Study on the Effects of Degradable Plastic on Recycled Feedstocks

North Carolina Department of Environment and Natural Resources

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Executive Summary

Plastics are used to make a wide variety of consumer and durable products. Increasingly, many manufacturers are using recycled plastic resin to make these products just as increasing amounts of plastics are also being collected for recycling at the end of their useful life.

Plastics that are designed to break down under specific conditions are also being introduced into a range of products. These "degradable" plastics come in a few basic forms and are produced and marketed with the intent of reducing various environmental impacts from plastic disposal and littering.

Questions have been raised about the effects of degradable plastics on the recycling of traditional plastics, and in particular whether degradable plastics and degradable versions of regularly recycled plastics have a negative effect on the use of recycled plastic as a feedstock for manufactured products. As a state with a particularly heavy presence of recycled plastics processors (or "reclaimers") and manufacturers who use large amounts of recycled plastic, North Carolina has a direct stake in this issue. Plastics recycling in North Carolina is supported by a plastic bottle disposal ban that is intended to increase the supply of material to these reclaimers and manufacturers, who have made large-scale investments in the state and employ hundreds of North Carolinians.

North Carolina reclaimers, plastics product manufacturers, and key groups representing plastics recyclers and the general recycling industry are concerned that degradable plastics pose a serious problem to the plastics recycling system and to the integrity of recycled plastic products, especially those that are designed for durable uses. The potential negative effect of degradable plastics, which cannot be distinguished from traditional plastics by average consumers without specific labeling or other information, and usually cannot be machine-sorted automatically by reclaimers, could harm North Carolina's plastics recycling industry and hamper efforts to increase plastics recycling. There are also general questions about the actual advantages of degradability in plastics.

This study concludes that North Carolina should take steps to prevent potential damaging impacts of degradable plastics on the state's plastics recycling industry, including labeling requirements and other measures that help differentiate degradable plastics from traditional materials in the recycling process.

Introduction

This study is hereby submitted to the Environmental Review Commission to fulfill Session Law 2012-200, which instructs the Department of Environment and Natural Resource to “study and evaluate degradable plastics products and their potential to contaminate recycled plastic feedstocks” and to “develop and recommend standards for degradable plastic products, including labeling requirements and education and outreach programs, to prevent contamination of recycled plastic feedstocks.”

The use and marketing of degradable plastics has expanded in recent years and has resulted in wider distribution of degradable plastics products to consumers. Consumers who receive these products must decide what to do with them after use, and specifically whether to recycle or dispose of them. The ability of consumers to recycle degradable plastics rests on the acceptability of those materials in the recycling marketplace. Ultimately that acceptability depends on whether or not the recycled plastics can be used as a feedstock for making new products. In addition, manufacturers who use recycled plastic feedstocks to make new products need assurance that those feedstocks will not harm the integrity or quality of those products. Thus, there is a direct tie between consumer plastic use and plastics product manufacturing in North Carolina that increasingly relies on recycled materials.

North Carolina is home to a robust and integrated plastics recycling industry that includes “reclaimers” who clean and prepare plastics for manufacturing and manufacturers who use recycled plastic feedstocks. The industry receives a significant amount of its plastics from local government curbside and drop-off recycling programs across the state, but also from other sources (for example, recycling programs in commercial facilities, such as office buildings and restaurants, and schools and universities).

Over the last ten years or more, the supply of plastic from recycling collection programs has consistently failed to keep up with demand, leading to underutilization of capital investments in reclamation capacity and shortfalls in meeting the feedstock needs of manufacturers. North Carolina responded to this supply issue with the passage of a plastic bottle disposal ban in 2005, which was fully implemented in 2009. Although the ban is essentially unenforced, it has helped double plastic bottle recycling rates in the past four years, providing valuable additional feedstock to reclaimers and their manufacturing clients, and helping reduce North Carolina’s dependence on landfill disposal.

This study provides a general overview of the use and marketing of degradable plastics and focuses specific attention on the effect of these materials on the recycling of plastic bottles, in part because of the size and importance of the plastic bottle recycling industry in the state and in part because degradable plastics use in bottles is the most problematic aspect of this issue. With more than three million plastic bottles recycled each day across the state, the use of degradable plastics in bottles is a primary way that potentially negative aspects of degradability could be introduced into the recycling system.

This study also touches on other issues related to degradability in plastics, such as how it affects litter, what implications it has for landfills, and what existing standards might apply to degradable plastics that could be used in North Carolina. Finally, the study makes recommendations on standards, labeling requirements, and education and outreach that can prevent harm to recycled plastic feedstock use in manufacturing to the greatest extent possible. In its analysis and in its recommendations, the study paid close attention to three overriding factors:

- The importance of clarity for consumers in deciding what to do with a discarded plastic bottle – the everyday act of consumer participation in recycling is what starts a material on its path toward being an industrial feedstock.
- The importance of how degradable plastics behave in the sorting and plastic reclamation process – if degradable plastics are not compatible or may possibly harm use of recycled plastics as an industrial feedstock, then there must be assurances that the reclamation process can remove those degradable plastics from the feedstock stream.
- The importance of the attributes of recycled plastic feedstocks to the quality and integrity of the resulting products – recycled plastics are used to make many products designed for long-term use (*e.g.*, carpet) or where strength is critical (*e.g.*, plastic strapping) so it is important that degradable plastics do not compromise those uses.

Review of Various Types of Plastics

Plastics are used in huge array of products that can be differentiated into a few broad categories:

- *Consumer plastics* are used on a daily basis, mostly for containing consumable products, and they include:
  - Plastic bottles – For the delivery of liquids such as water, milk, and juice, but also detergents, cleaning products, personal care products, etc. The plastic bottle market is dominated by two resins, PET (#1) and HDPE (#2), which account for more than 96 percent of all bottle materials. North Carolina community recycling programs collected more than 22,000 tons of PET and 12,000 tons of HDPE in Fiscal Year 2010-11, material that flowed through reclamation facilities to a variety of industrial uses. An estimated 135,000 tons of plastic bottles are generated in North Carolina each year. Recycled PET and HDPE processed in North Carolina are used in part to make new bottles.

