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DEGRADABLE PLASTIC BAGS FOR THE COLLECTION OF COMPOSTABLE MATERIAL

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FACILITIES ENGINEERING
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DEGRADABLE PLASTIC BAGS FOR THE COLLECTION OF COMPOSTABLE MATERIAL

1. Purpose. The purpose of this Public Works Technical Bulletin (PWTB) is to transmit lessons learned for the use of biodegradable bags in the collection and processing of leaf and yard waste.

2. Applicability. This PWTB applies to all U.S. Army facilities engineering activities.

3. References. Army Regulation 420-49, Facilities Engineering: Utility Services, 28 April 1997.

4. Discussion. AR 420-49 contains policy for the operation, maintenance, repair, and construction of facilities and system, for efficient and economical solid (nonhazardous) waste management, including source reduction, re-use, recycling, composting, collection, transport, storage, and treatment of solid waste.

Points of Contact. Questions and/or comments regarding this subject that cannot be resolved at the installation level, should be directed to the U.S. Army Corps of Engineers Installation Support Center, CEISC-ES, 7701 Telegraph Road, Alexandria, VA 22315-3862, at (703) 806-5214, DSN 656 or FAX (703)806-5216; or the U.S. Army Construction Engineering Research Laboratories

Material Science and Technology Division at (800) USA-CERL, extension 5569, FAX (217) 398-5569, for Steven Cosper (e-mail: s-cosper@cecer.army.mil).

FOR THE DIRECTOR:

FRANK J. SCHMID, P.E.
Director of Engineering

LESSONS LEARNED
DEVELOPMENT AND USE OF BIODEGRADABLE BAGS

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1. Introduction.

a. Plastic bags have been used for solid waste collection for decades. Plastic bags have proven to be a convenient way to contain waste and odors, given adequate storage and collection frequency. However, plastic bags can spell disaster for composting systems incapable of dealing with them. Plastic bags can cause problems during feedstock preparation, processing, and finally in the end product quality.

b. In an effort to retain the convenience and ease of bagged collection, and to dispense with the potential composting problems associated with their use, entrepreneurs and manufacturers have invested in the development of biodegradable plastic materials. A wide variety of commercially available products are currently made with biodegradable plastic. (See Appendix A for a list of vendors.) This bulletin focuses only on compostable bags. Some newly developed compostable bags are now available commercially. Others are still under development and testing.

2. References. References cited in this lessons learned are listed in Appendix B. Appendix C lists sources of additional information.

3. Collection Methods.

a. The U.S. Environmental Protection Agency (USEPA) defines composting as "the controlled decomposition of organic matter by microorganisms into a stable humus material." Controls on a composting system are aimed at speeding decomposition, optimizing efficiency, and minimizing potential problems (EPA 530-R-94-003). One of these controls includes the method of collection for compostable materials. This bulletin focuses specifically on leaf and yard waste collection.

b. Leaf and yard waste collection often represents the most costly component of a composting program. Consequently, proper training and efficient collection programs can have the greatest impact on reducing the overall composting costs of these materials.

c. Leaves and yard waste can be collected using various collection equipment and techniques, but generally, the two main options are: bulk (i.e., rigid containers) and bagged collection. Field data indicates that bagged collection is most cost-effective as long as debagging is not necessary. A New

England study of two communities indicated that, for leaf-only collection, total bag collection costs are 45 to 65 percent lower than bulk collection costs (E&A Environmental Consultants, 1989 and Division of Solid Waste Management, 1988). The same is true for the collection of yard waste (grass clippings and brush trimmings) because the bulk collection of grass clippings is difficult to manage. The alternative to bags is the use of 20-gal plastic bins or 90-gal rolling bins. The procurement and distribution of such bins requires a significant capital expenditure. In some cases, leasing containers may prove to be cost competitive with biodegradable bag costs. Table 1, taken from the USEPA Report 530-R-94-003 (*Composting Yard Trimmings and Municipal Solid Waste)*, lists the basis for comparing yard trimming collection containers by cost and function.

