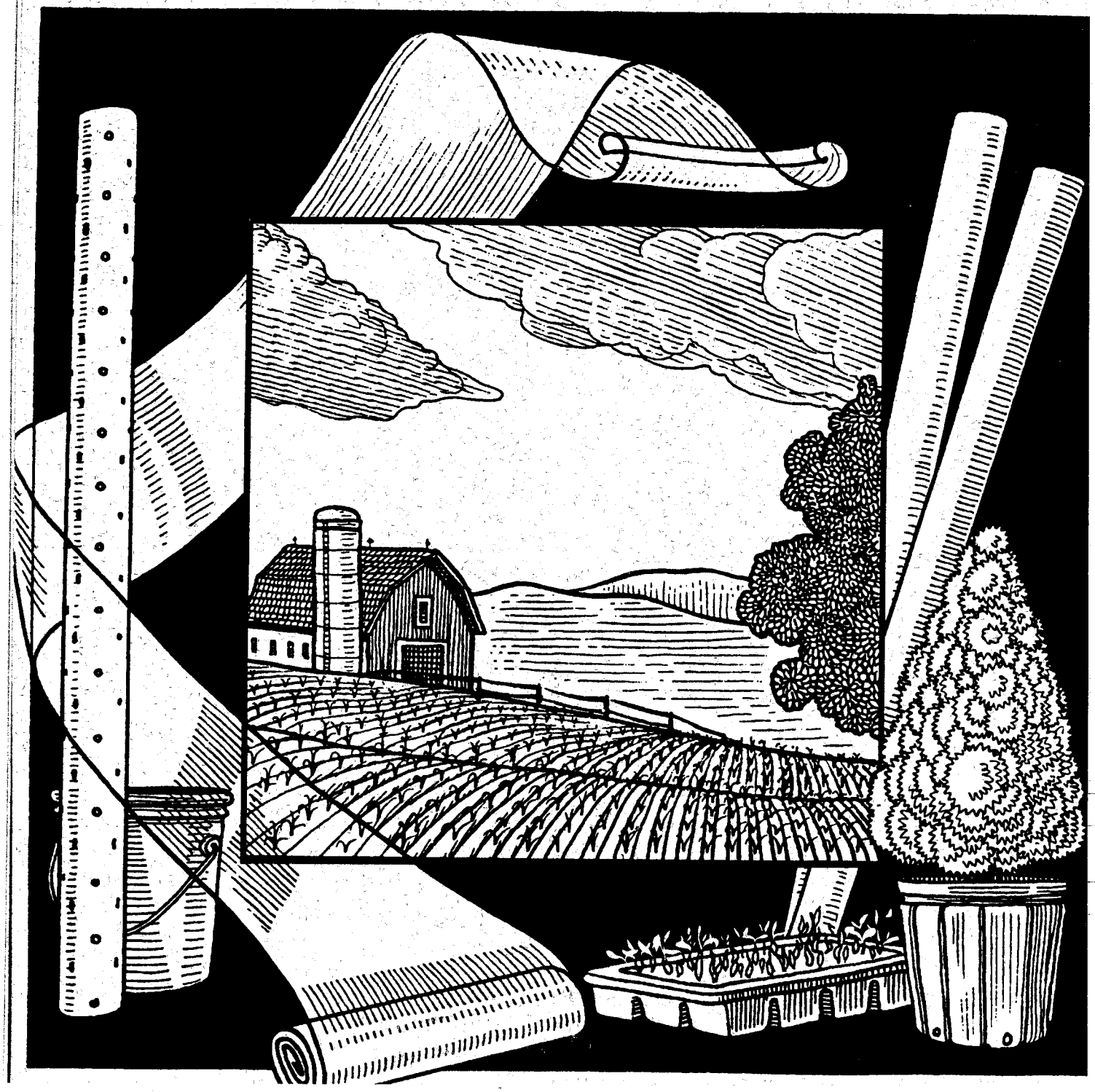
American Plastics Council

Use and Disposal of Plastics in Agriculture

Prepared by:
Amidon Recycling

For the American Plastics Counc
A Joint Initiative with
The Society of the Plastics Industry, Inc.



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EXECUTIVE SUMMARY

Over the past 20 years, plastics have been relied upon increasingly to help raise record food and fiber crops. As our population grows and as more uses for plastics are developed, more film and other plastic products will enter the greenhouse, nursery and farm environment to cut costs and increase productivity. Some of the essential benefits derived from agricultural plastics are:

- earlier crop production,
- higher yields per acre,
- higher quality produce,
- control of some pathogens,
- decreased costs,
- more efficient use of water, fertilizers and pesticides,
- increased transplant survival,
- minimized cold injury, and
- reduction of nutrient loss of cattle feed.

This report focuses on the major plastic markets within the agricultural sector and identifies characteristics of plastics used in agriculture, major manufacturers, current disposal methods, barriers to recycling and recyclers currently accepting agricultural plastics. A cross section of individuals and organizations, from manufacturers and distributors to users and reclaimers, was contacted. Wherever possible, multiple sources were used to corroborate information.

The research identified 38 current major manufacturers of plastic products in targeted markets and more than 20 markets for post-use agricultural plastics. While the markets for agricultural plastics as a whole are very diverse, the recycling markets for each type of plastic waste are very specific.

The 14 main markets researched for this document include low density polyethylene (LDPE) films, nursery containers and high density polyethylene (HDPE) pesticide containers. The following table depicts the use of plastics by the agricultural community.

Table I
1992 Estimated Quantities of Agricultural Plastics
(Million lbs.)

Film		
Greenhouse & Nursery Film	25.0	
LDPE Mulch Film	60.0	
Fumigation Film	12.5	
Degradable Mulch Film	3.0	
Irrigation Tubing	13.5	
Silage Bags	8.0	
Hay & Silage Bale Stretch Wrap	25.0	
Haysleeve Covers	2.5	
HDPE Mulch Film	2.0	
Film Totals		**151.5**
Nursery Containers		
Blow-Molded HDPE Pots	90.0	
Injection-Molded HDPE Pots	100.0	
Injection-Molded Polypropylene Pots	85.0	
Polystyrene Nursery Pots, Packs and Flats	70.0	
Nursery Container Totals		**345.0**
HDPE Agricultural Pesticide Containers		
Blow-Molded less than 2.5-gallon	8.0	
Blow-Molded 2.5-gallon	12.0	
Extrusion Blow-Molded 30-gallon	1.5	
Injection-Molded 5-gallon	1.5	
Rotational-Molded Returnable/Refillable	1.5	
Pesticide Container Totals		**24.5**
Total Agricultural Plastics Market		**521.0**

Current Disposal Methods

Disposal methods vary by material and location. As with most residential and commercial waste, the majority of agricultural plastics (agplastics) are legally landfilled. Some agplastics are illegally landfilled or burned on-site. As more appropriate options become available, illegal landfilling and burning are both decreasing. As more of the nation's waste is sent to waste-to-energy facilities, more agplastics also will be included for energy recovery. At present, less than 5 percent of all agricultural plastics are estimated to be incinerated for energy recovery.

A very small but growing amount of agplastics are being recycled. Although estimates for agplastic recycling fall below 5 percent, the agricultural community is developing a recycling awareness. Large amounts of agricultural film (agfilm) are concentrated at major nurseries, greenhouses, dairy farms and cattle ranches. These areas of high concentration are the major sources for current agplastics recycling and hold the greatest potential for future agfilm recycling. It will be necessary for these large growers to develop collection and preparation techniques that foster positive and mutually beneficial relationships with reclaimers.

Few nursery containers are collected for recycling; however, some product manufacturers, growers and reclaimers have developed arrangements targeting polystyrene nursery trays. The reclaimed plastic is recycled in a "closed loop" into new trays. A limited amount of post-consumer nursery pots are also recycled into plastic lumber.

Some agplastics are re-used in normal operation. Most of the re-use occurs at greenhouses and nurseries where containers are re-used internally for succeeding crops. A few container re-use businesses purchase, sort and resell used pots from the landscape industry. Over-wintering film, on a very limited scale, is re-used for the original purpose. Greenhouse film may be re-used as temporary tarpaulins. Nursery pots are frequently re-used commercially as well as by the retail consumer.

Agricultural pesticide containers are being collected in industry-sponsored programs available in 39 states. These programs are finding that a cooperative effort including pesticide manufacturers and distributors, growers, state and local government officials, and reclaimers and their subcontractors can develop and operate programs to collect non-refillable pesticide containers in a cost-effective manner. The success of these pesticide container recycling programs can be seen in Table II.

Table II

Estimated HDPE 1- & 2.5-Gallon Agricultural Pesticide Container Recycling Rates

(Million lbs.)

Year	Generated	Collected	Rate
1990	24.7	0.35	1.4%
1991	21.9	0.85	3.9%
1992 estimated	20.0	1.28	6.4%
1993 estimated	19.0	2.50	13.2%

Sources: American Container Recycling Council, National Agricultural Chemicals Association, Amidon Recycling

Many plastic manufacturers and their trade groups are engaged in recycling or promoting agricultural plastics recycling. Trade groups such as the Agricultural Container Research Council and the American Society for Plasticulture are among those that have actively promoted agricultural plastics recycling as a responsible method for managing plastic waste.

Barriers to Recycling

The barriers to recycling agricultural plastics fall into three basic categories: costs, contamination and the lack of information on recycling.

Plastics used in agriculture vary by resins, applications, quantities and benefits they provide. The characteristics of the resultant waste agricultural plastics are extremely diverse. Some are relatively clean, made of high-quality resins and in very good condition, making them readily recyclable. Other waste agplastics are less desirable due to the extreme service required and the resulting high levels of contamination and degradation caused by time and the elements.

Many nursery pots are manufactured using post-consumer plastics and industrial scrap. Often the pots, which perform their duties well, consist of commingled resins of varying characteristics. This at times makes used nursery pots less desirable for recycling than post-consumer residential packaging. Blow-molded nursery container manufacturers instead may prefer more predictable detergent and milk bottles. Because of the limited demand for post-consumer nursery pots, few municipal programs accept them.

Plastic pesticide containers also are not commingled with normal household plastic bottles. The possibility of pesticide residue is a large barrier to recycling for all types of agplastics. From the limited amount of research done on the subject, there is no current evidence of significant risk. Basic research is needed to determine the actual levels present on the various plastics.

Recyclers

Of the companies identified that either reclaim, handle or broker waste agricultural plastics, some service all areas of the country, while others service only their immediate locale. Still others service only growers that purchase certain manufacturers' products. Markets and specifications change depending upon industry variables.

The ability for reclaimers to accept agricultural plastic waste is dependent upon the capabilities of their washing and other processing equipment. Even though mulch film can be contaminated by up to 50 percent by weight with vegetation, sand, soil and stones, one Florida company is successfully sourcing mulch film and manufacturing roll cradles for sale to a mulch film manufacturer. Other plastics reclaimers are equipped only for virtually contamination-free plastics. The future for agricultural plastics recycling does look promising as more reclaimers begin operations and as new collection strategies are implemented.

The Road Ahead

Our research indicates that as seasons pass, recycling will become a more substantial method for managing the waste plastics generated by the farming, ranching, nursery and landscape industries. To facilitate the development of this area of agricultural waste management, the following items must be addressed and nurtured:

- information access and exchange,
- coordinated industry efforts,
- promotion of clean collections of valued agplastics,
- promotion of appropriate waste-to-energy options,
- pesticide residue research for agplastics,
- research on the safety of field-burning plastics,
- increased markets for collected plastics, and
- agricultural products made with recycled content.

One of the great challenges in the coming years will be the design of new products made of recycled plastics that can perform as well as, and be as cost-effective as, products made from virgin resin and traditionally non-plastic materials.

As the quality of recycled plastics is increased, processing costs will be reduced and we will see more plastic products with recycled content.

The future for plastics in agriculture seems unlimited. As growing techniques become ever more micro-environment specific, the agricultural and plastics industries will research and develop more methods for using plastics to decrease costs and to increase productivity on the farm and in the greenhouse. Our planning today will ensure collection systems to effectively and environmentally manage those waste plastics.

Disclaimer

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INTRODUCTION

This report presents the current status of the manufacture, use and disposal, including recycling, of the majority of agricultural plastics in North America. Agricultural plastics are grouped into three basic categories: film, nursery containers and pesticide containers. The following information is based upon conversations with agricultural plastics converters, plastics reclaimers, nursery and greenhouse growers, pesticide manufacturers and other individuals knowledgeable in the field of agricultural plastics and plastics recycling.

The low density polyethylene (LDPE) film market is detailed first. In these sections, three corollary items — LDPE degradable mulch films, high density polyethylene (HDPE) mulch film and LDPE irrigation tubing — also are included. The degradable films represent an alternative disposal method that may hold promise for some areas of the country. HDPE mulch film, exclusively manufactured in the United States by Sonoco Products Company, has been used in Europe for many years. It is unclear whether either LDPE degradable mulch or HDPE mulch film will command a significant market share in the near future. Irrigation tubing is included in the film section because it is closely related to agricultural film by resin type and by the industry it serves. A recycling facility able to recycle LDPE agricultural film could also process irrigation tubing. Film reclaimers would look favorably upon irrigation tubing as a bonus material, given the high-quality resins used in its manufacture and the heavy gauge.

The sections on plastic nursery containers address the various pots, packs and flats utilized by the greenhouse, nursery and landscape industries. This section covers HDPE blow-molded and injection-molded pots, polypropylene (PP) pots and polystyrene (PS) pots.

The pesticide container section concentrates on HDPE container collection and recycling. Although other packaging materials are used for some pesticides, the bulk of the containers are one-way HDPE plastic. Pesticide container recycling has grown dramatically in the past four years.

Included in the appendices are companies, associations and organizations that play either a direct role in, or are related to, the agricultural plastics infrastructure.

I AGRICULTURAL FILM

1.1 INTRODUCTION

Agricultural film (agfilm) plastics consist of mainly LDPE, which, depending on the usage, alternately may be called horticultural film. Agfilms' largest market is mulching film used by vegetable growers. Plastic mulch's first advantage to the horticulturist is that film increases the soil temperature, promoting increased and earlier yields of fruits and vegetables. Mulches are also used to discourage weed growth and to conserve water and fertilizer. Some mulches are light selective and allow only certain parts of the spectrum to pass through. It has been demonstrated that in some areas, plastic mulch acts as a deterrent to fungus infections and insect infestations, allowing reduction in chemical pesticide applications.

LDPE plastic is used extensively by flower and foliage growers for covering greenhouses. Because of cost and ease of installation, plastic has replaced glass as the dominant glazing in North America. Nursery growers use LDPE film for over-wintering protection of shrubs and plants, both in open fields and in "hoophouse" settings. Hoophouses, unlike greenhouses, have no artificial heat sources. When used on hoophouses, or in the fields directly over the plants themselves, the film protects plants and shrubs from the cold and wind chill. The film also helps conserve ground warmth, reducing winter injury. Over-wintering film is often white and reflects light, keeping the inside temperatures lower throughout the day to maintain the plants' dormancy. In some northern locations, the over-wintering film protects for three months or more, while in Florida and other southern U.S. locations, the material is often needed for only a matter of weeks.

Fumigation films are often left on fields for no more than one to four days after application. As the fumigation film is laid down, gas-forming pesticides are applied to the soil. The film creates a contained atmosphere for the gas to control the targeted pathogens.

As alternatives to vertical silos, silage bags are used by cattle ranchers and dairy farmers to produce corn silage and to protect it from spoiling. Haylage tubes and hay bale stretch wrap are used to protect hay from the elements.