  - Other plastic containers – Plastics are also used to contain a wide variety of other products such as yogurt, fruits, and baked goods, but are also used ubiquitously in food service applications, as well as for prepared and convenience foods. Polypropylene (#5), polystyrene (#6), and PET are resins commonly used in these applications, but there are also composites that use multiple plastics or combinations of metal and plastic, or paper and plastic. Some of these containers are starting to be accepted into the recycling stream as many programs now collect "all plastics containers" or "plastics #1 through #7" and as markets begin to accept these materials. Some of these containers include recycled content (such as black PET trays in convenience foods) and, when recycled, can be applied in a range of products.

- Plastic bags and film – In addition to shopping bags distributed by most retailers, plastic film, mostly in the form of LDPE/LLDPE (#4), HDPE and some composites, is also used in packaging of food stuffs ranging from cheese to bread and meat. Recycling opportunities for shopping bags and some additional films used by consumers (such as bread bags and newspaper wrapping) are available at most major retailers. The recycled films then are primarily used in durable products such as plastic lumber.

- *Durable goods plastics* are found in many different kinds of applications, including:
  - Electronics – Plastics are used in the housing and in parts of every electronic product from cell phones to computers, televisions, printers/copiers, and audio devices. As more electronics are collected and processed for recycling in North Carolina, many of these plastics are also being captured and remarketed as feedstocks in an array of industrial applications, including back into electronics. Common plastics used in electronics include ABS, polypropylene, and high impact polystyrene. Other products in this category would also include plastic media such as CDs and DVDs and their cases.
  - Appliances – Washers, dryers, refrigerators, fans, space heaters and many other appliances use plastics as structural and functional components, mostly in the form of the same kinds of resins used in electronics. Because many of these types of products are ultimately recycled at traditional scrap yards at end-of-life, there is somewhat less likelihood that the plastics will be captured, often ending up instead as residues from shredding processes designed to extract steel, copper, aluminum, and other metals.
  - Home/construction products – Carpet is an example of a plastics product that is both becoming more recyclable and, in the form of polyester, makes heavy use of recycled plastic feedstock. Different forms of nylon are commonly used in carpet, and plastics also are used in many other construction-related products, from decking to siding, windows, doors, and other applications. PVC (#3) is a principle feedstock in this category, but HDPE and LDPE are also prevalent, often as a recycled feedstock, in decking and other plastic lumber. Black plastic pipe is an example of a construction product that is a heavy user of recycled resin, mostly HDPE.
  - Vehicles – In part to achieve lighter weight vehicles for fuel economy, plastics are a growing portion of automobiles, from housings and shrouds to seats, dashboards, liners, bumpers, and auto body parts. PET, HDPE, nylon, ABS, and many specialty plastics are used in vehicles. Almost all major car manufacturers have made commitments to increase the recycled content of the plastics they use, helping drive a huge demand for more recycled feedstocks. Lead acid battery casings also represent a long-standing use of recycled polypropylene and are returned for use as industrial feedstock through a highly developed battery recycling infrastructure. Scrap yards return a large amount of plastic products back to use through parts stripping and reuse, but a fairly large portion

of automotive plastics are lost to "auto shredder residue" from vehicle shredding, similar to what happens with many appliance plastics.

- *Other plastics* – Many other products are manufactured with plastics, including applications such as:
  - Agriculture - Examples in this sector include pots and containers, many of which use recycled HDPE as a feedstock, but also films used as greenhouse plastics and row covers.
  - Shipping - Plastic is used in industrial and commercial shipping in the form of totes, barrels, bins, plastic pallets and other products. HDPE and polypropylene are leading resins in these applications. There are recycling options for many of these plastics and many also in turn contain at least some amount of recycled content. The grocery industry uses an array of plastic containers and trays, many of which are recyclable and which have been the subject of an ongoing recyclability project by the Association of Post-consumer Plastics Recyclers (APR). Plastic strapping is a particularly noteworthy kind of shipping plastic, used to contain loads of palletized bricks and lumber as well as other industrial goods. Plastic strapping stands out because it is a product frequently made from PET plastic bottle material, which places importance on the strength qualities of the recycled feedstock.
  - Garbage and recycling carts – North Carolina is home to three of the major U.S. manufacturers of rolling carts used in waste and recycling collection – Toter, Schaeffer, and Otto. All three manufacturers use at least some recycled material in their carts, which can have an effective use life of up to 15 years. North Carolina is also home to Rolltech, a manufacturer of the rubber/plastic composite wheels that can be used on carts and that also contain post-consumer recycled HDPE.
  - Textiles – Many textile fabrics are made from plastic, Polyester is a prominent example. North Carolina is home to a number of polyester fiber manufacturers and end-users of the fiber for textiles and related products. Polyester is easily and commonly made from PET plastic bottle material and a number of manufacturers and their suppliers in North Carolina and in the Southeast rely on supplies of "RPET" or recycled PET bottles. The fibers produced end up in a range of applications including carpet and apparel. In many cases, manufacturing recycled-content polyester has become a core business strategy of textile and fiber companies.

It is practically impossible within the scope of this study to describe in detail the many uses of plastics in products. However, regardless of those uses, two strong trends should be noted: 1) more discarded plastics are being returned to the economy through recycling, and 2) more manufacturers are relying on recycled plastic feedstocks to make an increasing spectrum of plastic products. As a substitute for virgin plastic, recycled plastic must meet the same kinds of specifications that virgin resin does to ensure the quality and integrity of manufactured goods. This is the central issue in the rising debate over the use of degradable plastics.

Overview of Degradable Plastics

Activity has accelerated in recent years to develop new types of degradable plastics and to use them in a variety of applications, including plastic bottles and other containers, films and plastic bags, and foodservice products.[1] Degradable plastics are ostensibly designed and intended to break down in landfills or possibly in the open environment, especially as a component of litter. In almost all respects, degradable plastics products are indistinguishable from non-degradable plastics to the average consumer, except through labeling that would explicitly and clearly make the distinction.

