility of recycling #5 plastic (polypropylene, PP)
- Continuous monitoring and proactive steps to ensure our plastics are free of endocrine disrupters.
- Life Cycle Assessment of our recycling system – this project is aimed at quantifying and comparing our recycled #5 plastics recycling system to virgin #5 plastics.

Founded in 1996 and located in Waltham, Massachusetts, Recycline designs, manufactures, and markets Preserve® products, a broad offering of style and performance-driven household products made from recycled and recyclable materials.

[1] www.novomer.com

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