The remainder of LDPE plastics used in agriculture include items such as bags to package soil amendments, irrigation tubing and drip irrigation components for both the greenhouse and the field. The quantity and quality of waste agfilms vary greatly by their uses and locations. In some areas, there are highly concentrated amounts of very clean used agfilm. In other areas, film is thinly scattered and extremely soiled.

Industries with waste film able to be economically reclaimed are identifying their disposal options. In the agricultural industry, "economically reclaimed" will have varied meanings, depending upon the material, quantity, location, available disposal sites (landfills, waste-to-energy plants) and the distance to a reclamation plant specifically designed to accept the material.

1.1.1 Agricultural Film Characteristics

Characteristics for the various films will be highlighted in individual sections, including resins used, colors, gauge ranges and annual demand, in millions of pounds, for the various agricultural film markets. The estimates of the annual demand should be viewed as a broad account of the industry.

The January 1994 issue of *Modern Plastics* magazine estimated the 1992-1993 sales of LDPE to the agricultural market at 236-244 million pounds. The following table is the aggregation of information received from members of the agricultural film plastics industry over the past three years.

Table 1.1 1992 Estimated Quantities of Agricultural Film (Million lbs.)

Film Market	Low	High	Avg.
Greenhouse & Nursery Film	20	30	25.0
Mulch Film	40	80	60.0
Fumigation Film	10	15	12.5
Degradable Mulch Film	2	4	3.0
Irrigation Tubing	12	15	13.5
Silage Bags	7	9	8.0
Hay & Silage Bale Stretch Wrap	20	30	25.0
Haysleeve Covers	2	3	2.5
Peat Moss & Fertilizer Bags			
LDPE Totals	**113**	**186**	**149.5**
HDPE Mulch Film	**1**	**3**	**2.0**

1.1.2 Major Manufacturers

The major known manufacturers for each film market are listed in alphabetical order and are contained in the corresponding sections. Also included are foreign manufacturers that ship significant volumes of agricultural film to the United States and Canada. Many manufacturers produce for multiple market areas, while others market exclusively one product for the agricultural industry. The listing of major manufacturers is not inclusive of manufacturers that may dominate a market on a regional or local level.

With regularity, many companies enter and exit the agricultural film market. The agricultural film plastics marketplace is in constant change. For instance, two years ago Tredegar Film Products of Richmond, VA, controlled a significant portion of the greenhouse film business. Today Tredegar no longer produces greenhouse film.

A full listing of all major manufacturers, including addresses, telephone numbers, contact people, the market serviced, etc., is provided in **Appendix A.**

1.1.3 Agricultural Film Contamination

LDPE film is a fact of life for most segments of the modern economy. In agriculture, the use of film has helped grow the most productive crops in history. Given plastic film's surface area-to-weight ratio, film can become contaminated very easily. Contamination, a problem for all recyclables, can become extreme in horticulture.

Contamination is anything that is not the targeted plastic or targeted film, including any other types of plastic, dirt, sand, grease, grime, vegetation and moisture. Glue, paper and tape, cans and bottles, latex greenhouse shading and ultraviolet (UV) light degradation are all contaminants. If the film has lost its flexibility and is crinkly, it has serious ultraviolet light damage. UV damage can severely limit the recyclability of plastic film.

1.1.3.1 Possible Pesticide Contamination

Another type of contamination is possible pesticide residue on greenhouse, over-wintering, mulch and fumigation films. However, given the low concentrations and low quantities of pesticides used, the indirect and incidental contact with the film and the speed with which applied pesticides break down in the presence of ultraviolet light and moisture, pesticide contamination should not be a major problem in reclaiming agricultural films. As previously mentioned, agfilms are used in a variety of settings. Any pesticide contamination on waste agricultural plastics will vary and will be very site specific and crop specific.

The potential areas of impact posed by possible residual pesticides on waste agricultural film plastics are:

- worker safety,
- air pollution,
- water pollution,
- solid waste pollution, and
- recycled product safety.

Variables that affect the levels of possible pesticide contamination of recyclable agricultural films include:

1.1.3.1.1 Pesticides applied

Different pesticides may be used on the same crops by neighboring growers. For example, two applications of insecticide A on Farm A can provide crop protection comparable to three applications of insecticide B on Farm B. Growers choose between various chemical applications depending upon their very localized insect, mite, weed and fungus infestations. Pesticide programs take into account pesticide applications over a period of years. Relying upon one pesticide in a narrowly defined pesticide program, for an extended period of time, can cause pathogen resistance. Depending upon a grower's needs and choice, pesticides may be applied at varying rates per acre. The application rate may have an effect upon residue, as would multiple applications of the same spray to combat a heavy infestation.

1.1.3.1.2 Pesticide concentration

Pesticides are diluted with water before application to growing crops. Dilution depends upon the pesticide, application equipment, crop and targeted pathogens. Farm A may apply the same amount of pesticide per acre as Farm B. Farm A may use only 10 gallons of water per acre. Farm B may apply the pesticide using 100 gallons of water. Both applications are proper and both have benefits and drawbacks. A very concentrated application may be redistributed by rain showers and provide a longer period of protection, while a very dilute application could be washed away. Conversely, a very diluted application will give a more thorough coverage when soaking is necessary to combat the pests. Pesticide concentration may have an effect upon pesticide residue on waste agfilm.

1.1.3.1.3 Elapsed time from application

Time between application of pesticides and handling of crops (or waste plastics) allows pesticides to break down. Pesticide breakdown is accomplished through exposure to water and light. Depending upon weather conditions and

pesticide application, most pesticides break down rapidly, many within two weeks of application. Time periods for re-entry of farm workers into fields are required for some pesticides. These periods of non-entry may be from 12 to 72 hours. Some pesticide labels call for protective clothing to be worn for up to one week after application.

> "Protective clothing means, at least, a hat or other suitable head covering, a long sleeved shirt and long legged trousers or a coverall type garment (all of closely woven fabric covering the body, including the arms and legs), shoes and socks."[1]

Many pesticide labels also require a certain number of days before a crop may be harvested following application. Increasing the time period between pesticide application and plastics handling will limit the potential presence of residual pesticides or their breakdown products.

1.1.3.1.4 Amount of residual contaminants in attached soil

Considerable farmland has been cultivated for decades. Residual breakdown products from years of pesticide spraying are present in many of these long-term fields. Metals such as arsenic, copper, lead, manganese and zinc have been shown to be present in many soils. These metals are in many cases breakdown products of pesticide applications. In Dade County, FL, studies have shown high but safe levels of heavy metals in waste water from fruit and vegetable packing operations. Sue Alspach, program manager for the Agricultural Waste Program of the Dade County Department of Environmental Resources Management, states that to date the levels of heavy metals have not caused a problem with ground water contamination. Ms. Alspach reports that packing houses routinely discharge wash water effluent either to the fields or to unlined in-ground pits.

To date, the pesticide residues most prevalently found in Dade County vegetable processing wash water are the result of Endosulfan (Thiodan®) sprays. Endosulfan is used to combat numerous insect pests on many fruit and vegetable crops throughout North America.

Endosulfan begins to break down as soon as it is applied. The products detected in Dade County are Endosulfan I, Endosulfan II and Endosulfan Sulfate. Endosulfan I and II (also known as alpha and beta) are stereoisomers of the pesticide. Endosulfan Sulfate is a breakdown product. The half-life of Endosulfan is 50 days; after 50 days, one-half of the active pesticide has hydrolyzed into breakdown products; in another 50 days, one-half of the remaining active ingredient will hydrolyze; etc. No concentrations of either the active ingredient or Endosulfan

[1] Excerpt from a Thiodan® specimen label, *Crop Protection Chemicals Reference, 8th ed.*, Chemical and Pharmaceutical Press, 1992, p. 895.

Sulfate have been found that warrant pre-treatment of any packing house wash water prior to discharge.

Because the residue is found in the soil and in the wash water, it must be assumed there may be some pesticide residue in soils collected with waste mulch plastics. We should also assume there may be pesticide contamination on the film itself.

Marcel Vezina of Tech Polymers, Inc., North Naples, FL, a reclaimer of agricultural mulch film, says that the company's "very elaborate water filtration system is second only to our plastic filtration system."

1.1.3.1.5 Type of crop

The type of crop grown may vary the amount of pesticide residue found on mulch film: large-leafed plants with running growth (cucurbits, e.g., squash, melons) would shade the film from pesticide applications more than small-leafed upright plants (nightshades, e.g., tomatoes, eggplant). Also, if the crop is ornamental, the pesticides allowed may be more hazardous or longer-lived than those allowed for application to food crops.

1.1.3.1.6 Related studies

Although some studies have researched the presence of pesticide pollution from incinerated or burned agricultural films, there are no studies currently available detailing the amount (or presence) of pesticide residues on recycled agricultural plastics. Until quantitative analyses are performed on the various waste agricultural films, the current best available information is from other related areas of agricultural waste management.

In the 1989 study, "Chemical and Biological Characterization of Products of Incomplete Combustion From the Simulated Field Burning of Agricultural Plastic," researchers from the U.S. Environmental Protection Agency (EPA), Environmental Health Research and Testing, Inc., and the Accurex Corporation analyzed various samples of agricultural mulch film.[2]

> "...one area of concern was the possible existence of pesticide residues on the plastic and the possibility of the emission of these residues as air contaminates during burning. Due to limited available resources and the uncertainty of the presence of each compound, pesticide stability information and sample history were used to determine the compounds for which the plastic should be analyzed from a list of possible pesticides, herbicides and fungicides used during the growing season.

[2] "Chemical and Biological Characterization of Products of Incomplete Combustion From the Simulated Field Burning of Agricultural Plastic," Linak, W.P., et al., *JAPCA*, June 1989, Vol. 39, No. 6, pp. 836-846. ©1989-Air and Waste Management Association.

A sample of used plastic (made available by the State of Florida) that had been left in the crop row and exposed to the elements for over four months after the end of the growing season was utilized for pesticide residue analyses. Because many of the possible pesticides used are water soluble, highly volatile, or subject to microbial or thermal decomposition, they were eliminated from the list of compounds for analysis. Ultimately, due to availability of resources and analytical capabilities, four gas-chromatographable compounds were chosen for analysis...

"The mass spectral data for chloropicrin, methamidophos, methomyl and the XAD-2 extracts and permethrin were used to screen both the XAD-2 extracts and dichloromethane washes of 454 g (1 lb) of used and unused plastic. None of these four compounds were detected in any of the semi-volatile (XAD-2) combustion samples or dichloromethane washes of the used plastic analyzed...

"In addition, a sample of used plastic was sent to an outside laboratory for analysis by GC/ECD. Standards of the four compounds were obtained from the US EPA Pesticides and Industrial Chemicals Repository and supplied to the laboratory. Again, none of the four compounds were detected in the dichloromethane wash of the 1 kg sample...."[3]

1.1.3.1.7 Protective clothing

Using dependable standard operating practices, fruit, vegetable and ornamental plant growers utilize pesticides and safely handle empty pesticide containers throughout North America. Some of these same practices are followed by recyclers handling pesticide containers. After proper rinsing, even HDPE pesticide containers, that have had direct, prolonged contact with undiluted formulations of pesticides are considered normal solid waste and not hazardous material. Nevertheless, handlers who collect HDPE pesticide containers wear protective clothing and respirators as precautionary measures. Just as every firearm must be handled as if loaded, it is prudent to handle HDPE pesticide containers with appropriate caution.

Preventive measures are judicious precautions to protect workers against possible pesticide residues on waste agricultural plastics. Workers handling the material can be provided protective clothing, such as appropriate pants, jackets, boots, gloves and hats. Similar clothing is worn by pesticide applicators. Protective clothing is also worn by reclamation workers at HDPE pesticide container recycler Envirecycle, St. Joseph, MO. These precautions are taken in light of the findings of an EPA pesticide residue removal study. The EPA analyzed 10 residue removal studies held between 1972 and 1990. Among the Agency's findings:[4]

[3] Ibid., pp. 841-842.

[4] *Container Study, Report to Congress*, U.S. EPA Office of Pesticide Programs, EPA 540/09-91-116, May 1992, p. xv.

> "Regardless of the formulation used in the test, triple rinsing generally removed 99.9999 percent of the residue from 1-, 2.5- and 5-gallon plastic containers."[5]

If handlers or reclaimers feel there is the possibility that air-borne pesticide pollution may result from granulation of waste plastic films, then precautionary measures should be taken. These precautions may include segregating and monitoring the granulating and/or pelletizing process air. Although pesticides are rendered harmless at incinerator temperatures of 2,000 degrees Fahrenheit, the much lower plastic extruder temperatures cannot be expected to destroy all possible pesticide residue.

Solid waste in the form of sludge from waste water treatment may also contain pesticide residues that may need to be treated. To date no studies have revealed levels of pesticide residues that would cause these sludges to be classified as anything but solid waste.

Given that there may be potential pesticide residues in reclaimed plastics derived from some agricultural plastic wastes, care must be taken to identify the products to manufacture with reclaimed agricultural plastics.

1.1.3.1.8 Pesticide residue causing film degradation

Research at the University of Florida, Gainesville, has shown that the fungicide cupric hydroxide can lead to premature degradation of mulch film because of the presence of metallic ions. An aliphatic acid crop oil (an insecticide that kills by suffocation) was also found to accelerate severe ultraviolet degradation of the film.[6]

Some contaminants are incidental to the film's usage, others are due to improper collection techniques. By quantifying and qualifying the nature of all contamination, we will be able to best offer suggestions on how to minimize contamination. Reducing contamination today will allow growers to more appropriately deal with their waste plastics in the years to come.

1.1.4 Barriers to Recycling Agricultural Films

There are two basic subsets of recycling barriers for agricultural films: contamination barriers and cost barriers. These barriers prevent widespread recycling of agfilms. Because of ultra-contamination from soil and vegetative residues, some waste agfilm presents unique barriers to recycling. The various kinds of contamination are discussed in each section on specific films. Some

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[5] Ibid., p. xvi.

[6] "Certain Pesticides Can Lead to Premature Degradation of Polyethylene Mulch in the Field," Hochmuth, G., et al., American Society of Plasticulture, 1993 Proceedings, Kansas, pp. 69-74.

contamination barriers can be addressed and remedied to make recycling agfilms more economical; others are inherent in the use of the film and must be accepted as a cost of doing business.

Most of the barriers to agfilm recycling are the same barriers many other recyclable materials face in today's economy. The high cost of recycling includes:

- distance to market,
- low local landfill tipping fees,
- low volumes of material,
- low inherent value of collected material,
- seasonal generation,
- lack of collection and densification equipment to adequately prepare for market,
- high cost of transportation,
- limited time available to prepare material to market specifications,
- lack of demand for recycled end products,
- technical limitations for using recycled material in products,
- lack of financial incentive, and
- specific to polyethylene, the current low virgin plastic resin prices.

In addition to this framework of recycling barriers, specific barriers that are especially significant to a particular agfilm are listed in the individual film's (greenhouse, mulch, etc.) section.

1.1.5 Current Disposal Methods

In most parts of the country, landfilling is the usual disposal method for municipal, commercial and industrial wastes. The same is true for agfilms. In some areas, agfilm is prohibited from disposal at municipal landfills. In these areas many growers contract with local or national haulers, many of which own and operate their own commercial landfills, for the disposal of agfilm.