There are two basic kinds of degradable plastics:

- Traditional plastics with additives that promote or facilitate the breaking down of products – for example, a PET bottle with additives that break apart the PET into smaller pieces over time and under certain conditions.
- Plastics that are made from singular resins that break down completely over time – for example, a bio or starch-based plastic fork that will wholly decompose under certain conditions.[2]

Degradable Additives

Degradable additives in the first category may be combined with traditional resins such as PET, HDPE, LDPE, polypropylene, and polystyrene. The additives make up a small percentage of the overall resulting plastic product, usually less than two percent. Degradable plastics in this first category can further be subdivided into two types, as described below.

The first type of additive-based degradable plastics relies on the activity of microbes to essentially consume the degradable additive and break down the plastic into small particles. These microbes are soil-based, so for full and relatively quick degradation, the plastics need to be in an environment that ensures vigorous microbe contact. These microbes may be present in landfills but may also be present in other circumstances where degradable plastics come into contact with soil. The Plastics Environmental Council is an industry association that represents companies who make additives and plastics designed for degradation in landfills. The council stresses that the degradation of products made with their

[1] "Degradable" plastics, for the purpose of this study, do not include "compostable" plastics specifically designed to decompose in a controlled composting operation. Compostable plastics are also becoming more available, especially in conjunction with efforts to divert food waste from disposal, and they are subject to a regimen of standards, as well as ongoing interaction between manufacturers and the composting community to address various technical issues.

[2] Coca Cola has developed a "PLANT" bottle that is bio-based, using plant material to create the chemical ethylene, which then becomes a component of the resin PET (polyethylene terephthalate). PLANT bottles are not designed or intended to be "degradable." The plant-based ethylene is the same chemical that is produced from the processing of natural gas or petroleum and so it behaves in all ways similar in the recycling process. A number of other consumer product companies are considering following Coca Cola's lead in using plant-based ethylene plastic in bottles and other containers.

additives does not take place outside a landfill environment – hence those products would not degrade while still in use. Some of the council member's websites also note that degradation can take place in other soil contact scenarios, including litter, and, generally speaking, in the presence of appropriate micro-organisms.

The other type of additive-based degradable plastic relies on exposure to sunlight and/or air and water to initiate a process in which the bonds holding together plastic polymers are induced to break. The resulting, progressively smaller pieces of remaining traditional plastic then theoretically break down faster than a whole plastic product normally would. A leading example of this kind of material is "oxo-degradable" plastic. Because oxo-degradables need exposure to moisture, light, and air, they will not decompose actively underground in landfills, so they are often offered principally as a way to reduce plastic litter. However, it is unclear how long the actual degradation process takes. Oxo-degradable materials are also particularly incompatible with traditional plastic recycling processes as well as with products made from recycled plastic.

Bio-based Plastics

Singular resin bio-based plastics, the second category of degradable plastics, are intended to degrade uniformly under certain conditions. An example is polylactic acid, or PLA, produced most prominently in the U.S. from corn-based feedstocks by NatureWorks, jointly owned by Cargill and PTT Global Chemical. To date PLA has been used in applications such as foodservice packaging and bottles, which has raised concern among plastic bottle reclaimers and recycled bottle plastic feedstock users. PLA has also been used in some textile applications, films, and in medical plastics. The resin can technically be recycled if sorted separately from other plastic bottles but its relatively low market penetration has made it difficult to be *practically* recycled – *i.e*., it is not present in sufficient, concentrated enough quantities to be cost effectively collected, processed, and marketed. PLA is also compostable under the right conditions. If acceptable to commercial composters or similar destinations, PLA may be compatible with collection of food wastes from sources such as cafeterias and restaurants.

As a general matter of practicality, all degradable plastics need to fulfill their original product purpose – for example, if used in food packaging, the plastics have to protect the food and keep it safe up to the point of consumption and discard. Degradable plastic producers therefore need to ensure that the degradable aspects of their material do not activate prematurely and/or do so only under specific conditions. The need to strike a balance between original use and degradation after discard leads to two central questions: when does degradability start and how long does it take?

Manufacturers of degradable plastics and degradable additives provide varying information on these questions, in part because the conditions that foster degradation are also highly variable. Natureworks notes that its PLA material does not break down any faster in a landfill environment than any other kind of plastic. The Plastics Environmental Council notes that, regardless of the moisture available in any given landfill, degradable additive plastics should decompose at rates similar to other kinds of degradable materials. The council states that "fast biodegradation makes no sense from an environmental standpoint." In relation to optimizing the capture of landfill methane, degradation would ideally occur at a "desirably modest magnitude." According to one council member, FP International, its biodegradable products "will biodegrade in 1 to 5 years or more, depending on conditions, when in the presence of microorganisms. There is no precise time frame for biodegradation, and if microbial activity is limited, then degradation could take many years." This statement highlights both the confidence of degradability in landfills, but also its unpredictability. In general, the timeframe of landfill degradation is subject to a number of factors that differ within a landfill environment, including where the landfill is located geographically, how it is designed, how it is managed, and what the mix of other disposed materials may be.

The American Society for Testing and Materials (ASTM) is an organization that develops standards and procedures on a wide range of technical issues. ASTM has addressed degradable plastics through a test method known as ASTM D5526-12, specifically focused on degradation in "accelerated landfill conditions." The ASTM standard does not state how long it takes for degradable plastic to decompose in a landfill per se, but instead provides a methodology for making that determination. Dissatisfaction with the ASTM methodology has led the Plastic Environmental Council to work recently on identifying an alternative testing methodology that may more accurately simulate a working landfill environment. There are additional ASTM standards that also provide guidance on testing the degradability or compostability of plastics in certain kinds of conditions or operations – *e.g.*, ASTM D6868, which addresses film-based products in a composting environment, and ASTM D5511-11, which addresses degradability under "high solids anaerobic digestion conditions."