Table 1

A Comparison of Yard Trimmings Collection Containers.

Container Type	**Cost**	**Advantages**	**Disadvantages**
Plastic Bags	$0.12/ bag	Inexpensive and readily available. Reduce the amount of time collection vehicles spend on routes because the yard trimmings are already separated and easily handled by workers; also true for other types of bags. Materials in bags are less likely to contain unwanted materials since they are not exposed; also true for other types of bags.	Can be torn open, scattering materials; also true of other types of bags. Require an extra debagging step because plastic can clog the tines on the turning equipment and wear out grinding blades in other machines. Plastic does not decompose and is considered undesirable in compost. As grass clippings decompose in plastic bags, they will become anaerobic and therefore malodorous. Workers and nearby residents might find these odors unacceptable when these bags are opened at the composting site.

Container Type	**Cost**	**Advantages**	**Disadvantages**
Biodegrad-able Plastic Bags	$0.20/ bag	Supposed to degrade by microbial action or in the presence of sunlight, eventually becoming part of the compost.	Degradability is uncertain. Some studies have shown that these bags can take several years to fully degrade, so bits of plastic still will be visible when the compost is finished. These contaminants can reduce the marketability of the finished compost.
Paper Bags	$0.25-0.45/ bag	Can offer additional holding strength over lightweight plastic bags. If paper bags get torn or crushed early in the composting process, such as in the compactor truck, the composting process is enhanced because paper bags are compostable.	Can be more expensive than plastic bags.

Container Type	Cost	Advantages	Disadvantages
Rigid Plastic Bins	$50-60/bin	Bins are large enough to be practical yet small enough to be handled by collection crews and residents without undue strain. Bins allow the neat storage of yard trimmings while awaiting collection. The time that yard trimmings spend in anaerobic conditions is often minimized since the yard trimmings are emptied from the bin regularly and transported unbagged. This, in turn, reduces the potential for odor problems.	The initial costs of the bins might represent a prohibitive expenditure for some communities Might require extra collection time to empty bins and collect materials.
Source: Wagner, 1991.			

4. Advantages of Bag Collection. Table 1 shows many advantages to using bag collection containers for yard waste. The most significant advantages are efficiency, neatness, flexibility, and lower capital expenditures.

- *Efficiency*. Compacting materials reduces the number of trips to the compost site. A standard crew of three persons and one compactor truck can collect bagged leaves at least as quickly as alternative leaf collection methods (e.g., vacuum truck).

- *Neatness*. Using bags for curbside collection of leaves and yard waste minimizes the risk of blowing material.

- *Flexibility*. Bag collection is adaptable to both leaf and grass collection, while bulk collection systems are only effective for leaves. In addition, bag collection is typically not affected by adverse weather conditions. (Bulk collection can be greatly influenced.)

- *Lower Capital Expenditures*. Bag collection requires no specialized equipment. Thus installations can use existing vehicles, avoiding large capital expenditures for the collection of materials.

5. Curbside Collection Systems Using Bags

a. Studies have shown that, in many cases, the most efficient and cost-effective collection system for bagged leaves and yard waste consists of a rear or side loading packer truck, one driver, and two collectors. This collection may be performed by either in-house personnel crews or private haulers. When determining whether to contract out or handle collection in-house, the cost and quality of consistent collection service should be considered.

b. Once a decision has been made to use bagged collection, the installation now has a choice in the type of bag to use: plastic, paper, or biodegradable plastic. In the case where the installation operates a composting program, it is very important to consider the relationship between material collection and the compost process and operations. When considering the use of plastic bags, one must consider equipment limitations in dealing with the removal of the bags before processing, that is, debagging requirements. In the case of paper or biodegradable plastic bags, one must consider the degradability rate, and the desired end quality of the compost product.

c. Manufacturers’ claims about biodegradable plastic bags vary widely and should be closely analyzed before purchasing. With the help of ongoing research to continuously improve and test the use of biodegradable bags in the compost process, consumer decisions will steadily become easier.