Waste-to-energy (WTE) would seem to be an ideal disposal method for agfilm, especially for the more highly contaminated or UV-degraded materials. However, many WTE facilities do not have equipment to break apart bales of plastics. Baled plastics can cause "hot spots" in incinerators that can damage the refractories. The lack of WTE handling equipment can create a problem for those growers wishing to densify agfilms, by baling or rolling, for efficient transportation. If baled, there may be only two disposal options: to either recycle or landfill. Prior to

preparing any material for market, growers must determine how they can meet the market's specifications.

A very small but growing amount of agfilm will be recycled this year. Although much of the agfilm is scattered throughout the country on small, family farm locations, large amounts of agfilm are concentrated at major nurseries and greenhouses, and on dairy farms and cattle ranches. The following sections include the current recycling methods, if any, for the specific agricultural films.

Re-use is possible in some areas of agfilm disposal; however, usually after re-use, disposal is still necessary. From a purist's point of view, one of the best re-uses for agfilm would be as a permanent re-use, such as a vapor barrier under concrete floors. The challenge is to find floors equal to the generation of waste film and waste film in good enough shape to adequately perform the barrier duties without requiring excessive application labor or compromising a quality barrier.

In some cases the waste film may be given to other companies for a re-use application. At small operations, re-use is very applicable, but so too are landfilling and incineration. The current major disposal needs come from large corporate users of agricultural films. Luckily, that is also where the large volumes of film are that can be collected and prepared for reclaimers. It will be necessary for these large growers to develop collection and preparation techniques that foster positive and mutually beneficial relationships with reclaimers.

1.1.6 Agricultural Film Recyclers

Companies that handle, broker and reclaim agricultural films are listed in each of the individual film sections. Full company information on potential markets is included in **Appendix B**. All company listings are alphabetical and do not indicate volumes of plastics recycled. Market conditions fluctuate rapidly and specifications do change. Frequent communication with plastic recycling markets is a must for the success of any plastic recycling program.

1.1.7 Developments and Future Directions

The "Developments and Future Directions" sections discuss various methods to prepare agfilm for market. As in all recycling programs, the methods that work on one operation do not necessarily work on another. Each grower needs to determine which system can be adapted for their own particular set of circumstances. Also discussed are various future possibilities for the promotion of agricultural film recycling.

Appendix C is a listing of companies offering reclamation equipment for post-use agricultural film plastics. Future agfilm recyclers will find the specially designed equipment offered by these companies helpful in addressing the ultra-

contamination present in some agfilm collections. The basic difference between film reclamation equipment and agricultural film reclamation equipment is the extra washing capacity required by agfilm. Considering the overall expense of building and equipping a reclamation plant, the costs of additional washing capacity to accommodate agfilm are minor.

1.2 GREENHOUSE AND OVER-WINTERING NURSERY FILM

1.2.1 Characteristics

Table 1.2 Greenhouse and Over-Wintering Film

Resins	Virgin Blend of Low and Linear LDPE
Colors	Clear, white
Gauge Range	4.0-6.0 mils
Annual Volume	20-30 million pounds
Service Lives	One year; two, three and four years
Distribution	National; concentrated in CA, FL, MI, OH, TX, PA, NY, NJ, NC, CO, TN

1.2.2 Major Manufacturers and Importers

- AT Plastics Inc., Canada
- Armin Plastics Corporation, USA
- CT Film, USA
- FVG, Israel
- Startex, USA

1.2.3 Contamination

- Latex greenhouse shading
- Metal staples
- Moisture
- Normal surface grime
- Possible pesticide residue
- Rust from greenhouse structure
- Sand and soil from rain splatter on sections near the ground
- Sand and soil from film removal operation
- Ultraviolet degradation

1.2.4 Barriers to Recycling

- Improper post-use handling
- Low value of collected film
- Low volumes of film on small operations
- Limited access to baler or other densification equipment
- Limited reclamation facilities
- Widely scattered greenhouse and nursery locations

1.2.5 Current Disposal Methods

Most greenhouse and over-wintering film is landfilled. It is estimated that less than 5 percent of all agricultural plastics are incinerated for energy recovery. A smaller portion of this film is recycled. At times over-wintering film, on a very limited basis, is re-used for the original purpose. More often, the film is re-used as equipment covers or used as construction film. Clear film has also been sliced into strips for use as homemade "plastic strip doors." As mentioned previously, this material has been re-used as permanent vapor barriers for concrete floors.

Currently, disposal methods vary nationwide. The most cost-effective disposal option for a California grower may be to landfill used nursery film at $20 per ton. A Michigan grower, with 300,000 pounds of very clean, white over-wintering film, also may be forced to landfill at $35 per ton. An East Coast grower may have substantially greater landfill tipping fees in the $70 per ton range.

In Florida on the other hand, a grower with mulch film containing 40 percent contamination may pay a low tipping fee at a local reclaimer's facility. The difference in cost of disposal is not always a result of the contamination. Often the ability to recycle film plastics will be dependent upon the existence of a local reclamation

company. For a grower contending with high tipping fees, if a recycling facility is located nearby and will accept the material, it may be more cost-effective to recycle. Even if a reclamation facility is located within a reasonable hauling distance from a nursery, but is closed due to lack of sales, the grower with the cleanest material may be forced to landfill, or worse, to burn on-site.

1.2.6 Recyclers

- Avanguard Industries, Inc., TX
- Carlisle Plastics, Inc., NC
- Denton Plastics, OR
- Enviro Tech, MA
- ITW Angleboard, SC
- Ingenuity Corporation, CT
- Mobil Chemical Co., NY
- Nation Plastics, TX
- New Age Plastic Recyclers, FL
- Obex, Inc., CT
- Plastic Services of America, AL
- Poly-America, Inc., TX
- Poly Pro Products Inc., IL
- Regenesis Recycling, Inc., CA
- Tech Polymers, Inc., FL
- Webster Industries, MA

The above recyclers list includes companies that either reclaim, handle or broker waste film plastics, or all of the above. Some listed may have such strict specification requirements that, for all intents and purposes, the majority of agricultural film may not be acceptable.

Some companies service all areas of the country, while others service only their immediate locale and others service only nurseries that purchase certain manufacturers' films. To determine the viability of any market, growers must contact the markets directly. Markets and specifications change depending upon industry variables. Nurseries successful in recycling film are those that keep up to date with the market changes. Companies accepting nursery film today may not accept it tomorrow. Given the 4- to 6-mil thickness of nursery film, many film reclaimers will be interested in the film if it is collected with an absolute minimum of contaminants.

Denton Plastics, of Portland, OR, has accepted nursery film for over three years. The specifications are simple: baled, over 10,000 pounds and company representatives must view the material before acceptance. Company president Dennis Denton hopes to source funding from industry and government for additional plastics sorting and processing machinery. If successful in sourcing funds, the company would be able to increase capacity to recycle more plastics, including more agricultural films.

At present LDPE nursery film reclaimed at Denton Plastics is blended and compounded into 12 grades of resin. The pellets are marketed to companies manufacturing a variety of products, including thermoformed HDPE nursery pots manufactured by **Gage Industries, Inc.**, of Lake Oswego, OR.

Enviro Tech of Norwood, MA, is currently exporting some film from New England nurseries. Jon DeFreitas, vice president of operations, says the film is marketed to Asia where it is used for the manufacture of durable goods and film.

Ingenuity Corporation, a broker and handler of plastics from New Haven, CT, had planned to ship over 600,000 pounds of white hoophouse film from a few large Connecticut growers to North American Plastics Recycling Corporation (NAPRC) in the spring of 1993. The NAPRC facility ceased operations at that time and was subsequently sold to World Class Film of Yonkers, NY. World Class reclaims only clean post-industrial film. T.J. Goetting indicates his company is researching other markets and still plans to handle agfilm.

Nation Plastics of San Antonio, TX, accepts nursery film deliveries from local growers on a case-by-case basis. In the spring, the company receives from 10 to 15 telephone calls per week from nursery growers searching for markets for waste nursery film. Nation Plastics bales and granulates film and rigid plastics. In July 1993, the company was not charging to handle nursery film, but the company owner, Jim Nation, said that if the markets for the baled film do not improve, the company will have to either begin charging or discontinue handling the film. Mr. Nation's suggestion to growers is to develop a relationship with a market close to their operations. Nation Plastics markets baled film to reclaimers in the United States and Mexico and is a spin-off of Wood Industries, also of San Antonio.

New Age Plastic Recyclers, Pompano Beach, FL, are brokers of recyclable LDPE film. The company sources greenhouse and over-wintering film, both clear and white. New Age will arrange for pickup at grower locations anywhere in the eastern part of the United States. They require full truckloads of high density bales. If baled film is available at lower densities, depending upon the location, it may be picked up and the grower charged a fee to cover the freight.

Webster Industries, Inc., has a plant in Montgomery, AL, that accepts greenhouse and over-wintering films. The company has installed a large stand-alone

system that can cut, grind, wash and dry 12-15 million pounds of LDPE per year. Dennis Collins, former Webster commodity manager, estimated that in 1993 a total of 1-2 million pounds of greenhouse and over-wintering film would be processed through the system. This system represents another opportunity for greenhouse and nursery growers who wish to participate in plastic recycling programs. Webster will arrange for transportation for clean greenhouse and nursery film from most U.S. locations.

1.2.7 Techniques, Developments and Future Directions

A number of techniques and pieces of equipment have been developed to roll and to bale the removed greenhouse and over-wintering film. The following examples highlight some of the latest developments in these areas.

1.2.7.1 Nursery-Built Loader Arm Film-Rolling Machine

Clinton Nurseries of Clinton, CT, purchases and discards approximately 100,000 pounds of hoophouse covering each year. The single-thickness, 4-mil LDPE film is purchased in widths of 28 and 36 feet on 225-foot rolls. The nursery staff built a machine that will roll the film directly off the hoophouses, preventing removal contamination by not allowing the film to touch the ground.

The rolling machine, attached to the loader arms of a farm tractor and powered by a hydraulic motor, creates an 8-foot long, oval-shaped plastic "cigar," weighing about 110 to 115 pounds, with a cross section of 1.5 feet by 2.5 feet. The plastic removal machine will strip a 225-foot long house in seconds. The cigars are then strapped onto 96-inch by 42-inch oak pallets. Using this method, 12,500 pounds of material can be loaded into a 40-foot road trailer. The nearest landfill that will accept the LDPE film is 42 miles from the nursery. Clinton Nurseries has been able to market the film to various recyclers over the past two years, and in the process has saved thousands of dollars in avoided tipping and trucking fees.

1.2.7.2 Dropcloth Method

Keeping nursery film off the ground reduces post-use contaminants to a minimum. Condensation on the film's interior side, when dropped on the ground, acts as a magnet for any dirt contacted. When the film is subsequently rolled or baled, the attracted dirt and sand is wrapped up for delivery to market. A very successful removal technique is to lay down a dropcloth. The dropcloth will protect the other film sheets from contact with the ground. This method requires the removal crew to continually move the dropcloth from site to site. It is also mandatory that the crew does not contaminate the dropcloth by walking on it.

The following instructions are provided to nursery growers by T.J. Goetting of **Ingenuity Corporation**, New Haven, CT.

> "To keep mud and ground water off the greenhouse film while stripping, use the film from the first hoophouse as a ground cloth. Cut the film at the first hoophouse along the nailer or poly-lock and pull it across to the other side that is still nailed or locked. Then stretch the film out in the row or road alongside the hoophouse with the inside surface of the film facing up. If the road is not wide enough, cut the film to the appropriate size, making two or more ground cloths. Then cut the film at the second nailer or poly-lock. (Be sure to keep muddy and wet boots off the cloth at this cutting.) The ground cloth is ready.
>
> "With the ground cloth still alongside the first hoophouse, go to the next hoophouse and cut the film at the nailer/poly-lock alongside the road. It is important to make this cut before moving the ground cloth so that the ground cloth does not get walked on. Then pull the ground cloth alongside the second hoophouse. Cut the film at the nailer on the side opposite the ground cloth and pull it across the hoops onto the ground cloth. Roll or gather the film from the edge of the ground cloth. DO NOT WALK ON THE GROUND CLOTH. Using the ground cloth and not walking on it are the simple secrets for keeping the greenhouse film clean. Proceed to the third hoophouse, cutting the film at the nailer/poly-lock alongside the row before pulling the ground cloth alongside the third hoophouse. Cut the film at the other nailer on the third hoophouse and pull it onto the ground cloth. Roll or gather and proceed to the next hoophouse. If you find that you need to tie the bundle of plastic in order to get it to the baler, please use only polyethylene binder twine. Any other kind of twine contaminates the polyethylene film.
>
> "After stripping two or three houses you will find that you can customize this procedure to fit your own resources. The number of laborers available and the method of gathering and rolling determine the length and width of the ground cloth. It usually ends up one-half to one-third the length of the hoophouse and six to ten feet wide. It may be staked or weighted to the ground on windy days. (If you can choose the time, we encourage stripping on sunny days with a mild breeze. The sun and breeze dry the film and the breeze cools the laborers.)"[7]

1.2.7.3 Commercial Roller

Rol-Zit is a commercially available roller manufactured by **Agrotec**. (See address in **Appendix D.**) Rol-Zit uses a 10-foot long, 3-inch diameter PVC pipe as a roll-core. With one person operating the tractor and two to four others guiding the loose plastic, Rol-Zit will roll a 100-foot length of film in a few seconds. Wide material must be folded to a 10-foot width to fit the roller. Besides rolling greenhouse

[7] "Keeping Greenhouse Poly Clean," guidelines for recycling nursery film, Goetting, T.J., Ingenuity Corporation, New Haven, Connecticut.

and over-wintering film, this roller can also handle other plastics such as mulch film, etc.[8]

1.2.7.4 Nursery-Built Three-Point Hitch Roller

A tractor-mounted, power roller has been developed by **Imperial Nurseries** in Granby, CT. The unit attaches to the three-point hitch of a farm tractor and is powered by the tractor's power-take-off through a chain and sprocket. The roller is large enough to handle 24-foot by 500-foot sheets of plastic that are removed from over-wintering houses.[9]

1.2.7.5 Commercial Balers

In 1990, several **New Holland** hay balers were tested at Imperial Nurseries. No modifications were made to any of the machines; however, a baler with cross feed tines worked better than one having an auger feed. To keep the plastic clean, the plastic was removed from the greenhouse directly to the baler feed. Care was taken to not allow the plastic (22 feet by 100 feet) to touch the ground. The plastic was gathered off the structure by a crew of four or five men and fed into the baler that was stopped adjacent to the side of the house. Once the plastic was started into the baler, the feed mechanism pulled it in and baled it. The baler was then moved to the beginning of the next sheet. The bales were 14 inches by 18 inches by 18 inches and weighed 50-60 pounds.[10] A density of over 20 pounds per cubic foot was achieved.

1.3 MULCH FILM

During the course of the research it has been a challenge to determine what actually is an agplastic and what is not. Figures on mulch film have been placed from a possible low of 25 million pounds per year to a high of 150 million pounds. Using the various estimates by industry representatives, we have settled on a range from 40 to 80 million pounds per year. The real truth is expected near 60 million pounds. Whether the extreme ranges reported are the result of double-counting by industry surveys or non-differentiation between "agricultural film" (agfilm) and "construction and agricultural film" (C&A) is not clear. Carl Hoefer, executive secretary of the American Society for Plasticulture, suspects the problem "may originate in the blurry distinction between stabilized and un-stabilized films, both natural and

[8] "Recycling Film Plastic," Bartok, John W. Jr., presented June 21, 1992, at the 1992 International Summer Meeting, Paper No. 92-4031, American Society of Agricultural Engineers, 2950 Miles Rd., St. Joseph, Michigan 49085-9659.
[9] Ibid.
[10] Ibid.