The U.S. Federal Trade Commission has also addressed the issue of degradability through its work in helping consumers understand product claims and in helping to ensure those claims are accurate and reliable. In its recently revised Green Guide, the FTC "advise[s] marketers not to make an unqualified degradable claim for a solid waste product unless they can prove that the entire product or package will completely break down and return to nature within one year after customary disposal." However, the FTC does allow for the possibility of "qualified" claims – *i.e.*, that manufacturers or vendors of degradable plastic products could communicate their own substantiated characterization of degradability and not be out of step with the FTC guidelines. The FTC states that "[d]egradable claims should be qualified clearly and prominently to the extent necessary to avoid deception about: (1) the product's or package's ability to degrade in the environment where it is customarily disposed; and (2) the rate and extent of degradation."

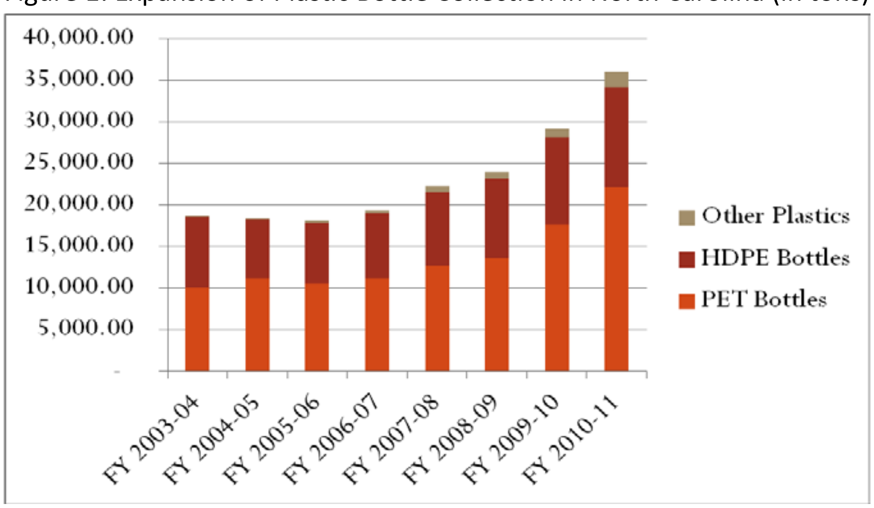
Although the Plastics Environmental Council applauds this allowance under the Green Guide, it is actively trying to get the FTC to modify its guidelines, specifically to recognize that degradable plastic should be viewed in comparison to other commonly disposed wastes that degrade more slowly than a year in a landfill (*e.g.,* paper or food waste). Research by Dr. Morton Barlaz, an expert on landfill operation at North Carolina State University, on degradable plastics in landfills also suggests that excessively quick degradation may lead to larger uncontrolled releases of methane because control systems are typically not in place immediately after disposal on the active landfill area. In effect, that also means that the landfill space-saving benefits of degradation are also limited (see more discussion on this point below). However, until the FTC revises its Green Guides or unless degradable plastics companies undertake qualified determinations, the one-year standard applies to degradable products.

Plastic Recycling in North Carolina

The gradually increasing presence of degradable plastics in consumer products is occurring at the same time as two other important trends: 1) recycling rates are rising for key consumer plastics, and 2) communities are expanding the mix of plastic collected in their recycling programs. For North Carolina's plastic reclamation and end use industry, degradable plastics are a cause of concern, and particularly when degradables are used in bottles and other containers that are being increasingly captured in collection programs.

It is therefore especially important to examine the potential effects of degradables in the recycling of two resins widely used in bottle applications: PET (#1) and HDPE (#2). These resins are of paramount importance as feedstocks in North Carolina's plastics recycling industry. North Carolina is home to some of the nation's most important processors and users of plastic bottle resins; as a region, the southeastern U.S. is also particularly rich in reclamation and manufacturing capacity for plastic bottles. North Carolina has effectively made a statutory commitment to increase bottle supply of material to this industry through its plastic bottle disposal ban in G.S. 130A-309.10(f)(11). As displayed in the figure below, North Carolina has had success in increasing plastic bottle recycling since the ban's inception, with help from resources available through the state's disposal tax that provides funding for recycling program and industry expansion.

Figure 1: Expansion of Plastic Bottle Collection in North Carolina (in tons)



Recycled bottle plastic is an important feedstock for a wide array of products, many of which are intended for durable uses. Examples include:

- Textiles and clothing – With the ability to easily convert PET bottle plastic into polyester fiber, it is feasible to use bottle plastic in a range of textiles, including clothing applications such as outerwear, pants, and shirts. These applications are obviously intended for long term use, underscoring the need for durability and quality in the recycled feedstock materials.
- Carpet – Similar to textiles, polyester carpet is another common fiber application of bottle-based materials. The carpet industry was one of the pioneers in using recycled PET. A few of the leading manufacturers of polyester carpet, such as Mohawk and Shaw, are still some of the largest investors in reclamation capacity. Durability is arguably an even more important quality in carpet than in clothing textiles.
- Geosynthetic textiles – Durability is also a major factor recycled-content fabrics that are used in highway, railroad bed, and other civil engineering constructions. These products are buried in soil and expected to last decades. Failure, such as due to unexpected biodegradation, would mean the engineering design may not perform as planned with negative consequences of loss and perhaps personal injury. Recycled PET and polypropylene are two resins used for geo-textiles.
- New bottles – Use of recycled PET and HDPE to make new bottles, which directly closes the recycling loop, is increasing. Large-scale investments have been made to process and clean bottle plastic for new bottles, often at the behest of prominent consumer product companies such as Coca Cola, Pepsi, and Proctor & Gamble. In some cases, bottle-to-bottle recycling entails a sophisticated process to ensure safe food-grade applications that require U.S. Food and Drug Administration approval. Because of the high-pressure filling of bottles and exacting specifications, recycled bottle feedstock for new bottles must have high and predictable quality.
- Automotive parts – As many automotive manufacturers work to increase the recycled content of their vehicles, bottle-based reclaimed plastic is increasingly finding its way into seat fabrics, ceiling liners, and floor mats.
- Building and gardening products – The common black flower pot is typically made with recycled HDPE bottles. Recycled HDPE is also used in more demanding applications such as black drainage pipe used in construction and civil engineering, including highway construction. Plastic lumber, made of recycled polyethylene films and bottles, is intended for long-lived uses that include contact in microbially-rich soils in which wood will rot. Recycled HDPE can also be molded into large vessels that would be buried, such as septic tanks. Durability is clearly important in these products. Degradable plastic that begins to break down in the presence of soil may pose a significant risk to these kinds of recycled-content products.
- Industrial strapping – Many heavy and bulky building products, such as lumber and bricks, are shipped wrapped in plastic strapping made from PET plastic bottles. Palletized industrial materials are also often contained by PET strapping. Strength of the material is extremely important in such applications and there is little room for risk of premature degradation leading to product failure (possibly initiated, for example, by exposure to soils during storage).