6. Development of Biodegradable Bags

a. It is important to note the distinction between the two types of degradable plastics: photodegradable and biodegradable. Photodegradable plastics begin to break down when exposed to ultraviolet light (a component of sunlight). Biodegradable plastics are degraded by biological organisms found in soil, landfill, and in this case, a compost pile.

b. The 1990s have seen a dramatic increase in the development and study of technology to manufacture biodegradable bags. The goal is to produce a product that biodegrades and meets required performance specifications. Degradable plastic bags have to be strong enough to perform leaf and yard waste collection and still degrade quickly enough to accommodate the compost process. Several questions have surfaced regarding whether these plastics create any environmental threats, and a number of companies and educational institutions continue to test these new plastics.

c. Biodegradable bags can be made with natural or synthetic resins. Natural polymers are based primarily on renewable resources, including polylactic acid, cellulosics and starches, and polyhydroxyalkanoate. Synthetic polymers are petroleum based, including polyester and polyethylene (PET) polymers. Most biodegradable bags are made using a blend of natural and synthetic polymers.

d. Industry research has indicated that synthetic polymers, like plasticizers, increase compostable bags' durability and shelf-life. All of the blends must have the ability to fully biodegrade under composting conditions and within timeframes to meet the compostability claims.

7. Plastic Degradation

a. Plastics are made up of synthetic polymers – long chains of carbon molecules that are very strong and resistant to deterioration. Most plastic bags are made out of PET. Some natural polymers also serve as good food for microorganisms (bacteria and fungi) in the soil. Cornstarch is one example of a natural polymer being used to produce biodegradable plastic bags.

b. Biodegradability is often a two step process: (1) hydrolytic or oxidative splitting of chains of polymers, then, once the chains get shorter, (2) the microbes can use the polymers as a food source. Step one is a decomposition process; biodegradation occurs after step one. Enzymes secreted by microorganisms break down both natural and synthetic polymer chains during step one, beginning biodegradation. Complete mineralization to CO_2 and water occurs in step two.

c. A typical biodegradation process for plastic is illustrated by the degradation of PET formulated with the addition of cornstarch. Cornstarch molecules are interwoven with PET chains in a plastic bag so that, as microorganisms digest the cornstarch, the synthetic chains are also broken down. The plastic structure develops many small holes and begins to fall apart. Soil organisms can more easily digest these shorter carbon chains, and thus reduce the plastic to benign materials such as carbon dioxide and water. However, there are limitations. As more cornstarch is added, the probability of ripping and tearing during use increases. The trick is to produce a biodegradable cornstarch bag that balances strength and good degradation. To further improve biodegradability, manufacturers are adding oxidative catalysts into the PET. These catalysts also help break long chains into shorter ones. Such catalysts work more rapidly as temperature increases. They speed degradation as the composting process generates higher temperatures (ADM 1989).

8. Biodegradability: Definition and Claims

a. The interest in the 1980s in biodegradation brought to light many differences of opinion about how to define "biodegradability." The American Society of Testing and Materials (ASTM) definition, updated in 1994 (ASTM Standard D-5488-84d) has established labeling terminology to be used on packaging materials and packages that "communicate environmental attributes" to consumers/users. This standard addresses both compostable and recyclable packaging.

b. ASTM defines "biodegradable" as "capable of undergoing decomposition into carbon dioxide, methane, water, inorganic compounds, or biomass in which the predominant mechanism is the enzymatic action of microorganisms, that can be measured by standardized tests, in a specified period of time, reflecting available disposal condition." Compostable is defined as "capable of undergoing biological decomposition in a compost site as part of an available program, such that the material (that is, feedstock) is not visually distinguishable and breaks down to carbon dioxide, water, inorganic compounds, and biomass, at a rate consistent with known compostable materials." ASTM defines "available program" as "a qualified term which can be used in the definition of recyclable, reusable, refillable, returnable, compostable, establishing limits; for example by population and access within geographic areas."