[pigmented]." Accordingly, poundage figures quoted by some manufacturers may include un-stabilized C&A film rather than only multi-year greenhouse film (**Section 1.2**) and stabilized mulch film reported here.

1.3.1 Characteristics

Table 1.3 Mulch Film

Resins	Virgin Low and Linear Low Density Polyethylene
Colors	Clear, black, brown, green, red, white/black
Types	Smooth, embossed, photo-selective
Gauge Range	0.7-1.5 mils
Annual Volume	40-80 million pounds
Service Lives	One season: 3-9 months
Distribution	National

The majority of mulch film is a blend of low and linear low density polyethylene. The linear low density polyethylene imparts additional stretch and strength to the mulch film. The various proprietary blends are the secrets to successful products. Upon application to the field, mulch film is stretched. Too weak a film will break under the tension necessary for its application. Most manufacturers say this precludes the use of post-consumer material as feedstock for mulch film.

1.3.2 Major Manufacturers

- AEP Industries, Inc., USA
- Armin Plastics Corporation, USA
- CT Film, USA
- Edison Plastics Company, USA
- Tredegar Film Products, USA

1.3.3 Contamination

Mulch film can have contamination of up to 50 percent by weight. This level of contamination is unique in plastics recycling. The contamination is mostly from dirt, sand, moisture and vegetation.

- Crop residue
- Moisture
- Normal surface sand or soil
- Potential pesticide residue

1.3.4 Barriers to Recycling

- Ultraviolet degradation
- Extreme levels of contamination
- Potential pesticide residue concern from solid wastes and waste water from processing
- Difficulties in cleaning in the field, baling, transportation
- High tipping fees at recyclers for very contaminated material
- Lack of facilities to handle ultra-contaminated film

1.3.5 Current Disposal Methods

Most mulch film waste generated in North America is currently being landfilled or burned. Mulch film recycling has been practiced on a limited basis for over 10 years in western Europe. In 1991, British Polythene Industries PLC recycled 3,750 tonnes (8.25 million pounds) of polyethylene films from farmers and agricultural sources.[11] Considering the relative value of virgin plastics in Europe to the cost of reclaiming waste agfilm, the European horticulturist may have an easier time justifying the costs of recycling his waste plastics than the American farmer.

In 1992, **Tech Polymers, Inc.,** of North Naples, FL, began accepting and recycling mulch and nursery films. Since opening, Marcel Vezina, part owner and plant operator, estimates his company has reclaimed between 4 and 5 million pounds of combined agfilm, mostly from the Florida area. **F.B.M** equipment (see address in **Appendix C**) is used by Tech Polymers to reprocess the film. The company charges growers or handlers by the ton to drop off waste agfilm at the company's door.

[11] "Recycling Farm Plastics," by J.R.H. Sale, British Polythene Industries PLC, *Plasticulture*, Vol. 97, 1993.

Agricultural Plastics Retrieval, a Bonita Springs, FL, company, provides a service to vegetable growers by picking up the waste mulch film from the fields. The company uses equipment that shakes excess soil from the film and bales or rolls the waste plastic. The film is delivered to Tech Polymers where it is cleaned, shredded and then molded into film "roll cradles." The roll cradles are used by the film industry to load film rolls onto pallets for storage and shipping. **CT Film** is one company that purchases the cradles to use for their new mulch film sales.

Another "disposal" method has actually been on-site storage. This is often due to spirited collection programs preceding the essential knowledge of required market specifications. These problems have been reported in New Jersey where some growers have baled mulch plastic with large "round bale" hay balers, only to later discover the market could not accept the high level of contamination. Bales were then placed on the edge of fields like massive stone walls. Another storage technique has resulted in a very large stockpile at the Collier County landfill in south Florida. The film, available to any interested party at no charge, is reported to be in the millions-of-pounds category.

A small amount of mulch film is assumed to be incinerated in waste-to-energy facilities.

On-site, portable incinerators are also used on a very limited basis in the Southeast to burn mulch film. The practice is to mechanically lift the film "tuck" out of the soil. Field workers then cut the film into manageable lengths that they "ball-up" and throw into the incinerator like a basketball. The vertical, 6-foot diameter incinerators are mounted and transported on a wheeled axle and fired by propane gas. The temperature is sufficiently high to prevent any black smoke that could result from inadequate oxidation. Because of the extreme temperatures at which these incinerators operate, they are potentially dangerous for the field workers and are not a popular form of disposal.

Propane is also used to burn the mulch film in place. This is accomplished with tractor-mounted burners. Each row burner is equipped with three nozzles. The nozzles are positioned in the middle and on each side of the plastic mulching strip. The nozzles are attached to a boom and fed from a 500-gallon propane tank mounted on a tag-along trailer. Models are available in both one- and three-row configurations and are priced in the $4,000 to $5,000 range. **Kennco Manufacturing, Inc.**, of Ruskin, FL, is a manufacturer of various pieces of agricultural equipment, including row burners. Joseph Sobel, sales manager, says costs per acre to burn the film vary greatly depending upon terrain and the resultant tractor speed.

After burning, the unburned tucked film is pulled out of the soil by hand and gathered for disposal. In some municipalities, burning mulch film in the fields has been prohibited. Restriction of field burning seems to be the wave of the future. Sue

Alspach, Dade County Department of Environmental Resources Management, reports the air is "black with smoke" from field burning in some Dade County areas.

1.3.6 Recyclers

- Agricultural Plastics Retrieval, FL
- Polychem Products, Ltd., Quebec
- Tech Polymers, Inc., FL

1.3.7 Developments and Future Directions

Mulch film recycling could benefit from research and development for collection equipment to reduce the amount of soil adhering to the film. Washing equipment, to reduce the bulk of the soil contamination, is a possibility. Baling equipment developments by **Sonoco Products Company** for HDPE mulch film are detailed in **Section 1.6.** Equipment of this kind, combined with an on-site pre-washer, can increase the recyclability of the film by densifying the film and reducing the pounds of contaminating soil. Both actions will help to ensure more cost-efficient transportation and reduce the costs of waste soil disposal at reclamation facilities.

Reclamation equipment is costly, and illegally burned or buried mulch film is cheap in the short run. Until it becomes more difficult to dispose of the film on-site by burying or burning, there will be little impetus for companies to invest in the capital-intensive reclamation equipment needed to reclaim this ultra-contaminated film.

1.4 FUMIGATION FILM

Fumigation service companies purchase fumigation film and apply it to the soil while simultaneously introducing a liquid stream of pesticide to the soil. The pesticide vaporizes and fumigates the soil, killing targeted pathogens. The unscented fumigant used is methyl bromide, necessitating a 2 percent scented chloropicrin as a safety feature. Methyl bromide is used extensively on strawberries and tomatoes.

One of the latest developments in fumigation techniques is the experimental "solarization" research being conducted in Florida. Daniel Chemellemi, plant pathologist at the University of Florida, is hoping to eliminate the need for the chemical pesticides. By leaving light-green transparent film with photosynthetically active radiation (PAR) inhibitors on fields for 4 to 6 weeks, researchers have

increased the soil temperatures to 120 to 130 degrees Fahrenheit. The intent is to pasteurize the soil and kill the harmful pathogens.

Dow Chemical Company manufactures a blended polyethylene barrier film that is used by manufacturers of fumigation film.

1.4.1 Fumigation Film Characteristics

Table 1.4 Fumigation Film

Resins	Virgin blends of L/LLDPE/HDPE
Colors	Clear, light-green
Gauge Range	1 mil; some 2 & 3 mils for tobacco
Annual Volume	10-15 million pounds
Distribution	CA, FL, GA, NC, SC

The 2- and 3-mil fumigation film sometimes used on tobacco is first utilized for fumigant application and later lifted for use as a seedbed cover to promote germination and early growth.

1.4.2 Major Manufacturers

- AEP Industries, Inc., USA
- Armin Plastics Corporation, USA
- Cadillac Products, Inc., USA
- Dow Plastics, USA

1.4.3 Contamination

- Glue
- Moisture
- Sand and soil

1.4.4 Barriers to Recycling

The largest barrier to recycling fumigation film is the current disposal method. In removing the film from the fields, the film removal crews gather the clean film and the very contaminated glued tuck sections simultaneously. The glue can weigh as much as 75 pounds per acre. At 1 mil, the weight of the plastic film per acre is around 210 pounds. (Polyethylene weighs 4.8 pounds per mil of thickness per

1,000 square feet applied.) Glue contamination in this case is 25 percent, too high for efficient reclaiming. Even a water soluble glue that could be washed could increase the cost of water treatment so as to prohibit the film's recycling. The glue also attracts soil and other contaminants.

Low landfill tipping fees also reduce the impetus to recycle. In Florida, permits for on-site burning of fumigation films are slowly being eliminated as rural locations become more suburbanized.

1.4.5 Current Disposal Methods

There are two types of fumigation film applications: bed and broadcast. Bed is when strips of film are placed only over the field beds and not on the walk-path. Both edges of the bed-film are tucked 6 inches into the ground. In broadcast or "tarp" fumigation, the entire surface of the field is covered by row upon row of 10.5- to 13.5-foot sections of fumigation film. The first strip of film is double-tucked into the ground. With each subsequent strip, one edge of the film is glued onto the previously applied row of film and the other edge is tucked into the ground. This process is repeated until the field is completely blanketed in film. The price for broadcast fumigating one acre is in excess of $1,000, a modest cost considering the value of the fruit and vegetable crops grown.

Fumigation film is usually removed from the field one to four days after it is applied. In some areas the film remains on the soil for up to a few weeks. Removal is usually performed by independent "pullers" utilizing four-wheeled "all-terrain vehicles" equipped with two tuning-fork-shaped yokes located over the front wheels. The sections of glued-together film are first cut into the original widths: A vehicle with a cutter travels back and forth, cutting the film down the middle of the clear-spans, leaving the tuck in the ground with two 6-foot wide wings of film. The tuck, which includes the glue strip, is pulled out of the ground by hand and threaded through the puller vehicle yokes. The vehicle is slowly driven ahead and the "pulled" film is placed under the rear tires. Now the vehicle can travel through the field at 10-15 mph (very fast) pulling the film out of the ground. The film is then retrieved by crews, placed in trucks and removed to the landfill.

1.4.6 Recyclers

Regenesis Recycling, Inc., CA

1.4.7 Developments and Future Directions

There is a need to design and utilize equipment that would cut the useful, clean film from the area between the two glued "tucks" prior to the "pullers" ripping up and disposing of the tucks. Film-rolling equipment, very similar to the machine

designed by Clinton Nurseries (see **Section 1.2.7.1**) could be used to collect the film. The roller located on the bucket-arms of a farm tractor could have "out-riggers" placed just ahead of a 12-foot roller. The out-riggers could ride on small, possibly 10-inch diameter, wheels and be equipped with blades to slice the film. As the film is sliced, the roller would take-up and roll the film at the same speed as the tractor moving down the field. Because of the tuck, the film could be removed under tension. This tension would enable the film to be elevated slightly from the soil surface, facilitating the cutting and allowing the roller to roll the film very tightly for efficient handling.

A counterweight on the rear of the tractor could allow the rolling of 2,000 pounds or more before the roller would need to be emptied. After the good film is removed from the field, the pullers could begin pulling the tuck and glue from the field for landfilling. This operation could result in approximately 90 percent (190-200 pounds per acre) of the film being collected for recycling and only 10-20 pounds of film and 75 pounds of glue landfilled. Landfill space saved could be substantial and a valuable resource would be harvested.

In areas such as Southern California, which have high broadcast fumigation film usage, there are millions of pounds of fumigation film that could lend themselves to high efficient recovery rates. **Tri Cal, Inc.**, of Hollister, CA, is the largest fumigation service in the United States. Tri Cal dominates the fumigation business, with an estimated 75 percent share in California and 90 percent nationwide. Given the concentration of the fumigation film business in one company, business opportunities may exist for exploration of a recycling connection.

1.5 DEGRADABLE MULCH FILM

1.5.1 Characteristics

Table 1.5 Degradable Mulch Film

Resins	Virgin L/LLDPE
Colors	Clear, black
Gauge Range	1 mil
Annual Volume	2-4 million pounds
Service Lives	One season: 30-140 days
Distribution	Southeast United States

Degradable films degrade in two manners: biodegradation and photodegradation. When it comes to breaking down at the right time, biodegradable films have not fared well. The current industry perception is that biodegradable mulch film is a dead end. Whether the future performance of biodegradable films will change this sentiment has yet to be determined. It would be very beneficial to the agricultural industry if formulations and manufacturing techniques develop that would allow the widespread use of biodegradable mulch film. **Cornell University** engineers reported in 1992 that when several biodegradable films were digested, both aerobically and anaerobically, very little [film] weight was lost.[12]

All films are eventually photodegradable but some are specifically formulated with the express intent to photodegrade on schedule.

1.5.2 Current Major Degradable Manufacturer

Plastigone Technologies, Inc., USA

1.5.3 Contamination

Not applicable to films designed to remain in the field, although field contamination may occur as a result of non-degraded buried pieces.

12 "Biodegradability of Modified Plastic Films in Controlled Biological Environments," by Larry R. Krupp and William J. Jewell, *Environmental Science and Technology*, January 1992.

1.5.4 Barriers to Recycling

Not applicable to films designed to remain in the field, although degradable films, when commingled with films to be recycled, can create havoc for a product not intended to degrade.

1.5.5 Current Disposal Methods

The following excerpts are from sales brochures detailing the passing of degradable mulch films.

Stages of Disintegration[13]

The disintegration process occurs in stages.

STAGE 1 - Small cracks will appear transverse across the top of the bed, never in the direction of the row.

STAGE 2 - Disintegration will be fairly rapid. The cracks will become larger.

STAGE 3 - Film will pop up like a cigarette roll and when rubbed between fingers, will flake.
(Stage of Embrittlement)

STAGE 4 - "PLASTIC-GONE!"

Note: Once the process has reached Stage 3 (Stage of Embrittlement), nothing can stop the disintegration and the process will continue even in the absence of light.

"At the end of the season, in order to hasten breakdown, growers may bush hog (rotary mow) the crop or spray a herbicide or a desiccant to remove completely the dying vines and expose the film to the sun. BIOLAN® films break down to small pieces which can be readily angle disked into the soil.

"With respect to the tuck, some growers have found that cross disking several times brings the tuck up to the surface, thereby exposing the film to light which then degrades the tuck. Others lift the tuck after disking, using a sharp flat blade similar to that used to lift potatoes. Still others have rototilled the field, cutting the tuck into small pieces and bringing it to the surface for exposure to the sunlight."[14]

BIOLAN® films were formerly produced by CT Film. They were designed to photodegrade when exposed to sunlight and then biodegrade to humus, carbon dioxide and water. CT Film has stopped manufacturing degradables and has dedicated the machinery time to the manufacture of non-degradable mulch films.

[13] Plastigone® brochure, Plastigone Technologies, Inc.
[14] BIOLAN® product sheet, Consolidated Thermoplastics Company (CT Film).

1.5.6 Recyclers

Not applicable to films designed to remain in the field.

1.5.7 Developments and Future Directions

Plastigone Technologies, Inc., is now the only significant manufacturer of degradable mulch films in the United States market. The company's mulch is an "ultraviolet activated, time-controlled biodegradable plastic." Richard Wetherford of Plastigone says degradables cost an average 10 percent more than non-degradable mulch film.