There are a host of other applications for bottle-based plastics and the market demand for recycled resins is expanding. As stated previously, the integrity of recycled plastic feedstocks – encompassing such features as consistency, strength, purity, and durability –- is critical to the successful marketing and use of recycled bottle material.

North Carolina has a heavy presence of reclaimers and manufacturers who use bottle-based material. North Carolina reclaimers also rely on nearby markets in other states, as do their principle suppliers, material recovery facilities (MRFs), which receive most of the curbside and drop-off collected recyclable materials in the state. The following list is a representative sampling of companies in North Carolina who have a stake in the recycling of PET and HDPE bottles, either as reclaimers or as manufacturers that rely at least in part on the recycled material as industrial feedstock:

- Clear Path Recycling – A joint venture between Shaw Industries, the world's largest carpet maker, and DAK, a leading manufacturer of PET resin, Clear Path operates a PET bottle reclamation plant in Fayetteville that opened in 2010 to process PET bottles into clean flake for carpet and textile applications. The plant, which employs approximately 125 people, is one of the largest of its kind in the U.S. It receives and processes around 160 million pounds of PET bottles annually.
- Envision Plastics – At its plant in Reidsville, Envision processes more than 90 million pounds of HDPE bottles into custom color pellets for use in bottles and other products such as bags, nursery containers, and piping. Envision was one of the first HDPE recyclers in the U.S. to receive FDA approval for food grade uses of its recycled plastic. The facility employs 70 people.
- Plastics Revolutions – Also in Reidsville, Plastics Revolution processes more than 80 million pounds of plastic each year, including HDPE bottles for feedstock use in pots, piping, drums, cable jacketing and other manufactured products. Plastics Revolutions has approximately 90 employees and also recycles a variety of other post-industrial resins ranging from polypropylene to LDPE, polystyrene and PET regrind.
- Unifi – In 2010, Unifi invested $8 million and added 25 new jobs in its Yadkinville facility to convert bottle-based PET resins into a branded polyester textile fabric called Repreve. In 2012, Unifi was on track to recycle the equivalent of 400 million PET bottles into such products as Patagonia and Northface jackets, Haggar slacks, and the seat fabric in the Ford Fusion hybrid.
- Sonoco – With three large MRFs and additional source-separated recycling centers, Sonoco is a major processor of collected recyclable commodities in North Carolina. Sonoco markets more than 30 million pounds of bottle plastics from its North Carolina processing facilities each year. As one of the nation's largest packaging manufacturers, Sonoco also relies on the flow of bottle-based resins to help make a range of products, including food-grade black PET thermoform trays used in convenience foods and manufactured in Waynesville, N.C.

- Waste Management/Recycle America – At its plant in Raleigh, Waste Management/Recycle America turns more than 100 million pounds of mixed plastics bottles into resin-specific flake material that is used in the making of carpet, agricultural and construction products.
- Blue Ridge Plastics – The Blue Ridge Plastics facility in Rockingham County processes more than 30 million pounds of plastic bottles and other types of post-commercial and post-industrial plastics for applications ranging from black pipe to plastic lumber and other rotational and injection molded products.
- Rolltech – A manufacturer of molded wheels for use in carts, furniture, and other related applications in Hickory, N.C., Rolltech uses recycled bottle HDPE and recycled rubber from tires in its process.
- Freudenburg – At its Durham facility, Freudenburg extrudes and bonds polyester material to make non-woven textiles for such applications as landscape cloth and automotive and commercial carpet backing. Freudenburg is an international company with many locations making a wide-variety of polymer products, including “Eco Nonwovens” produced from natural, regenerated and recycled fibers. Many of the company‘s applications are durable in nature and some are intended to have soil contact.
- Modern Densifying – Located in Shelby, N.C., and linked to Eastern Plastics, which buys and sells material for the company, Modern Densifying converts pre-consumer and some post-consumer PET and other polyester scrap into pelletized feedstocks, which it markets to a range of industrial users. Modern Densifying specializes in accepting a wide spectrum of fiber, fabrics, films and other material, including postconsumer PET, that may be too wet or too fine or was otherwise rejected from other processes.
- Fiberon – Fiberon makes composite decking material made in part from recycled HDPE bottle material at its plant in New London. The company’s 390,000–square-foot facility, which employs 200 people, combines recycled plastic with wood flour to make branded products sold in major home improvement stores.
- Engineered Recycling Company – Engineered Recycling operates a facility in Charlotte that converts HDPE bottle plastic into pellets for blow-molding and injection molding applications. Common product uses for the company’s recycled pellets include a number of durable goods, some of which have contact with soil, such as septic tanks, corrugated drainage pipe, dock floats, nursery containers, dumpster covers, undercarriage of automobiles, mats, and plastic drums.
- Colbond – With a plant in Enka, N.C., Colbond is a manufacturer of non-woven fabrics used in such applications as geosynthetics, automotive products, flooring, athletic fields, and building and roofing products. The company uses a variety of resins, including some post-consumer based PET.