c. ASTM also developed a standard laboratory test methodology to measure biodegradability under composting conditions (ASTM D-5338-92). The one issue not addressed by ASTM is "environmental acceptability." Current tests do not test the residuals left after a material degrades.

d. There is also strong disagreement as to whether traditional plastics, such as PET, can ever completely biodegrade, even in the presence of degradable additives. To address this concern, some manufacturers use plant phytotoxicity testing on the finished compost that contains degraded polymers. While a product may not impact plant growth in the short term, over time it could become phytotoxic due to the buildup of inorganic materials, and slow down soil productivity. Many believe that companies should provide long term data to the consumer. Note that synthetic polymers are not alone in causing problems in the compost end product. Organically derived compost products can also be harmful to plants and crops. For example, one test combined 90 percent onion waste and composted it with woody wastes to produce a compost end product with high levels of aluminum that could also harm plant growth (BioCycle November 1995).

e. Sorting through manufacturers' claims of biodegradability is difficult, even for scientists. While questions still remain, it is important to stay focused on the application for biodegradable material. Those who will use biodegradable bags to package leaves and yard waste should first consider the disposal method and how well the bag will suit the composting process. As yet, it is not sufficient to simply buy plastic bags labeled "biodegradable." Until there are clear biodegradability tests and standards, and a larger market in North America for biodegradable bags, municipalities, generators, haulers, and composting facilities can expect to do a lot more research and to pay more for durable, strong, and moisture-proof biodegradable bags.

9. Selection of Biodegradable Bags for Collection

a. After deciding to use biodegradable bags for collection, one must first determine the number of bags required. The number of bags per household will vary, but a good "rule of thumb" is to allow two bags per week for medium-size lots and five bags per week for large lots. In addition, bid specifications must include desired bag characteristics, performance, and degradability.

b. Distribution of the bags can be handled in a number of ways:

- Bulk delivery to residents at the beginning of the season.
- Periodic delivery at the time of collection(s).
- Distribution through designated pick-up points.

c. To ensure the success of any composting program, public education is a necessity. It is very important that collection schedules be widely publicized and adhered to. Resident confusion, resentment, and hazards resulting from late collection can result in significantly lower participation and recovery rates. Therefore, education and awareness programs need to address the following issues:

- Community commitment to the composting program.
- Economic and environmental benefits of the program.
- The need for uncontaminated leaves and yard waste.
- Instruction on set-out procedures for collection.
- Instructions on collection schedules.
- Follow-up feedback on the progress of the compost operations.
- Information on how and where the compost will be made available to residents.

10. Composting Biodegradable Plastic: Case Study

a. Several projects in Germany have been conducted to research the effects of biodegradable plastics on the composting process and the end quality of compost made from source-separated organic materials.

b. One German study focused on the biodegradable plastic Biopol. Biopol is an aliphatic polyester produced via a microbial process on sugar-based substrates. It consists of the copolymer PHB/PHV (polyhydroxybutyrate/polyhydroxivalerate) with the addition of a softener (triacetine/estaflex) and the components titanium dioxide and boron nitrate. The product is used for both blown and injection-molded bottles and plastic films.

c. Chemical analysis illustrates that Biopol is a completely organic product that contains only very small amounts of plant nutrients (macronutrients), with the exception of nitrogen. The Carbon-to-Nitrogen (C:N) ratio is 70:1. The degradation of Biopol chips and bottles was measured through quantitative reisolation from the compost and not through CO_2 production.

d. An accurately measured addition of Biopol chips, between 1 and 5 percent by weight was added to 25 L of standard biowaste, then mixed and placed into a fine mesh (l mm) sample bag. The bag was then inserted into the center of a 150-L container filled with biowaste.

e. Under controlled conditions, the experiments determined that temperature, moisture, and the starting material C:N ratio held a significant influence on degradation. Unlike the timing of turning or mixing, which had no significant influence on the degree of Biopol degradation.

f. Optimum conditions for Biopol degradation during a 10-week composting period were 60 °C, 55 percent moisture, and C:N ratio of 18:1. Biopol reached close to 100 percent degradation rate under these conditions.