If the film can truly break down (and not just break up), degradables could become a very attractive alternative to conventional films. Plastigone has installed a new coextrusion die to allow the buried tucked edges to be manufactured from a different formulation than the body of the film. The clear edges are manufactured to degrade under the soil without the advantage of bright sunlight. The bulk of the film exposed to the sun is formulated to degrade over variable lengths of time depending upon crops treated and climatic conditions.

1.6 HIGH DENSITY POLYETHYLENE ENVIROMULCH™ FILM

1.6.1 Characteristics

Table 1.6 HDPE Mulch Film

Resins	Virgin High Density Polyethylene
Colors	White/black, black
Gauge Range	1 mil and under
Annual Volume	1-3 million pounds
Service Life	One season
Distribution	Southeastern United States

HDPE is stronger than LDPE and can be manufactured in thinner sheets, covering more area per pound. HDPE however has less ability to stretch than LDPE-type films, making application to the ground at times more difficult.

1.6.2 Sole Manufacturer

Sonoco Products Company, USA

1.6.3 Contamination

Same as LDPE mulch film

1.6.4 Barriers to Recycling

Same as LDPE mulch film

1.6.5 Current Disposal Methods

Sonoco Products Company developed "Enviromulch™" at the beginning of 1991. When the company began marketing the HDPE mulch film, they also offered to recycle the film by picking up the baled waste at the farm for no charge. Sonoco planned to site a reclamation plant for the mulch film by the end of 1991. The program, limited to the Southeast, has experienced growing pains in the past two years. The company did not build the anticipated recycling plant; instead, the company decided to send their collected material out for reclaiming.

Early in the development of Sonoco's collection program, it became evident that the growers were unable to collect the film for recycling without sophisticated equipment. Accordingly, Sonoco engineers developed a baler that could move from farm to farm to collect and densify the film. Sonoco has a patent pending on the tag-along baler. Seven balers have been manufactured to the company's specifications and all are currently used for the collection of Enviromulch™ film from customers' fields.

To begin the collection and baling operation, a tractor equipped with a "lifter" travels through the fields lifting the two tucked edges of the mulch film out of the soil. Then the baler is pulled through the field following the lifter. Farm workers thread the loose film onto a conveyor that feeds the hydraulically operated baler. Two-thousand-pound bales are produced from the very contaminated film.

During 1993, Sonoco used some collected HDPE mulch for the manufacture of garbage bags and new mulch film. The company also sent some material to waste-to-energy facilities. In 1994, Sonoco will be directing all of the collected mulch film to waste-to-energy facilities, citing this disposal option as more cost-effective than reclaiming the material and using it in new film products.

1.6.6 Recyclers

None at present

1.6.7 Developments and Future Directions

If Sonoco Products Company is granted a patent for their mulch film baler design, the company may market them to mulch film customers.

1.7 IRRIGATION TUBING

1.7.1 Characteristics

Table 1.7 Irrigation Tubing

Resins	Virgin Blend L/LLDPE
Colors	Clear, blue, orange, white, others
Gauge Range	6-10 mils
Annual Volume	12-15 million pounds

Approximately nine companies manufacture irrigation tubing. Most of the tubing is used in the southern and western United States: Texas, Missouri, Arkansas, Michigan, Louisiana, Colorado and California. All resin used is virgin to insure against failure from the weight of the moving water. Crops irrigated are primarily rice, cotton, corn and soybeans. Over the past 20 years, LDPE irrigation tubing has come from obscurity to commanding over 80 percent of the above-ground irrigation tubing market. LDPE tubing for the most part has replaced PVC above-ground tubing and the heavier and more expensive steel and aluminum irrigation tubing.

Irrigation tubing can be used only on very level fields and cannot be pressurized. Also, water cannot be pumped uphill through the flexible tubing. The pressure would burst the tubing like a balloon. Irrigation tubing is also called both poly pipe and poly tubing, names identified with individual manufacturers' products.

1.7.2 Major Manufacturers or Distributors

- Armin Plastics Corporation, USA
- Automated Agricultural Systems, Inc., USA
- Continental Products, USA
- IPSCO, USA

Some of the above are sole distributors (not manufacturers) of irrigation tubing that is manufactured by other companies exclusively for these companies. Accordingly, because these distributors are the companies who have direct contact with the users of the tubing, they are listed here in place of the actual manufacturer.

1.7.3 Contamination

- Deposits of iron oxide
- Fish and other wildlife pumped from reservoirs
- Indirect contact with pesticides
- Sand, clay and loam in the 10 percent range

1.7.4 Barriers to Recycling

- Contamination
- Lack of collection systems
- Lack of reclamation facilities

1.7.5 Current Disposal Methods

Most tubing is removed from the fields using homemade tubing rollers attached to the three-point hitch and hydraulically or power-take-off powered. Current disposal methods are predominantly on-site landfilling and burning. Almost all states where the irrigation tubing is used have restrictions against on-site burning.

1.7.6 Recyclers

- Arkansas Plastic Recyclers, Inc., AR

1.7.7 Developments and Future Directions

One way to collect and recycle the irrigation tubing is to roll (like a fire hose, the tubing will lie flat when empty) on-site, load on a flatbed trailer and transport to a reclamation plant. Another option could be to utilize a portable granulator for on-site densification of the tubing prior to transport.

The fewest possible number of steps between the grower and the reclaimer will be the most cost-effective for the grower. Existing purchasing cooperatives that purchase the new tubing could act as drop-off sites. According to Joseph Alexander of **Armin Plastics Corporation**, many such groups are willing to participate to address the farmers' needs in a cost-effective manner.

Ken Rial, sales manager for **Arkansas Plastic Recyclers, Inc.** (APR), reported that installation of a new reclamation plant in Stuttgart, AR, was expected to be completed by February 1994. Plant capacity will be 1,000 pounds per hour, and the company plans to operate 24 hours a day and close to seven days a week, if possible. Their initial plan is to source irrigation tubing exclusively. In the future, APR may expand to include HDPE bottles as feedstock.

The plastics reclamation equipment was designed and built by the **Cumberland Engineering Division of John Brown, Inc.**, South Attleboro, MA. APR will reclaim the irrigation tubes, blow film stock and convert the film to consumer products such as trash can liners. Some of the production is also expected to be available for sale to other end product manufacturers. By August 1993, APR was accepting irrigation tubing at the Stuttgart location from growers in the Arkansas Delta area. Growers or handlers deliver waste irrigation tubing either in rolls or in lengths cut to 20 or 30 feet. At present the company does not have stringent specifications for acceptance of the material, rather their immediate concern is to source enough irrigation tubing to enable APR to process continually. Although APR expects initially to source material from Arkansas, Louisiana, Mississippi and Missouri, APR also has received interest from growers in Texas. APR operates a consolidation location in Mississippi where growers may deliver collected tubing.

The Cooperative Extension Services located at the University of Arkansas and at Mississippi State are working with APR to develop a network to assist growers in collecting the waste irrigation tubing for delivery to APR.

1.8 SILAGE BAGS

1.8.1 Characteristics

Table 1.8 Silage Bags

Resins	Virgin L/LLDPE/EVA
Colors	White, white-on-black
Gauge Range	4, 5, 7.5 and 9.5 mils
Annual Volume	7-9 million pounds

Silage bags, also called silage tubes, are from 8 to 12 feet in diameter and 100 to 250 feet long, weighing from 100 to 200 pounds each. The bags are used by dairy farmers and cattle ranchers to store corn silage in horizontal piles on the farm or ranch. Silage has provided farm-grown fodder at low cost for years. LDPE silage bags provide a low-cost manner of storage. In the past, farmers and ranchers constructed expensive vertical silos. In an attempt to reduce costs, horizontal concrete silos were developed, but they also caused high storage losses. Conversion from concrete to plastic, for the storage of silage, provides low-cost silage with minimal spoilage.

The heaviest use of silage bags is on the West Coast, followed by Eastern New Mexico and Texas and finally the Northeast, from Minnesota to New England. New England farms average under 100 head of livestock and may use one to two silage bags per year. Nebraska farms at 500 head and California ranches of 1,000 head may be considered "small." Western ranches using 20,000 pounds of silage bags per year are not uncommon.

1.8.2 Major Manufacturers

- AT Plastics Inc., Canada
- Poly-America, Inc., USA
- Startex, USA
- UpNorth Plastics Corporation, USA

1.8.3 Contamination

Because silage is a fermented corn product, most of the contamination consists of solid and liquid organics as well as soil and sand from normal usage. Soil contamination is introduced by tractor tires. When the bags of silage are cut open in the process of removing the silage, they are driven onto with a bucket loader tractor.

1.8.4 Barriers to Recycling

- Heavy contamination
- Limited volumes
- Rural locations
- Odor of cooked silage in reclaimed plastic pellets

1.8.5 Current Disposal Methods

Landfilling plastic wastes with high levels of organic contaminants can pose a threat to ground water. Modern lined landfills do provide ground water protection. Because of the isolated locations and minimal number of silage bags in much of North America, much of the disposal of silage bags is reported to take place on the farm by mostly pile-burning and limited on-site burying.

1.8.6 Recyclers

Stephen Clarke of the Ontario Ministry of Agriculture and Food, Kemptville, began a pilot program in the spring of 1993 to collect silage and haylage bags for recycling. Other sponsors of the pilot program included:

Manufacturers:

- AT Plastics Inc.
- Mobil Canada

Distributors:

- Ag-Bag International Ltd.
- Tube-O-Later

Reclaimers:

- Plast Re Tech
- Polychem Products Ltd.

Others:

- Eastern Ontario Soil & Crop Association
- Local Ford and New Holland equipment dealers
- Ontario Forage Council
- Ottawa-Carleton Soil & Crop Association
- Renfrew Soil & Crop Association

Around 35 local farmers volunteered to have their waste bags baled. An unmodified New Holland 315 baler was used.[15] Fourteen tons were collected and shipped to **Polychem Products, Ltd.** in Saint-Jean-Sur-Richelieu, Quebec, where they were processed into pellets. A problem with the reclaimed pellets is that they sometimes exhibit an unpleasant odor due to the un-removed contamination. Polychem's normal production time was doubled due to plugged filters caused by the levels of non-plastic contamination.[16] Ron Parquette of Polychem Products says the company has been experimenting for a few years with agricultural plastics recycling. The company welcomes more agricultural film and cautions that utmost care must be taken to reduce the amount of contamination. The greatest problem in reclaiming agfilm waste at Polychem is the abrasion to the reclamation equipment caused by the sand and soil embedded in the film.

Polychem shipped some of the reclaimed pellets to AT Plastics for quality testing.

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15 "Baling Silage Bags," *Farm Show*, Vol. 17, No. 5, 1993.
16 "Agricultural Plastics Recycling Currrent Status," Steve Clarke, OMAF, December 1993.

A portion of the bales were sent to Plast Re Tech, a plastic lumber manufacturer. The collected agfilm was too wet and dirty for Plast Re Tech's process of plastic lumber manufacturing. Other plastics collected with the silage bags included stretch wrap. Bales of stretch wrap were processed into pellets by Mobil Canada and shipped to Mobil Chemical (U.S.) for evaluation.

In late summer 1993, **Ag-Bag International** began a recycling program for their silage bag customers in the southeast United States. The U.S. program is based upon a collection truck with an 18-foot flatbed that hauls a 24-foot trailer. Mounted on the trailer is a horizontal baler and a "cherry picker" similar to those used by the logging industry to load logs onto trucks.

The operator picks the waste silage bags from piles at the farm, shakes off the loose contamination and loads the baler hopper. The baler produces 1,200-pound bales that are loaded onto the truck's flatbed. The bales are then stored at an Ag-Bag facility until a back-haul can be provided by Poly-America.

- Ag-Bag International Ltd., OR
- Poly-America, Inc., TX
- Polychem Products, Ltd., Quebec
- UpNorth Plastics Corporation, MN

1.8.7 Developments and Future Directions

In most areas, incineration at a WTE plant would be the most environmentally acceptable method of disposal for silage bags. In rural areas with great concentrations of silage bags however, WTE facilities usually are not available. Even though the contamination may be high, the heavy film gauge range of 4 to 9.5 mils may add enough value to the material to warrant profitable recycling.

As with agricultural film in general, much cleaner, more cost-effective post-use plastics are available for recycling. If not today, then soon, less-contaminated films will threaten many recycling attempts of ultra-contaminated films.

1.9 Low Density Polyethylene (Hay and Haylage) Bale (Stretch) Wrap Film

1.9.1 Characteristics

Table 1.9 LDPE Bale Wrap Film

Resins	Virgin LLDPE
Colors	White
Gauge Range	0.9-1.0 mil
Annual Volume	20-30 million pounds

Stretch wrap is used to protect 1,600-pound round hay and haylage (moist hay) bales from the elements. This market has increased significantly over the last few years. The plastic helps reduce spoilage and loss of nutrients in the hay. In the haylage bales, fresh, high-moisture alfalfa or clover-type hay will be completely covered with the stretch film to prevent oxygen invasion. In an anaerobic atmosphere, the moist haylage ferments to create a high-nitrogen, very nutritious dairy ration. Hay wrap is usually 50 to 65 inches wide, while haylage wrap is more often marketed in widths of 20 to 30 inches.

1.9.2 Major Manufacturers

- AEP Industries, Inc., USA
- Mobil Chemical Company, USA

1.9.3 Contamination

- Mold from haylage
- Product residue from hay and haylage
- Ultraviolet degradation

1.9.4 Barriers to Recycling

The barriers to recycling bale wrap are similar for other agfilms. A bale requires approximately 2 to 2.5 pounds of LLDPE film for full coverage. An average farmer may have 500 bales to feed his herd during a 6- to 8-month period. At the end of the season, the farmer would have a pile of film that had been cut off the bales and stored in a barn for half a year. The amount of incidental barn dust that can fall on a pile of waste film can be substantial.

1.9.5 Current Disposal Methods

On-site burning and landfilling are the most widely used disposal methods. Limited amounts of stretch agfilm are reported recycled.

1.9.6 Recyclers

- Mobil Chemical Company, Canada and USA
- Polychem Products, Ltd., Quebec

1.9.7 Developments and Future Directions

Continued landfilling of this material seems to be the most realistic direction for most farmers to pursue. Although Mobil Chemical Company has a nationwide stretch wrap recycling program, the minimum quantities are 5,000 pounds of clean, baled material. These normal industry standards highlight the fact that landfilling and resource recovery through WTE are the most appropriate methods currently available.

In 1991 and 1992, there were limited moves by members of the bale wrap industry to design and make available a fence post mold. The idea was that livestock ranchers would be able to convert the waste bale wrap into fence posts for on-site use. To date, advancement of this idea has not met with success.

1.10 HAYSLEEVE COVERS

1.10.1 Characteristics

Table 1.10 Haysleeve Cover Film

Resins	Virgin L/LLDPE
Colors	White
Gauge Range	0.9-1.0 mils
Annual Volume	2-3 million pounds

Haysleeve covers are LDPE tubes that slip over round hay bales. They are alternatively called balesleeves, bale bonnets and slip-ons. The bale is placed on its rounded side. The sleeve protects the hay from rain and ground moisture. The ends of the bale are left open for ventilation.

1.10.2 Major Manufacturers

- AEP Industries, Inc., USA
- Armin Plastics Corporation, USA
- Crayex Corporation, USA

1.10.3 Contamination

- Mold from hay
- Product residue from hay
- Ultraviolet degradation

1.10.4 Barriers to Recycling

- Limited volumes
- Rural locations

1.10.5 Current Disposal Methods

On-site burning and landfilling are the most widely used disposal methods.