- Peninsula Packaging – A national company with facilities in California, Washington, and Florida, Peninsula Packaging also operates a plant in Wilson, N.C. making PET thermoform packaging for produce, bakery goods, and other FDA food-grade container applications. The company touts its central focus on using PET bottle material to make its products.
- Crumpler Plastic Pipe, Inc. – At its facility in Roseboro, N.C., Crumpler Plastic Pipe makes a variety of products using up to 100 percent recycled HDPE content. Product applications include road culverts, parking lot detention-retention drains, landfill drains, industrial wastewater systems, golf course landscape drains, sewer composting and septic sewers. The company operates the largest corrugated plastic pipe manufacturing plant under one roof on the east coast.
- Dubose, Inc., – Dubose is a manufacturer of PET-based plastic strapping and strapping systems with a plant and company headquarters in Clinton, N.C. The company is a user of some post-consumer material, and its products are used to contain commodities such as bricks, lumber, metals, fibers, paper and industrial materials.
- Intertech – With a plant in Winston Salem, Intertech is a blow-molder of plastic containers used in such applications as bottles for milk, water, and cleaning chemicals. The company uses varying levels of post-consumer resin to make its products.
- Advanced Drainage Systems – ADS is a large, international manufacturer of drainage and pipe, geosynthetics, and landscape products with 45 plants, including one in Charlotte. The company is a large user of recycled HDPE bottle resin, and a consumer of material from some of North Carolina's HDPE reclaimers.
- O'Mara, Inc. – With a manufacturing facility in Rutherford College, O'Mara makes polyester and nylon yarns and threads for use in carpet, apparel, and other textile applications. Among O'Mara's branded products is "Eco-Fil," made from 100 percent post-consumer plastic bottles.

This list of companies in North Carolina who reclaim plastic bottle material or who manufacture products from recycled bottle plastic is not meant to be comprehensive. It is likely in fact that there are even more in-state firms with a stake in the recycling and use of recovered bottle resins. What is clear, however, is that the industry is extremely well-established in North Carolina, possibly more than any other state in the U.S. There is also a strong link between plastics recycling and the state's textile industry, which has been subject to its own serious competitive pressures over the past decade. Recycled-content products are helping the industry stay competitive and, in some cases, develop whole new brands that help the industry return to growth. This strong link between plastic bottle recycling and a traditional manufacturing sector in North Carolina underscores even more the need to be careful about potential negative impacts from degradable plastics on industrial feedstocks.

Concerns about Degradable Plastics

The Association of Post-Consumer Plastics Recyclers (APR), which represents more than 90 percent of the post-consumer plastic processing capacity in the United States, Canada and Mexico, has been vocal in its concerns about degradable plastics, especially in relation to claims of recyclability and impacts on recycled-content products. NAPCOR, the trade association for the PET container industry in the United States and Canada, has formally called for restraint in the use of degradable additives due to similar concerns. The Southeast Recycling Development Council (SERDC), a regional coalition of large recycling-based manufacturers, material processors, and recycling programs in the southeastern U.S., has issued an explicit statement opposing the use of degradable additives in plastic packaging.

The positions of these organizations reflect a growing alarm in the plastics reclamation and end-use industry about the potential negative effects of degradable plastics on their operations and products. This concern has been exacerbated by the degradable industry's failure to provide convincing evidence that their products will do no harm to the plastics recycling system. Individual interviews with North Carolina-based reclaimers and end-users underscore this issue, which starts with the difficulty of differentiating degradable and traditional plastics in the recycling process and includes concerns about costs and about ensuring the integrity of products made with recycled plastics.

Some of the main concerns include:

- Increased costs of sorting and quality control – By introducing material extraneous to the desired end product, degradable plastics require reclaimers and manufacturers to install additional equipment or to establish other costly control mechanisms to ensure degradable materials are removed. Some singular degradable plastics can be identified by automated sorting equipment machinery, but sorting efficiency is not 100 percent,so it is difficult to ensure complete removal of the degradables from processed materials. The automatic sorting machines used by the plastics recycling industry cannot detect normally durable plastics rendered degradable by additives. The machines seek the spectroscopic signature of the plastic and will see packaging with and without the additives as the same. Removal means manual sorting, with personnel needing to read individual labels on crushed bottles – a process that would be extremely difficult in many reclaiming operations where bottles are processed at rates of more than 1,500 per minute. Oxo-degradable materials are particularly difficult to identify and represent a growing concern for reclaimers, but PLA is also posing problems in many systems. A recent study completed by Petcore, a European trade association representing PET resin producers that works on PET recycling issues, found that the presence of PLA below even .1 percent "will make any [recycled PET] resin unsuitable for most applications and thus dramatically reduces PET's recycle value."

- Loss of material – The "bale yield," or amount of usable material that reclaimers can get out of the incoming plastic bottle bales, has been declining due to contamination in recent years. For many reclaimers, a 70 percent yield has become normal, which means two types of fiscal impacts on their companies: 1) loss of the money spent on bales that do not lead to subsequent material sales, and 2) increased costs associated with disposing contaminants.

- Impacts on final products – This area of concern is directly related to the main purpose of this study, which is to evaluate the “potential to contaminate recycled plastic feedstocks.” Manufacturers using recycled plastic articulate a number of risks in this arena:

  – Impacts on the manufacturing process – As resins are introduced and used in sophisticated and sensitive machinery to make final plastic products, unwanted materials can cause stoppages of work, loss of product, and downtime cleaning or repairing equipment.

  – Impacts on the quality and functionality of the finished product – As stated by Dave Cornell, the Technical Director of APR, and as echoed by North Carolina reclaimers and recycled-content manufacturers: “Many recycled plastics are used to make durable goods. Failure of these next-use products, such as carpets or piping, could range from distressing to tragic.”

  – Impacts on customer satisfaction and downstream sales – Predictable quality and functionality are keys to the ability of plastics recyclers and users to continue to gain customers and make sales. Product failure due to introduction of problematic materials can seriously affect a supplier or manufacturer’s reputation and business. It can also potentially harm the general growing trend to use recycling plastic in lieu of petroleum or natural gas based virgin resins.