g. To illustrate that a high rate of degradation could also be reached under practical conditions, trials were conducted with alternating layers of paper and of Biopol. Results showed a complete degradation of these materials within a 4- to 5-week composting cycle.

h. A standardized plant growth test was also conducted using the compost from each degradability experiment. The results clearly proved that the compost led to plant growth yields above the 100 percent level.

i. The study concluded that Biopol can be successfully composted as part of biowaste from source separated collection, under pilot conditions. In addition, the compost quality, in regard to its chemical composition and use in plant growth, is not reduced if Biopol (1 percent) is included in the composting process.

11. Degradable Cornstarch Bags and Leaf and Yard Waste Composting: Case Studies

a. A number of communities and military installations have shown interest in field testing the first generation of biodegradable cornstarch bags. The major questions are whether the bags will decompose as rapidly as leaf and yard waste in the compost pile, and if there are residues, leachate, or volatile gases produced by the plastics during composting that might pose an environmental hazard.

b. Preliminary results indicate that the bags handle as well or better than traditional plastic yard waste bags (Hanlan 1989; Darling 1989). The University of Missouri has also conducted laboratory analysis of plastic films containing 0 to 9 percent cornstarch. Tests have indicated that cornstarch is degraded within a matter of weeks to several months. One study concluded that plastic film strength is reduced by an average of 25 percent and as much as 60 percent after 12 to 24 weeks (Iannaotti, Tempests, et al. 1989). Another lab analysis found that a cornstarch pro-oxidant polyethylene film lost 94 percent of its original toughness after 6 months of soil burial (ADM 1989). Preliminary results from both laboratory and field tests have proven that polyethylenes will not decompose as rapidly as the leaves and yard waste.

c. The City of Urbana, IL, has operated a leaf and yard waste reclamation program for many years. During 1988, the city received a grant from the Illinois Office of Solid Waste and Renewable Resources to use bags made of film formulated from plastic and cornstarch in a demonstration project. For the 1988 season, the city purchased 60,000 bags from Manchester packaging at $0.18 per bag. Biodegradable bags were distributed through local retailers at a cost of $0.50 per bag. This cost covered collection fees that would otherwise be charged to residents. The city reported that the bags performed equally well during collection as conventional bags. However, the bags were not easily shredded using the Wildcat windrow turner. Tests of finished compost product were not conducted.

d. Dr. Richard Wool, formerly of the Department of Materials Science at the University of Illinois, conducted a bench-scale yard waste composting experiment to assess the degradability of several new plastic lawn bag technologies. He used the relatively new ASTM Composting tests and rated the bag performance in pilot yard waste reclamation tests with the City of Urbana. His studies determined that polyethylene based plastics containing an oxidizing additive additives and a low starch content illustrated little degradation in 1 year. However, bags with high starch contents in polycaprolactone (PCL) matrices (relative to the average of 30 percent for compostable bags) showed complete degradation and also exhibited excellent mechanical properties as compared to regular (non-compostable) plastic bags (before composting). Unfortunately, at the time of the study, most of the bags were not yet commercially available. Dr. Wool recommends that bags made from naturally degradable plastics and composites made with starch, should be considered as suitable candidates for yard waste reclamation, providing the costs are feasible (OSWR Special Newsletter, Summer Edition, 1996). Dr. Wool’s study (OSWR Report No. 37-10-014, 1994, R1.50) can be obtained by submitting a written request to the Office of Solid Waste Research, University of Illinois, 1101 W. Peabody Drive, Urbana, IL 61801.

12. Vendor Information

a. To illustrate current vendor data, all four of the vendors listed in Appendix A were contacted and asked to provide information about their biodegradable plastic bags. Two of the four biodegradable bag vendors responded to this request for information: EPI Environmental Products, Inc., and Indaco.