1.10.6 Recyclers

Unknown

1.10.7 Developments and Future Directions

Unknown

II PLASTIC NURSERY CONTAINERS

2.1 INTRODUCTION

The use of plastic pots in the nursery industry has expanded greatly in the last few years. As in other areas of commerce, horticultural businesses have taken advantage of plastic's light weight and low cost. Plastic is the packaging material of choice for growing and marketing flowers and foliage to an expanding public market with a "green thumb." The nursery container industry is itself a large market for recycled post-industrial plastic scrap. Most container manufacturers use no virgin resins.

Plastics used by nursery container manufacturers range from virgin resins to plastic bag scrap, and from milk and detergent bottles to old nursery containers themselves. Within the blends of scrap used for many containers, there are mixes of not only various melt indices within resin families, but also commingled mixes of different resins. The melt index (MI) is a measure of viscosity. It is an approximate function of, and is inversely proportional to, the molecular weight of the resin.

When a polymer's molecular bonds are broken, either by design or by UV degradation, a smaller polymer chain is the result. The smaller the chain, the faster the plastic "flows," "runs" or "drips" when heated for molding. As this characteristic of flow increases, and as the length of the polymer chains decrease, the plastic becomes more suitable for injection-molding rather than blow-molding operations. Accordingly, if a blow-molded HDPE nursery pot sustains UV degradation, it may be that the pot's resin cannot be used to blow mold another pot, but it may be suitable material for injection-molded pots.

Polypropylene at times can be processed in a mix with high density polyethylene for molding nursery pots. As with plastic lumber manufacturing, a small percentage of polypropylene — 10 percent or less — usually does not cause problems in the manufacturing process. Mixing the two polyolefin resins has no inherent value and it is not done by design, but rather as a result of resin cross-contamination.

2.1.1 Nursery Container Characteristics

The nursery industry uses high density polyethylene, polypropylene and polystyrene as the three basic resins from which to manufacture containers. The following table gives estimated quantities of these resins consumed by this market. As the table indicates, there is much more agreement among container

manufacturers as to the quantities of pots manufactured than there is among the manufacturers of agricultural films.

Table 2.1 1992 Estimated Quantities of Nursery Containers (Million lbs.)

Container Market	Low	High	Avg.
Blow-Molded HDPE Pots	80	100	90
Injection-Molded HDPE Pots	100	100	100
Injection-Molded Polypropylene Pots	80	90	85
Polystyrene Nursery Pots, Packs and Flats	60	80	70
Plastic Nursery Container Totals	**320**	**370**	**345**

2.1.2 Major Manufacturers

The major manufacturers of the various kinds of nursery containers are listed in the individual container sections and a full listing is provided in **Appendix A.**

2.1.3 Contamination

Most nursery pot contamination comes from residue from potting soils. Because many nursery pots spend their lifetimes in the sun, many containers also have advanced ultraviolet degradation. Contamination by pesticide residue is a very remote possibility for nursery containers.

2.1.4 Barriers to Recycling

- Lack of collection infrastructure
- Limited markets
- Lower-quality resins
- Mixed resins
- Ultraviolet degradation

2.1.5 Current Disposal Methods

Most of the nursery pots manufactured find permanent homes in landfills. Nursery containers are purchased by consumers and are eventually set out with the trash. Re-use is a strategy that works for many companies and homeowners. Often flowers and shrubs are begun at the nursery in small 1-gallon containers, only to be re-potted in a few months into larger containers. The used 1-gallon containers are

often re-used for the next crop. Homeowners always seem to have enough pots on hand in the garage, barn or basement when one is needed for a re-potting job.

Few municipal recycling programs accept nursery pots regardless of polymer type. Accordingly, the majority of pot recycling is done within the confines of the horticultural industry. Very little material is at present reclaimed. Landscapers are one group that can accumulate a sizable amount of plastic pots through everyday activities. Landscaping businesses require the purchase of many potted plants. Wholesale and retail plant growers sell the pots along with the plants and therefore usually do not have large quantities on hand.

As a customer service, many retail garden centers accept nursery pots from their customers for later re-use, recycling or disposal. **Obex, Inc.**, a plastic lumber manufacturer located in Stamford, CT, has developed a network of retail operations in the Northeast that collect their customers' used commingled pots. The small amount of residual soil does not interfere when incorporating the pots into Obex's NovaWood™ products. Obex also markets products made from the nursery pots back to the retailers in the form of compost bins, landscape timbers and planters.

2.1.6 Recyclers

Companies that accept nursery pots for recycling or re-use are listed as recyclers in the following sections. Complete company information is located in **Appendix B**.

2.1.7 Developments and Future Directions

The nursery container market is an area where vast quantities of post-consumer plastics such as milk and detergent bottles could be utilized. Some companies are using millions of pounds of these reclaimed containers today. The future will see more manufacturers actively pursuing this material.

More collection programs will begin at nurseries and garden centers that will give the consumer the opportunity to return their used pots to be either re-used by the grower, packaged and shipped to a reclaimer, or collected for the manufacture of plastic lumber as in the case of **Obex**.

2.2 BLOW-MOLDED HIGH DENSITY POLYETHYLENE POTS

2.2.1 Characteristics

Blow-molded high density polyethylene nursery pots are made from the same material as milk and detergent bottles. In fact, some companies manufacture their pots exclusively out of post-consumer HDPE bottles. Other companies manufacture with primarily virgin resin. Pots manufactured from virgin resin can be competitive in part by large-volume resin purchasing. The purity of the virgin resin also allows the manufacture of extremely thin-walled containers. Most blow-molded HDPE pots have thicker walls, necessitated by the lesser quality off-grade and scrap resins used by the industry.

Table 2.2 Blow-Molded HDPE Containers

Resin	Virgin, Post-Industrial & Post-Consumer HDPE
Colors	Green, black
Annual Volume	80-100 million pounds
Distribution	National

2.2.2 Major Manufacturers

- IEM Plastics, Inc., USA
- ITML Inc., Canada
- Lerio Corporation, USA
- Nursery Supplies, Inc., USA
- Zarn, Inc., USA

Most of the manufacturers of blow-molded HDPE nursery pots have used industrial scrap for years. Some company representatives say they have never seen virgin resin used in their plants. Other companies use only virgin material and compete through high-volume resin purchases and thin-walling the containers.

IEM Plastics and **Zarn** are related companies located in Reidsville, NC. The majority of their resins come from municipal collections of milk and detergent bottles. **Nursery Supplies** is probably the largest U.S. nursery container manufacturer, using mostly virgin resin at three locations to manufacture pots. **Lerio** has four manufacturing facilities across the United States. **ITML** is partially owned by the government of the Netherlands.

2.2.3 Contamination

- Commingled containers of non-blow-molding HDPE resin
- Potting soil residue
- Sand

2.2.4 Barriers to Recycling

- Contamination
- Commingled resins
- Lack of collection infrastructure
- Limited markets
- Lower-quality resins
- Resins with mixed melt indices

2.2.5 Current Disposal Methods

Most used nursery pots are landfilled. Some have their inherent energy recovered at waste-to-energy plants.

2.2.6 Recyclers and Re-users

- Denton Plastics, OR
- Hillside Growers, FL
- IEM Plastics, Inc., NC
- Obex, Inc., CT
- Plastic Recycling Services, Inc., WV

In 1992, **Plastic Recycling Services** (PRS) began a plastic recycling program specifically for HDPE blow-molded containers with the Landscaper Contractors Association (LCA) of Gaithersburg, MD. LCA collected, sorted and stretch wrapped pallets of HDPE containers. Forty-four pallets, weighing 13,000 pounds, were double stacked and trucked to West Virginia. PRS paid for the transportation. Dick Bonnet, PRS president, reports that the sand and dirt are very abrasive to the granulators, but the plastic is not difficult to clean. PRS marketed the clean flake to two manufacturers of nursery pots.

Organizations that are interested in developing similar programs should be aware that the low value of the collected pots will in most cases prevent the processor from being able to pay for the pots. PRS did not reprocess the LCA material in 1993, citing high transportation costs and low prices for clean flake.

Hillside Growers of Weirsdale, FL, has developed an extensive re-use program. In the summer of 1991, after buying used pots for their own use for three years, Gail and Cal DeRousse began a business that collects, sorts and resells HDPE blow-molded nursery containers. The DeRousses purchase used containers from various sources throughout the state of Florida. Their best-known source is Disney World in Orlando. The used pots are brought back to the Hillside nursery where they are sorted by size and manufacturer and then inventoried for future sales to other Florida plant growers. Transportation was originally handled by one three-quarter ton van. By the summer of 1993, the operation had grown to a point where three vans and seven trailers were needed to service the expanded collection locations throughout the state.

2.2.7 Developments and Future Directions

Some manufacturers of HDPE blow-molded nursery containers are purchasing and using post-consumer homopolymer (milk, water and cider jugs) and copolymer (pigmented household and industrial cleaner bottles) HDPE from reclaimers. The material has been characterized as very workable. Millions of pounds of curbside and drop-off material will be used this year to manufacture nursery pots. **IEM Plastics, Inc.**, reclaims post-consumer HDPE bottles and also manufactures HDPE blow-molded nursery containers. IEM pots are manufactured with 100 percent post-consumer material. The company has reclaimed some nursery pots collected by the landscape trade. Since 1992, the **Lerio Corporation** has increased the percentage of post-consumer HDPE used as feedstock for their blow-molded nursery pots. As plastic recycling becomes more widespread, more manufacturing companies make the plunge into utilizing post-consumer material for their products.

There is no technological reason that increased amounts of nursery pots could not be sourced and reclaimed for further nursery pot manufacture. The reclamation equipment currently available has evolved enough to be able to clean the most contaminated nursery pots. However, the ease with which baled HDPE bottles can be turned into nursery containers may hinder closed-loop recycling of significant volumes of nursery pots.

The future will find more use of post-consumer HDPE in the manufacture of nursery pots. Of the collection programs that will be implemented at retail garden centers, most will be sponsored by either the centers, plastics reclaimers, nursery pot manufacturers or a combination of two or more of these groups. The containers will be re-used as pots, used as feedstock for "plastic lumber" products or recycled into more nursery pots.

2.3 Injection-Molded High Density Polyethylene Pots

2.3.1 Characteristics

The nursery industry uses injection molding for containers up to 2 gallons. Much of the HDPE that is injection-molded is post-industrial scrap that varies by resin (HDPE, LLDPE) as well as by melt index. The industry has used some post-consumer material such as soda bottle base cup resin.

Table 2.3 Injection-Molded HDPE Containers

Resins	Virgin HDPE and Post-Industrial and Post-Consumer HDPE and LLDPE
Colors	All
Annual Volume	100 million pounds
Distribution	National

2.3.2 Major Manufacturers

- Lerio Corporation, USA
- Nursery Supplies, Inc., USA

2.3.3 Contamination

- Commingled non-injection-molded HDPE containers
- Potting soil residue
- Sand

2.3.4 Barriers to Recycling

- Contamination
- Lack of collection infrastructure
- Limited markets
- Lower-quality resins
- Mixed resins

2.3.5 Current Disposal Methods

Most used nursery pots are landfilled. Some have their inherent energy recovered at waste-to-energy plants.

2.3.6 Recyclers

- Denton Plastics, OR
- Obex, Inc., CT
- Plastic Recycling Services, Inc., WV

2.3.7 Developments and Future Directions

In the past, soda bottle base cups have been used as feedstock. Some manufacturers experienced difficulties with this material because of the widely fluctuating melt indices (MIs), generally ranging from 25 to 60 and sometimes going down to blow-molding grades of less than 1. The more dissimilar the MIs are when melting together various grades of resin, the greater the chance of getting flow separation (lamination) when injection molding nursery containers. This separation of the different resins causes a loss of strength in the injection-molded pot because the lamination prevents the manufacture of a single homogeneous piece of plastic. This is especially true when there are long flow paths in the molds. When the MIs are within a range of 10 there will be no separation of the resins. Flow separation is usually not a problem when molding containers up to the 1-gallon size. The nursery industry uses injection molding for containers up to 2 gallons. Given the flexibility of injection-molding nursery pot manufacturing, and the desire by many communities to increase the plastics recycled, it could be that a few communities may find localized markets for some of their injection-molded containers. Even quart yogurt containers consisting of HDPE with an MI of 55 and LLDPE lids with an MI of 85 can be manufactured into 1-gallon nursery pots that are free of flaws and readily marketable.

Denton Plastics of Portland, OR, collects all types of HDPE containers, including injection-molded dairy containers. Some of the reclaimed plastics are used by Gage Industries of Lake Oswego, OR, for the manufacture of nursery pots. **Plastic Recycling Services** of Parkersburg, WV, grinds and washes injection-molded HDPE nursery pots to produce clean flake for injection molding.

2.4 INJECTION-MOLDED POLYPROPYLENE POTS

2.4.1 Characteristics

Table 2.4 Injection-Molded Polypropylene Containers

Resins	Virgin, Post-Industrial PP
Colors	All
Annual Volume	80-90 million pounds
Distribution	National

2.4.2 Major Manufacturers

- ITML Inc., Canada
- Kord Products Ltd., Canada
- Lerio Corporation, USA
- REB Plastics, Inc., USA

2.4.3 Contamination

- Commingled non-polypropylene containers
- Potting soil residue
- Sand

2.4.4 Barriers to Recycling

- Contamination
- Lack of collection infrastructure
- Limited markets
- Lower-quality resins
- Mixed resins

2.4.5 Current Disposal Methods

Most used nursery pots are landfilled. Some have their inherent energy recovered at waste-to-energy plants. A small portion of these containers is collected and used for the manufacture of commingled plastic products such as plastic lumber.

2.4.6 Recyclers

- Denton Plastics, OR
- Obex, Inc., CT
- Plastic Recycling Services, Inc., WV

2.4.7 Developments and Future Directions

In the coming years, injection-molded polypropylene containers will capture more of the dairy food container industry. With an appropriate collection and reclamation system, this post-consumer waste could be a good feedstock for the nursery pot industry. Additionally, both dairy and nursery polypropylene containers may be reclaimed for use in melt-blown fiber manufacturing operations.

2.5 Polystyrene Nursery Pots, Packs and Flats, and Bedding Plant Containers

2.5.1 Characteristics

Table 2.5 Polystyrene Nursery and Bedding Plant Containers

Resins	Virgin, Post-Industrial & Post-Consumer PS
Colors	Black, white, gray, green, others
Annual Volume	60-80 million pounds
Distribution	National

2.5.2 Major Manufacturers

- Blackmore Company, Inc., USA
- East Jordan Plastics, Inc., USA
- Landmark Plastic Corporation, USA
- Lerio Corporation, USA
- Sandusky Plastics, USA
- Summit Plastics, USA
- T.O. Plastics, Inc., USA

2.5.3 Contamination

- Non-polystyrene plastics
- Paper labels
- Potting soil residue
- Sand
- Staples

2.5.4 Barriers to Recycling

- Contamination
- Lack of collection infrastructure
- Limited markets
- Lack of high-quality resins
- Mixed resin collections
- High cost of post-consumer resins

2.5.5 Current Disposal Methods

Most polystyrene nursery pots, packs and flats are either disposed of through municipal and commercial channels or burned on-site. A small but growing amount of nursery containers are being collected and recycled, while many are re-used by commercial growers.