North Carolina’s reclaimers and recycled-content manufacturers discussed these issues with DENR staff in phone interviews and email exchanges. Many expressed the need to have dependably high quality feedstocks and a concern that even small amounts of extraneous material or contamination can dramatically impact final products. Manufacturers discussed challenges in getting pure enough material to meet quality specifications and the potential for impurities to lead to costly extra processing or operation disruptions. In general, it is strongly felt that the presence of degradables would lead to lesser quality, weaker material and would, in some cases, cause adverse process reactions that, according to one reclaimer, “would potentially be a nightmare.” Many mentioned the overriding need for high quality feedstocks and the potentially damaging effects from degradable material on both equipment and production time. Rigorous specifications in a number of product applications leave little room for error.

In addition, reclaimers discussed the inability of even some sophisticated equipment to detect unwanted or harmful degradable plastics; in combination with shortfalls in testing practices and lack of universal commitment to testing, this could, according to one leading North Carolina reclaimer, “insert paranoia in the finished goods industry.” And if degradables are indeed detectable and then removed, it would still mean that reclaimers and manufacturers have to make up for material they may have purchased but can't use, adding costs to their processes.

One reclaimer succinctly summarized the perspective of many companies in saying, "We are strongly opposed to degradable plastics as the integrity of our recycled materials will be significantly compromised." A maker of recycled-content septic tank and construction products also pointed to potentially serious problems for products that are expected to last 10 to 100 years – degradable plastics that are designed to trigger in the presence of soil-based microbes would be extremely problematic for these applications.

The overall concern of North Carolina-based reclaimers and manufacturers about the effects of degradable plastics, particularly in the recycling of plastic bottles, is an issue the state should take seriously, especially as those companies become an increasingly important part of the state economy. It is possible that these concerns could be at least partially over-ridden if degradable plastics were useful in addressing other environmental aspects of material discard. The following section looks at the examples of environmental utility offered by degradable plastic proponents and assesses the contribution degradable plastics may be able to make.

Assessing the Utility of Degradable Plastics

Saving Landfill Space

Degradable plastics currently represent a very small portion of the overall disposed waste stream. To use the prominent example, if the market share of bottles with degradable plastics was currently one percent and they were all disposed, then approximately 580 tons of degradable plastic bottles from North Carolina would be placed in landfills each year. As a percentage of total waste disposed (9.4 million tons in Fiscal Year 2011-12), degradable plastic bottles would represent .006 percent of all disposed waste. At best, the materials would make an extremely minor contribution to the saving or creation of landfill space post-disposal. Although there is almost no available data on the actual presence of degradable bottles in North Carolina, many industry observers think it is much less than one percent, reducing further the amount possibly entering landfills and the advantages of degradables as a landfill space-saving strategy.

Additionally, if decomposition of degradable plastics takes more time than is currently defined in the FTC standard, there will be even less beneficial effect on landfill space. The Plastics Environmental Council, representing the degradable plastics industry, has in its own right argued for a longer standard of degradability for its products. The presumption that degradable plastics will experience ideal conditions for decomposition may also not be the case in every landfill. The manufacturer of one type of degradable plastic, PLA, acknowledges that its resin does not break down in landfills effectively or any more quickly than traditional plastics. Given these considerations, the utility of degradable plastics in improving landfill airspace capacity appears negligible at best.

One other aspect of degradability in landfills should be mentioned. If, as designed, degradable plastics help host and grow a microbial community within a landfill that specializes in attacking plastics such as HDPE, then they may also pose a risk of degrading the HDPE plastic liner placed under many landfills. These liners are the heart of the systems in modern landfills that protect groundwater from landfill leachate. It is uncertain if or how a robust degradable microbe community could effectively be kept from damaging a landfill liner system.

Methane Capture and Use

The Plastics Environmental Council states that its mission includes quantifying "the contribution of such plastics biodegradation to recoverable energy generation in landfills and other facilities." Decomposition of waste in the anaerobic conditions of a landfill emits methane, a powerful greenhouse gas that can be captured for energy use or destroyed through flaring. According to Dr. Morton Barlaz, an estimated 30 percent of landfills do not capture methane currently, although that number is declining. For the 70 percent that do capture methane, about half is used for energy production and half is flared. Degradable plastics could feasibly contribute to energy production in the estimated 35 percent of all landfills that have landfill gas-to-energy systems. However, as noted above, the current small presence of degradable plastics means this contribution would also be extremely small and not likely to become substantial in the near future. Moreover, plastic degradation at landfills where gases are not controlled would actually exacerbate negative effects of methane release. Overall, the question of methane is linked to the timing of degradation. If plastics degrade quickly, the resulting gas may not be controlled; if they degrade over longer periods, there is a better chance of capture and beneficial use, but not in all landfills.

Helping Consumers Understand What to Do with Discarded Plastics

Since the late 1980s, North Carolina and its communities have taken steps to encourage strong public participation in recycling, from the provision of curbside and drop-off collection services to the passage of the plastic container disposal ban in 2005. Recycling opportunities are now also expanding to many away-from-home locations, including workplaces, sports fields, parks, entertainment venues, beaches, airports, and events and festivals. The state recycling program and municipalities and counties across North Carolina conduct outreach programs to help citizens understand the importance of recycling; in recent years, that educational effort has stressed recycling's growing importance to the state's economy.

Considerable effort has also been made to help citizens understand which plastics are recyclable and which are not, a topic that can be very confusing to the public and one complicated by the evolving nature of plastics recycling. Could degradable plastics help reduce this confusion and help the public understand more clearly what should be done with discarded plastics? It is uncertain how degradable plastics might help; indeed it may make the task even more complicated. Citizens may hear mixed signals, understanding on one hand that recycling plastics is important but on the other hand that some plastics are fine to dispose of in landfills. Citizens would then be left with a more complex task of deciding which plastic is truly recyclable and what should be thrown away. At the very least, citizens would need a dependable and accurate system of product labeling to help make their decision.

Effective recycling outreach programs have found that simple messaging is critical. Contrast that need to an explanation offered on the website of one degradable plastic manufacturer trying to describe the fate of their material in landfills and differentiating it from compostable plastic:

> "If plastics are biodegradable in biologically active landfills, per ASTM D5511, they may not necessarily be biodegradable ("compostable") in municipal and industrial composting facilities per specifications outlined in ASTM D6400. The reverse is also true. Compostable plastics may not biodegrade in a landfill. Commercial composting sites grind material and turn over the piles at high temperature to achieve biodegradation and disintegration. Home composting takes at least two times as long to achieve the same results."