EPI Environmental Products, located in Conroe, TX, has developed a degradable/compostable (DCP) bag. The DCP technology, patent pending, claims to degrade polyolefins at controllable rates during composting. It has tailored polyethylene plastic bags to degrade at various temperatures depending on the specifications of the compost facility. For example, the CP 530 bag degrades between 30 and 60 days, while the CP 560 bag takes from 60 to 90 days, and the CP 590 takes more than 120 days. Table 2 illustrates EPI's comparison between their compostable film plastic and typical liner film plastic. Product data was also provided for both the CP 530 and CP 560 bags. Table 3 summarizes this data.

Table 2
EPI's Comparison Between Their Compostable
Film Plastic and Typical Liner Film Plastic.

EPI's Compostable Film	**Typical Film Liner**
Compostable	Not Compostable
Limited shelf life	Longer shelf life
Distinctive Enviro color; light green with EPI's logo: word "compostable"	Plain with no marking; clear, black or dark green in color
Specialized packaging	Packaging not critical
Keep film away from direct sunlight and heat (photo, chemical, and thermal degradation; the "essence" of a compostable product)	Sunlight and heat not a major factor
Approximately 1.25 mils thick	Approximately 1.0 mil or less thick
15-25% higher price ($0.23-$0.25 per bag)	Cheaper ($0.20 per bag)
Environmentally friendly and benign; reduced to CO_2 and water	Becomes contaminant in compost and litter in landfills

Table 3

Summary of EPI Comparison Data.

CP 530 and CP 560 Product Data (units)	**Test Results***	**ASTM Test**
Melt Flow (g/10 min)	1.5	ASTM D-1238
Density (g/cm^3)	0.925	ASTM D-1505
Tensile properties at break (psi, MD direction)	3800	ASTM D-882
Ultimate elongation	370	ASTM D-882
Dart drop strength, g/mil	130	ASTM D-1709
* Results for CP530 and CP 560 were identical.		

b. Indaco, Manufacturing Limited, provided information regarding their *Bio-Solo* compostable bags and liners. Their product is formulated to break down in an aerobic compost in 35 to 45 days depending on conditions. Degradation of this product is activated by heat and oxygen rather than bacteria. They recommend shredding the bag and contents, then composting all together at an average temperature of 140 °F and turning twice weekly to optimize degradation. *Bio-Solo* bags are said to compost completely, without leaving any visible or toxic residue behind.

c. According to the vendor, *Bio-Solo* was tested for 3 years and is now available in various sizes and thicknesses depending on requirements. In addition, all bags are printed boldly to distinguish them from ordinary bags. At the time of this inquiry, they carried a stock of 22 x 24 in. kitchen bags, 30- and 33-gal leaf and yard waste bags, a 26 x 36 in. industrial bags, as well as five sizes of liners for food waste containers to fit anything from a 30- to a 95-gal plastic toter. These products are packed in either 100, 200, or 500 bags per case, depending on size. The leaf and yard waste bags, as well as the kitchen bags, were to be made available as retail packs in the near future (see Appendix A). Indaco also offers customized orders should the size, gauge, or printing required be different from the stock items.

d. The *Bio-Solo* compostable plastic bag is advertised as ideal for wet/dry collection, environmentally friendly, made with recycled PET, heat and oxygen activated, nonpollutant/nontoxic, adjustable to meet degradation rate requirements, and tested and proven by professional composting companies.

13. Economics and Market Demand

a. Despite improved bag technology, composting facilities and compostable generators and haulers have expressed minimal interest in compostable bags. Until larger markets are established, manufacturers will produce only enough bags for pilot programs and testing. This, of course, drives up the prices of the bags. BioCycle magazine conducted a survey of manufacturers and determined the price range to be between $0.18 and $0.85 per bag, depending on size and volume. Traditional plastic bags are a few cents each, and uncoated paper bags are about $0.30 each. Until a greater demand for biodegradable bags can be established, it will be impossible for resin manufacturers to reach the competitive price range.

b. The market for biodegradable bags is growing much more quickly overseas than in the United States. Higher tipping fees and restrictions on nondegradable and nonrecyclable packaging in Europe are helping to drive the market demand. According to Mojo of Galatech, Inc., most of the Netherlands and Austria are using some type of municipal collection of food and yard waste, and about half of all German households are diverting compostables from their waste streams.