2.5.6 Recyclers

- Canadian Polystyrene Recycling Association, Ontario
- Denton Plastics, OR
- National Polystyrene Recycling Company, CA, NJ, IL
- Obex, Inc., CT
- Plastic Recycling Services, Inc., WV
- Western Gold Thermoplastics, CA

Plastic Recycling Services (PRS) of Parkersburg, WV, has collected and processed PS nursery containers since 1991. The company granulates and washes solid polystyrene nursery pots, packs and flats. The clean flake is marketed to three nursery pot companies: Blackmore, East Jordan and Summit. These companies use the reclaimed polystyrene for the manufacture of new sheets for forming new nursery containers. PRS sources most of their polystyrene from nurseries east of the Mississippi River. **Western Gold Thermoplastics**, of Los Angeles, CA,

performs similar polystyrene nursery container processing for the western part of the country.

2.5.7 Developments and Future Directions

Two companies, **Bouldin & Lawson, Inc.**, of McMinnville, TN, and **McConkey-Gleason, Inc.**, of Wilsonville, OR, manufacture washing equipment for polystyrene flats and germinating trays, such as "plug trays." Plug trays are approximately 1 foot by 2 feet and 1-2 inches deep, with 250 to 300 plug indentations on each tray. The plug trays are used exclusively by commercial growers to germinate plants from seed. These trays, if clean and containing no pathogens, can be re-used in normal business practice. Complete listings on these two companies can be found in **Appendix D**.

Manufacturers of polystyrene products for the nursery and bedding plant industry have traditionally used plant scrap from related divisions, such as dairy container manufacturing, purchased other companies' industrial scrap and sourced off-grade virgin material. It is only a matter of time before some of the manufacturers install washing facilities to enable them to service their customers more fully. As in much of the plastic recycling future, the nursery container industry will be taking a larger role in product stewardship.

III AGRICULTURAL PESTICIDE CONTAINERS

3.1 INTRODUCTION

The agricultural industry in the United States generates 60 million waste pesticide containers each year. For liquid concentrates, the majority of the non-refillable containers are 1 to 2.5 gallons, although the containers range from the quart-size to 50-gallon barrels to 110-gallon rotational molded bulk containers. Some of the larger-sized pesticide containers are refillable.

Over the last 15 years, plastic containers have gradually replaced many of the metal containers and polyethylene-coated paper bags. Today plastic containers are the packaging of choice for most agricultural pesticides, commanding an estimated 80 to 90 percent of the liquid and dry concentrate pesticide container market. All plastic pesticide containers are fluorinated to various degrees, making the plastic essentially impervious to migration of the mineral distillates through container walls. After proper rinsing, HDPE pesticide containers are classified as normal solid waste.

3.2 HIGH DENSITY POLYETHYLENE PESTICIDE CONTAINERS

3.2.1 HDPE Agricultural Pesticide Container Characteristics

Table 3.1 1992 Estimated Quantities of Pesticide Containers (Million lbs.)

HDPE Agricultural Pesticide Container Market	Low	High	Avg.
Blow-Molded less than 2.5-gallon	6	10	8.0
Blow-Molded 2.5-gallon	10	14	12.0
Extrusion Blow-Molded 30-gallon	1	2	1.5
Injection-Molded 5-gallon	1	2	1.5
Rotational-Molded Returnable/Refillable	1	2	1.5
Pesticide Container Totals	**19**	**30**	**24.5**

The above estimates give a rough approximation of the size of the pesticide container market used specifically in agriculture. Table 3.2 is a summary of pesticide container surveys conducted by the National Agricultural Chemicals

Association (NACA). The NACA surveys indicate that in recent years there has been a decrease in resin consumption in 1- and 2.5-gallon blow-molded pesticide containers. This downward trend may be due in part to the increased use of bulk pesticides in refillable containers.

Table 3.2 NACA Agricultural Pesticide Container Summary (Million lbs.)

Year	1- & 2.5-gallon Containers
1988	30.5
1989	30.0
1990	24.7
1991	21.9

Source: Steven Hutton, DowElanco

This reduction of resin usage for pesticide containers, coupled with the increase in pounds of pesticide containers collected for recycling, suggests the percentage of waste containers collected is increasing at a rapid rate.

Along with agricultural pesticide containers, many other waste plastic pesticide containers are generated in North America by non-agricultural pesticide applicators and by homeowners in the industrial, institutional and structural pesticide markets. The above figures do not reflect these additional market areas, nor do they include plastic containers used to market micro-nutrients, stickers, spreaders or other adjuvants used in agriculture and horticulture. In 1992, Dr. John H. Thorne, director of the Alliance for a Clean Rural Environment (ACRE), placed the total U.S. plastic pesticide container market at nearly 46 million pounds.[17]

3.2.2 Major Manufacturers

The major manufacturers of plastic pesticide containers are:

- Continental Plastic Containers, Inc., USA
- Texberry Container Corporation, USA

Continental Plastic Containers presently uses both homopolymer (milk bottles) and copolymer (household-and-industrial-cleaner type bottles) recycled resin pellets as part of the feedstock to manufacture agricultural pesticide containers. Four years ago, the company began integrating post-consumer plastics

[17] "Tips for the Safe Disposal of Pesticide Containers," Dr. John H. Thorne, *Greenhouse Product News*, May/June 1992, p. 28.

into their production bottles. Continental uses mono-layer production techniques when using reclaimed homopolymer content and multi-layer technology for copolymer content. **Texberry Container** has also used post-consumer resin in container manufacturing.

3.2.3 Contamination

- Labels
- Residual pesticides
- Sealing foil
- Soiled containers

When the containers are handled according to the current industry guidelines, the collections are cleaner than many municipal plastic collections. In mature pesticide container recycling programs, the collections are very clean due to the close educational assistance provided by the programs.

3.2.4 Barriers to Recycling

- Low cost of burning and burying
- Lack of enforcement of proper disposal techniques
- Public misperception of dangers of pesticide containers
- Lack of identified end products to utilize collections
- Lack of resources to assist implementing programs
- Lack of identified end products to make from containers

By the late summer of 1993, the bulk of pesticide containers were being disposed of on-site even though 45 states had some type of agricultural industry-supported pesticide container collection program. The lack of resources in some states to fund the necessary personnel to monitor the programs is a large stumbling block that is preventing the universal implementation of recycling programs.

3.2.5 Current Disposal Methods

- Landfilling
- On-site disposal
- Recycling
- Waste-to-energy resource recovery

After triple rinsing, plastic pesticide containers are classified as solid waste. They are no longer hazardous waste, and according to state and federal pesticide

rules, they may be safely disposed in landfills or at waste-to-energy plants like any solid waste. However, there is a widespread belief among many municipal and commercial landfill and waste-to-energy plant personnel that pesticide containers are hazardous waste. The majority of North American facilities will not accept the containers if they are aware the containers have been used to package pesticides. Part of the rationale for non-acceptance at landfills and transfer stations is that pesticide containers are not always properly rinsed and accordingly cannot be accepted by any but licensed hazardous waste handlers.

Additionally, even properly rinsed pesticide containers are not acceptable in municipal plastics recycling programs. Invariably, post-consumer plastics market specifications prohibit all pesticide containers. It is easy to understand that neither the plastics markets nor the transfer stations have the personnel, nor the expertise, to adequately monitor the cleanliness of the containers.

Because of the misconception that the containers are hazardous, many growers also believe the triple-rinsed containers are hazardous waste and must be disposed of at expensive hazardous waste locations. The cost and inconvenience of hazardous waste disposal has caused many growers to burn or bury the containers on-site. It is estimated that prior to 1990, more than 75 percent of all pesticide containers were burned or buried on-site.

3.2.6 Recyclers

- Agricultural Container Research Council, Inc., USA
- Crop Protection Institute, Canada
- SCT Environmental, Inc., TX
- Tri-Rinse, Inc., MO

Pesticide container recycling began in the spring of 1989 as a pilot project in Washington County, MS. The program was the result of a group effort to rinse, collect and recycle pesticide containers. The assembled task force included the National Agricultural Chemicals Association, Du Pont's Agricultural Products Department, the Division of Plant Industry (the regulatory arm of the Mississippi Department of Agriculture and Commerce) and approximately a dozen other major producers and distributors of agricultural pesticides.

> "The task force selected Washington County, a major row crop area of the Mississippi Delta, because of high volume of farming activity and pesticide use. Its efforts were aided by an $80,000 grant from the Environmental Protection Agency (EPA) Office of Pesticide and Toxic Substances Program. Support also came from the Washington County Board of Supervisors, who purchased collection equipment and supplied labor....

"The initial Mississippi project worked this way: the extension staff in Washington County began an educational program encouraging farmers to rinse empty containers by either triple rinsing procedures or use of pressurized nozzles donated by ICI Americas. The rinsate was emptied into spray tanks for...application on cotton, soybeans and other row crops. Farmers then hauled empty containers to one of eight designated collection sites, which were donated by the county's aerial applicators....

"At the collection sites the containers were separated into two groups, using labor supplied by the county. The metal ones were sold for scrap iron; the plastic ones were baled like cotton at an old gin owned by Washington County row crop farmer Rex Livingston. The bales were then shipped out of state for processing. A sample of plastic containers—different brand names, shapes and sizes—were pulled by Du Pont and analyzed for residue....

"More than 48,000 pounds of plastics were collected and baled in 1989 in Washington County....

"And in 1990, the project progressed one step further. Seven more counties in Mississippi began rinsing/collection/recycling programs. And Livingston purchased a portable granulator so the containers could be ground on the spot at collection sites in several counties. More than 128,000 pounds of plastic containers...were granulated. The cost of granulation averaged 10 cents per pound of plastic....

"Much of the plastic material...was recycled into new containers....

"'The containers we have evaluated have been as good or even better than new bottles made with virgin resin,' (Dr. Ralph) May (of Du Pont) says. 'When we're finished with recycled containers, they'll be put right back into recycling again. We think the containers can be recycled as many times as we want to....'

"The key to any type of container disposal program is proper rinsing. Once an empty pesticide container has been properly rinsed (either pressurized or triple-rinsed) it no longer can be classified as hazardous waste. Properly rinsed containers are considered solid wastes...."[18]

"The collection program in Madison County, MS, was the first program to designate certain days for collection. Two sites in the County and one day out of each month starting in May, June, July and November were designated. The end users brought in the containers which were stored in the building. Someone from the MS Department of Agriculture or from the Department of Environmental Quality is there accepting or refusing the containers. The program really generates a lot of good material because they know there's going to be an inspector there. There is however a strong indication that we don't get the total poundage out of this program as we do in Washington or Sunflower or Bolivar county programs but the quality and cleanliness of the material is superior to what we get in the other programs. All other counties will follow this type program."[19]

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[18] "Prototype for the Nation: Pesticide Container Project Makes Up for Lost Ground in Disposing of Plastic Waste," Patti Drapala, Mississippi State University Information Services, *Agricultural Aviation* magazine, June 1991, pp. 9-11.

[19] Sidebar, *Agricultural Aviation* magazine, June 1991, p. 11.

In 1989, the Container Management program of the Crop Protection Institute (CPI) was begun in the prairie provinces of Canada to administer the collection, shredding, washing and recycling of used agrichemical containers. The costs of the program are funded by the manufacturing member companies of CPI. A voluntary container levy was initiated on every one-way plastic or steel container shipped into prairie provinces. Since the 1992 season, the levy has been applied throughout Canada, contributing millions of dollars to the recycling fund. By 1993, the program became available to virtually all Canadian farmers through approximately 600 designated container collection sites.[20]

In 1992, the Agricultural Container Research Council (ACRC) was formed as an outgrowth of the early pilot programs by NACA and others. ACRC is expanding the concept of product stewardship for waste pesticide containers in the United States. Like CPI, ACRC is a nonprofit cooperative effort among 35 major agricultural chemical manufacturers, formulators, distributors, dealers, packagers and others in the agricultural industry. The group's mission is to promote the collection and recycling of empty plastic agricultural pesticide containers into innovative, environmentally sound end uses.[21] For information on local state pesticide container recycling programs, refer to **Appendix I**, or contact state pesticide control boards or county cooperative extension services.

ACRC has been active in assembling and distributing educational information on how to recycle pesticide containers. Among their publications are pamphlets, inspection checklists, articles and videos. The "Triple Rinse/Jet Rinse" video, which instructs pesticide applicators how to clean pesticide containers on a step-by-step basis, is available in both English and Spanish and has recently been updated in the 1994 version.

For Pressure Rinsing[22]

1. Empty contents of container into spray tank, turning the container so that any product trapped in the handle is allowed to flow out. Once flow is down to a drip, allow the container to drain for an additional 30 seconds.

2. Immediately begin rinsing procedures or the product may become difficult to remove.

3. Hold the container so the opening can drain into the spray tank.

[20] Crop Protection Institute brochure "Crop Protection Packaging: Waste Reduction and Recycling in Canada."
[21] Agricultural Chemical Research Council, Pamphlet No. 9301.
[22] Ibid.

4. Force tip of the pressure nozzle through the lower portion of the side closest to the handle.

5. Connect nozzle to a clean water source of at least 40 psi. Turn the nozzle inside the container to assure good coverage of all sides, including the handle.

6. Rinse for at least 30 seconds.

7. Drain all rinse water into the spray tank.

For Triple Rinsing[23]

1. Empty contents of container into spray tank, turning the container so that any product trapped in the handle is allowed to flow out. Once flow is down to a drip, allow the container to drain for an additional 30 seconds.

2. Immediately begin rinsing procedures or the product may become difficult to remove.

3. Fill empty container one-quarter full of water.

4. Replace the cap on the container. With the container opening facing left, shake the container left to right over a distance of 4 to 6 inches. Shake the container about twice per second for 30 seconds.

5. Drain rinse water into the spray tank as previously described.

6. Fill the container one-quarter full with clean water a second time.

7. Recap the container. With the opening of the container pointed toward the ground, shake the container as described before. Then drain the rinse water into the spray tank.

8. Finally, fill the container one-quarter full once more with clean water.

9. Recap the container. With the container in the normal, upright position, shake the container as before, 30 seconds with a 4- to 6-inch vertical motion, twice per second.

10. Pour the rinse water into the spray tank. Carefully rinse and spray residue from the outside of the container.

Container caps usually are not recyclable, so they should be rinsed thoroughly and disposed of properly. Don't put caps back on containers. Store empty, clean containers out of the rain prior to collection site delivery to prevent inspectors from mistaking rainwater

[23] Ibid.

for residue and rejecting the containers. The types of one-way containers accepted into ACRC recycling program include pesticide, crop oil, surfactant, fertilizer and micro-nutrient containers.

Similar to the programs begun through NACA in Mississippi, the ACRC programs also rely upon the state pesticide control boards, or other state or local officials, to monitor the collections to ensure the containers' cleanliness. At the collection sites, one of ACRC's two handling contractors, SCT Environmental, Inc., or Tri-Rinse, Inc., or their subcontractors, will granulate the containers with mobile equipment.

The granulated plastics are packed in supersacks and become the property of the handlers. The contracts between handlers and ACRC call for the handlers to store the granulated material until the ACRC designates a market for the flake. The market may be a blow molder that will manufacture new pesticide containers, or it may be a waste-to-energy plant that will recover the energy from the waste plastics.