These kinds of ambiguous and complicated explanations bode poorly for the already difficult task of educating the public with comprehensible messages about plastics recycling. And given the economic benefits to North Carolina from plastics recycling, it is important that those messages succeed.

<u>Impacts on Litter</u>

There is a similar concern about the touted benefits of degradable plastics for the problem of litter. Information on degradable plastics could confuse the public and undermine educational efforts to prevent litter behavior. This situation is further complicated by having different kinds of degradable plastics, some of which break down in the presence of air and water, some of which degrade only in landfills or in long-term soil contact, and some of which do not degrade any faster than traditional plastics, even in landfills. For materials such as oxodegradable plastics that claim to degrade as litter, the first step in the degradation involves the plastics breaking down into small pieces, thus actually increasing the number of particles of littered material.

There is also a question about how much degradable plastics may be able to help solve the broader litter problem. The national anti-litter organization, Keep America Beautiful, has released a profile of the composition of litter on U.S. roads. Although the profile notes that "the incidence of plastic items in the litter stream has increased over 165% [reflecting] a 340% per capita increase in use of plastic packaging over the past 40 years," plastics is still only 19.3 percent of all disposed litter. With little market penetration of degradable plastics to date and with a good fraction of that material not readily degradable as litter, the potential benefit of degradability on litter issues is extremely small.

<u>Replacing Petroleum or Natural Gas-Based Resources</u>

One argument put forth by manufacturers of plant-based degradable plastics is that these materials reduce reliance on hydrocarbon sources of plastic resins. While it is superficially true that there is a one-to-one replacement of traditional plastic items by plant-based versions, it is also important to think about additional use cycles for any given plastic product. For example, hydrocarbon resins that are used in a bottle that then are returned for use in a new bottle effectively accomplishes the goal of replacing the virgin hydrocarbon inputs. Manufacturers of carpet, drainage tile, textiles, and plastic strapping that seek and use bottle-based plastic also replace virgin hydrocarbon resins in their process, at least for the first use and possibly in later product cycles.

In contrast, plant-based degradable plastics have struggled to achieve practical recyclability that succeeds at all stages, from collection to processing to end-use. Degradable materials generally suffer from not having enough volume in the marketplace to achieve practical recyclability (*i.e.*, to justify investment in additional sorting and processing equipment), nor has an alternative collection system emerged that might bypass traditional recycling and thereby achieve practical recyclability. A case can be made that if degradable plastics can gain more market share, then many of the volume-associated issues of recyclability might be solved. However, given the concerns that degradable plastics already pose to the plastics recycling system at their currently low-market penetration, a greater market presence would only seriously compound those issues.

With severe limits on practical recyclability, degradable plastics will likely not return to beneficial use after the first cycle. Discarded original degradable products will then be disposed and have to be replaced by new degradable plastic products. Thus, unlike many traditional plastics, degradable plastics will continually rely on virgin resource use that undermines their potential environmental benefits.

Possible Beneficial Applications of Degradable Plastics

As described above, degradable plastics have limited utility to address environmental issues. They also could have severe disruptive effects on the use of recycled plastic feedstocks for a wide range of products. But are there at least some applications for degradable plastics that could have some beneficial utility? More specifically, are there plastic products that will likely be truly disposable for the foreseeable future and thus make a conflict with recycling unlikely? A few possibilities include:

- Garbage bags, which are deliberately intended for landfill disposal.
- Disposal diapers, which are a large disposed waste stream that presents enormous challenges for diversion through traditional recycling and composting (as much as 112,000 tons of disposal diapers are generated and disposed of in North Carolina each year).
- Composite packaging – Some packaging uses multiple kinds of materials, often laminated together and not easily separable in the recycling process (*e.g.*, a flexible pouch). These packages, with their high likelihood of disposal, may be good candidates for use of degradable resins. However, it is important to realize that recycling technologies may improve to make composite packaging at some point sortable in a MRF and marketable as a commodity. Composite packaging manufacturers would need to balance potential benefits from using degradable plastics with potential recyclability.

Conclusion and Recommendations

Since the passage of the Solid Waste Management Act of 1989 (Senate Bill 111), North Carolina has been engaged in a vigorous effort to build a recycling infrastructure that reduces the state's dependence on landfill disposal and that captures materials for introduction back into the economy. With an increasing understanding of the importance of these materials to manufacturers and the economic benefits associated with recycling, it is important to ensure that all possible efforts are made to encourage plastic recycling in North Carolina, especially of bottle material.

It is unclear how degradable plastics can help achieve this goal. There is a lack of demonstrated practical collection and recycling of degradable plastics and a very strong indication that the materials will actually harm traditional plastics recycling.

North Carolina enjoys a strong presence of recycled plastics reclaimers and manufacturers who have made substantial capital investments and who collectively employ hundreds of North Carolinians. This presence corresponds with a growing collection of plastic materials for recycling across the state and a growing demand for recycled-content products. The state's reclaimers and manufacturers are concerned about potentially damaging effects of degradable plastics to their operations and products. It is difficult for the public to differentiate degradables from conventional recyclable plastic. It is also expensive and may be impossible for reclaimers and manufacturers to ensure degradables do not end up in their feedstock streams. Because so many applications of recycled plastics rely on qualities of strength and durability, there is also high potential for damage to the integrity of recycled content products.

North Carolina should take steps to minimize these potential harms and the associated impacts to a significant part of the state economy. Specifically, the state should seek to increase consumer awareness by requiring clear and explicit labeling on degradable plastic products, stating that the materials are not recyclable and should not be recycled. This step will help accomplish the twin goals of helping citizens understand what to do with discarded degradable plastics and helping prevent the inclusion of these materials in the recycling stream.

North Carolina has an important stake in the issue of degradable plastics use and its impacts on the state's expanding plastics recycling industry. Measures to both grow and protect this industry can have long-term benefits for both North Carolina's environment and economy.

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