c. In addition to price, bags must meet certain operational and functional criteria for use in the composting arena. The bags must be able to hold heavy food residuals and liquid waste. Restaurants often use a 64-gal or larger container for collection of food residuals. These containers can weigh up to 300 lb when full. Most biodegradable bags on the market were designed for 30- or 36-gal containers and to withstand weights of 50 to 75 lb. These design criteria greatly limit their use in the commercial market sector.

d. In addition, liquids alone can cause another problem with degradable bags. Some bags produced with a cellulose lining cannot hold liquids and must rest on a dry surface to keep the outer paper layer from weakening. Some bags are porous and will leak after periods of time. This is why the user must understand the functional limitations of the biodegradable bag before purchase.

e. Some bags are produced using recycled PET, helping not only to reduce and reuse the plastic waste stream, but also to provide a means to degrade such plastics while also functioning as an adequate collection and temporary storage bag for compost materials. With greater research into the long term results of such degradation, these degradable products will surely gain strength and integrity in the consumer's market place.

14. Summary

a. Several commercially available biodegradable bags are compostable (according to ASTM standard laboratory testing) and can be assessed for use in military composting programs. However, installations should exercise caution in selecting a biodegradable bag well suited for site specific requirements such as collection frequency, wet/dry materials, degradation rate, and end product quality requirements.*

b. Well planned compost programs and collection systems can use biodegradable bags for material collection and processing. However, the long term environmental impacts of the use of biodegradable bags have not yet been scientifically determined. Continuing study will aim at determining the limitations of plastic degradation, assessing impacts on compost end quality, and addressing environmental concerns associated with long term use. Consumers can anticipate improved functionality and lower costs for biodegradable bags as the scientific and academic communities continue testing and researching this new generation of plastics.

*Prospective buyers should contact the institutions listed in Appendix C for the latest information on bag performance and availability.

APPENDIX A
Contact List for Suppliers

Biocorp USA (starch-based bags)
2619 Manhattan Beach Blvd
Redondo Beach, CA 90278
(888) 206-5658
(310) 643-1622 fax
info@biocorpusa.com
<http://www.BiocorpUSA.com/>

Petoskey Plastics, Inc. (BioSolo, recycled polyethylene)
4226 US 31 South
Petoskey, MI 49770
(616) 347-2602
(616) 347-2878 fax

Technicoat (compost bags)
PO Box 277
75 Cole Avenue
Winnipeg, Manitoba
R3C 2H5 Canada
(800) 528-3302
(204) 669-7823
(204) 668-5277 fax
info@technicoat.com
http://www.technicoat.com/technobag.htm

APPENDIX B
References

Wool, Richard P., Office of Solid Waste Research Special Newsletter, Summer 1996 Edition, Institute of Environmental Studies, University of Illinois at Urbana-Champaign.

Office of Solid Waste Management, School of Public Health, University of Illinois at Chicago, Chicago, IL., Composting Fact Sheet.

"Degradable Additives for Plastic Compost Bags," BioCycle, March 1995.

Farrell, Molly and Nora Goldstein, "Unraveling the Biodegradable Plastics Maze," BioCycle, November 1995.

APPENDIX C
Information Sources

Degradable Polymers Council
Society of the Plastics Industry
Suite 600
1801 K Street, NW
Washington, DC 20006-1301
(202) 974-5200
(202) 293-0236 fax<http://www.degradablepolymers.org/>

The Composting Council
4424 Montgomery Avenue
Suite 102
Bethesda, MD 20814
(301) 913-2885
(301) 913-9146 fax
<http://CompostingCouncil.org/>

Institute for Local Self-Reliance
2425 18th Street, NW
Washington, DC 20009-2096
(202) 232-4108
(202) 332-0463
<http://www.ilsr.org>

USEPA Office of Solid Waste
<http://www.epa.gov/epaoswer/osw/index.html>