In 1992, ACRC-sponsored programs collected over 1.2 million pounds of pesticide containers nationwide. For the 1993 growing season, ACRC hoped to collect 3 million pounds, increasing to 5 million pounds during 1994. However, adverse weather and flooding in the Midwest may reduce the level of recycling in 1993 and may postpone reaching these projections. However, once a program has begun, the collections do increase rapidly. For instance, third-year Vermont collections in 1993 totaled 12,000 pounds, while the collections were only 4,000 pounds in each of the first two years.[24]

Table 3.3 HDPE Agricultural Pesticide Containers Collected

Year	Millions of Pounds
1990	0.35
1991	0.85
1992	1.28
1993 estimated	2.50

Source: Robert L. Denny, ACRC

By using the above collection figures from Table 3.3 and the generation figures from NACA from Table 3.2, we are able to calculate estimated recycling rates as shown in Table 3.4.

[24] AGRIVIEW, VT Dept of Agriculture, *Food & Markets*, August 16, 1993, Vol. 57, No. 17, p.1.

Table 3.4 HDPE 1- & 2.5-Gallon Agricultural Pesticide Container Recycling Rates

Year	Generated	Collected	Rate
1990	24.7	0.35	1.4%
1991	21.9	0.85	3.9%
1992 estimated	20.0	1.28	6.4%
1993 estimated	19.0	2.50	13.2%

Sources: ACRC, NACA, Amidon Recycling

3.2.7 Developments and Future Directions

The future development of more expanded pesticide container recycling is very positive. The ACRC is working with companies to find more end uses for the reclaimed resins. Some blow molders that provide containers for the industry have used the recycled containers to manufacture new pesticide containers. This closed-loop recycling is expected to increase as more pesticide manufacturers and private label packagers specify the reclaimed resin for the manufacture of containers for their end products.

The ACRC has approved the use of pesticide containers as the feedstock in the manufacture of new plastic pesticide containers and as fuel for the manufacture of cement. In Canada, through CPI, the agricultural industry has made fence posts from reclaimed pesticide containers. Other products either in production or in the testing phases include curbstops, highway guard rail posts, roofing and road-paving materials. In Manitoba, the CPI is funding a closed-loop recycling project in which collected containers are processed with virgin HDPE back into new herbicide containers.

In addition to new pesticide containers, ACRC is researching the use of the resin in "plastic lumber" products such as sign posts. Sewer pipes, drainage tiles and returnable pallets for refillable bulk pesticide containers also are being researched as possible new products in which to utilize the collected material.

In late summer 1993, ACRC held meetings with Responsible Industry for a Sound Environment (RISE). RISE is a two-year-old organization that represents the majority of the specialty, non-agricultural pesticide industry in the United States. Their members include lawn care specialists, roadside greenbelt groomers, golf course greens tenders, and residential and industrial pest control specialists. ACRC and RISE are planning on working together to develop new programs and expand

pesticide container recycling to allow non-agricultural pesticide applicators and homeowners access to pesticide container recycling.

RISE has a goal of surveying their industry to determine the kinds and pounds of pesticide containers generated on a yearly basis. To begin the survey, RISE will concentrate on commercial, industrial and institutional applications. Later, pesticide containers purchased by homeowners will be targeted. It is estimated that 25 percent of the total pesticide usage may be in non-agricultural settings.

The U.S. Environmental Protection Agency's (EPA) Office of Pesticide Programs is in the process of developing rules for pesticide container design and manufacture. The *1992 Pesticide Container Study Report to Congress* is available from the Government Printing Office for a modest charge.

AGRICULTURAL PLASTICS MANUFACTURERS

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South Hackensack, NJ 07606
800/999-2374
201/807-2309
fax 201/807-2489
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Fumigation Film
Mulch Film
Stretch Wrap, Hay & Haylage Film
Haysleeve Cover Film

AT Plastics Inc.
134 Kennedy Road South
Brampton, ONT.
Canada L6W 3G5
800/661-3606
905/452-6739
fax 905/451-0039
Harry Nagata
fax 905/451-1677
Greenhouse & Over-Wintering Film
Silage Bags

AT Polymers & Films, Inc.
562 Tull Road
Monroe, LA 71292
318/396-5167
fax 318/397-1889
Frank Folinari
Greenhouse & Over-Wintering Film
Silage Bags

Amoco Fabrics and Fibers
900 Circle 75 Parkway
Suite 550
Atlanta, GA 30339
404/956-9025
fax 404/984-4453
Polypropylene Fabric

Armin Plastics Corporation
414 Alaska Avenue
Torrance, CA 90503
800/421-1079
310/320-7373
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Fumigation Film
Greenhouse & Over-Wintering Film
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fax 918/627-3070
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fax 313/483-5454
Scott Blackmore
Skip Blackmore
PS Flats, Packs & Pots

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David Fiedler
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800/888-5364
203/357-7555
fax 203/257-7579
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Continental Plastic Containers, Inc.
800 Connecticut Avenue
PO Box 5410
Norwalk, CT 06856
203/855-5000
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Pesticide Containers

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Frank Waltrip
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Carolena Maier
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HDPE Blow-molded Pots
PP Injection-molded Pots

ITML Inc.
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HDPE Blow-Molded Pots

Kord Corporation
PO Box 217
Route 133
Lugoff, SC 29078
803/438-3785
fax 803/438-2764
PP Injection-Molded Pots

Kord Products Ltd.
4 Wilkinson Road, Unit #1
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PP Injection-Molded Pots

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Lerio Corporation
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800/457-8114
407/933-5435
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Lerio Corporation
PO Box 278
Valdosta, GA 31603-0278
800/457-8115
912/242-5781
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2550 West 5th North Street
Summerville, SC 29483
800/445-4674
803/873-5800
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George Milner
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Mobil Chemical Company
1159 Pittsford Victor Road
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Stretch Wrap, Hay & Haylage Film

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Hank Guarriello
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HDPE Injection-Molded Pots

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PP Injection-Molded Pots

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Reidsville, NC 27323-1350
800/678-2278
910/349-3323
fax 910/342-4101
HDPE-Blow-Molded Pots

Zarn, Inc.
6050 Boat Rock Boulevard
Atlanta, GA 30336
404/349-4990
fax 404/349-4991

Zarn, Inc.
1850 West Almond Avenue
Madera, CA 93637
800/272-7687
209/661-1730
fax 209/661-1845

Recycling Markets for Post-Use Agricultural Plastics

Ag-Bag International Ltd.
2320 Southeast Ag-Bag Lane
Warrenton, OR 97146
503/861-1644
fax 503/861-2527
Larry Inman

Agricultural Plastics Retrieval
26441 US 41
Bonita Springs, FL 33923
813/992-6790
Vince Myers
Mulch Film

Arkansas Plastic Recyclers, Inc.
3401 South Main Street
Stuttgart, AR 72160
501/673-7458
fax 501/673-7538
Jim Winkelpleck
Ken Rial
Irrigation Tubing

Avanguard Industries, Inc.
13301 Beaumont Highway
Building 13
Houston, TX 77049
713/458-6566
fax 713/458-5133
Jerry Clark
Greenhouse & Over-Wintering Film

Canadian Polystyrene Recycling Association
7595 Tranmere Drive
Mississauga, ON
Canada L5S 1L4
905/612-8290
fax 905/612-8024
PS Flats, Packs & Pots

Carlisle Plastics, Inc.
State Road 1419
Battleboro, NC 27809
919/977-9038
fax 919/972-5978
Pete Roy
Greenhouse & Over-Wintering Film

Denton Plastics
4427 Northeast 158th Street
Portland, OR 97230
503/257-9945
fax 503/252-5319
Dennis Denton
Greenhouse & Over-Wintering Film
HDPE Blow-Molded Pots
HDPE Injection-Molded Pots
PP Injection-Molded Pots
PS Flats, Packs & Pots

Enviro Tech
Division of Atlantic Poly, Inc.
670 Canton Street
Norwood, MA 02062
800/225-9892
617/769-4260
fax 617/769-5722
Jon DeFreitas
Greenhouse & Over-Wintering Film

Hillside Growers
14300 Southeast 151 Place
Weirsdale, FL 32195
904/821-2413
Gail & Cal DeRousse
Purchasers & Resellers of
HDPE Blow-Molded Pots

IEM Plastics, Inc.
606 Walters Street
PO Box 1975
Reidsville, NC 27323-1975
800/222-7564
910/342-0356
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Mike Ussery
HDPE Blow-Molded Pots

Recycling Markets for Post-Use Agricultural Plastics

ITW Angleboard
2217 East Bobo Newsom Highway
Hartsville, SC 29550
803/332-4860
fax 803/332-5125
Angela Turner
Greenhouse & Over-Wintering Film

Ingenuity Corporation
PO Box 7879
New Haven, CT 06519
203/776-4444
fax 203/624-3377
T.J. Goetting
Greenhouse & Over-Wintering Film

Mobil Chemical Company
1159 Pittsford-Victor Road
Pittsford, NY 14534
716/248-1532
fax 716/248-1714
Mike Vatuna
Greenhouse & Over-Wintering Film

Nation Plastics
PO Box 830028
San Antonio, TX 78283
210/225-5556
fax 210/229-1273
Jim Nation
Greenhouse & Over-Wintering Film

National Polystyrene Recycling Company
CRINC Recycling
P.O. Box 338
4 Kildeer Court
Bridgeport, NJ 08014
609/467-9377
fax 609/467-9494
Joe Quinn
PS Flats, Packs & Pots

National Polystyrene Recycling Company
Eaglebrook Plastics Operating Co.
1700 W. 199th Street, Unit 4
Chicago, IL 60643
312/568-1221
fax 312/568-9133
Ralph Holmes
PS Flats, Packs & Pots

National Polystyrene Recycling Company
NPRC West
1676 North California Boulevard
Suite 400
Walnut Creek, CA 94596
510/746-5262
fax 510/746-5256
George Milne
PS Flats, Packs & Pots

National Polystyrene Recycling Company
Talco Recycling, Inc.
720 S. Temescal Street
Corona, CA 91719
714/736-7040
fax 714/734-9588
Phil Fusco
PS Flats, Packs & Pots

New Age Plastic Recyclers
2301 W. Sample
W. Sample Building 3
Suite 1A
Pompano Beach, FL 33069
305/968-0156
fax 305/968-0194
Nathan Seskin
Greenhouse & Over-Wintering Film

Recycling Markets for Post-Use Agricultural Plastics

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mailing: PO Box 1253
Stamford, CT 06901
location: 737 Canal Street
Stamford, CT 06902
203/975-9094
fax 203/357-1325
Celeste Johnson
Greenhouse & Over-Wintering Film
HDPE Blow-Molded Pots
HDPE Injection-Molded Pots
PP Injection-Molded Pots
PS Flats, Packs & Pots

Plastic Recycling Services, Inc.
1001 Depot Street
Parkersburg, WV 26101
304/485-8062
Dick Bonnet
HDPE Blow-Molded Pots
HDPE Injection-Molded Pots
PP Injection-Molded Pots
PS Flats, Packs & Pots

Plastic Services of America
mailing: PO Box 964
Montgomery, AL 36101
location: 2811 Day Street
Montgomery, AL 36108
205/264-9578
fax 205/262-5067
Michael D. Stover
Greenhouse & Over-Wintering Film

Poly-America, Inc.
2000 West Marshall Drive
Grand Prairie, TX 75051
214/647-4374
fax 214/647-8061
Paul Kramer
Greenhouse & Over-Wintering Film
Silage Bags

Polychem Products, Ltd.
725 Gaudette Street
Saint-Jean-Sur-Richelieu, QC
Canada H2V 1C2
514/348-7392
fax 514/349-2225
Ron Parquette
Silage Bags
Mulch Film

Poly Pro Products Inc.
711 Benton Street
PO Box 69
Thornton, IL 60476
815/727-3739
Charles Ward
Greenhouse & Over-Wintering Film

Regenesis Recycling, Inc.
Division of BKK
2135 15th Street
Long Beach, CA 90804
310/432-3976
George Trezek
Fumigation
Greenhouse & Over-Wintering Film

SCT Environmental, Inc.
4808 Fairmont Parkway
Box 251
Pasadena, TX 77505
713/943-3145
Sam Gibson
Pesticide Containers

Tech Polymers, Inc.
2064 Elsa Avenue
North Naples, FL 33942
813/597-2000
fax 813/597-2312
Marcel Vezina
Greenhouse & Over-Wintering Film
Mulch Film

RECYCLING MARKETS FOR POST-USE AGRICULTURAL PLASTICS

Tri-Rinse, Inc.
mailing: PO Box 15191
St. Louis, MO 63110
location: 5200 Manchester
St. Louis, MO 63110
314/647-8338
fax 314/647-5028
Dan O'Brien
Pesticide Containers

Washington Penn Plastics Co., Inc.
Plastic Recycling Center
2560 West 5th North Street
Summerville, SC 29483-9699
803/851-5251
fax 803/851-5265
Roy Crosby
Polypropylene Fabric (Cotton Balewrap)
Fabric and PP Baling Twine

Webster Industries
58 Pulaski Street
Peabody, MA 01960
508/532-2000
fax 508/532-6963
William Crisafi
Greenhouse & Over-Wintering Film

Western Gold Thermoplastics
Ecoplast
840 East 60th Street
Los Angeles, CA 90001
213/235-3387
fax 213/233-8640
PS Flats, Packs & Pots

RECLAMATION EQUIPMENT FOR POST-USE AGRICULTURAL FILM PLASTICS

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Via Gameri, 16
28100 Novara (NO), Italy
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Glacier International, Inc.
5211 North 130th at US #61
PO Box 10756
St. Paul, MN 55110
612/429-8741
fax 612/429-1845

F.B.M. S.r.l.
Zona Industriale
Via per Zerbinate, 29/A
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Converting Systems International, Inc.
PO Box 7782
Naples, FL 33941
813/591-4825

John Brown, Inc.
Cumberland Engineering Division
100 Roddy Avenue
South Attleboro, MA 02703-7951
508/399-6400
fax 508/399-6654
Jim Glenn

Munchy, Ltd.
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Oxfordshire 0X9 5SG, England
011/44/84/435-2161
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R.W. Wolfe

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12 C John Road
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Sutton, MA 01590
508/865-7355
fax 508/865-9975
Douglas French

Reg-Mac s.r.l.
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4717 Sweden Road
Charlotte, NC 28273
704/552-5404
fax 704/552-5854
Phil Lail

Sorema Srl
Via per Cavolto 17
22040 Anzano del Parco
(Como), Italy
39-31-619-224
fax 39-31-631-911
Aldo Previero

Tecnofer
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111 Smith Hines Road
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Greenville, SC 29616
803/288-5050
fax 803/234-7544
Lonnie Morris

Appendix C

Reclamation Equipment for Post-Use Agricultural Film Plastics

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Mischer und Anlagen
One Henschel Platz
D-34112 Kassel
Germany
US Representative
Henschel Mixers America
4500 S. Pinemont
Houston, TX 77041
713/690-3333
fax 713/690-3353
Ed Quirsfeld

HANDLING EQUIPMENT FOR POST-USE/RE-USE AGRICULTURAL PLASTICS

Agrotec
PO Box 49
Pendletown, NC 27862-0049
Nursery Film Roller Manufacturer

Bouldin & Lawson, Inc.
mailing: PO Box 7177
McMinnville, TN 37110
location: 70 Easy Street
McMinnville, TN 37110-7177
615/668-4090
800/443-6398
fax 615/668-3209
Joe B. Ware
Polystyrene Nursery Tray Washers

Ford New Holland Americas
PO Box 1895
New Holland, PA 17557
717/355-1121
fax 717/355-3192
Gene Hemphill
Hay Balers (Suitable for Baling Film)

Kennco Manufacturing, Inc.
PO Box 1158
Ruskin, FL 33570
813/645-2591
fax 813/645-7801
Winston Lopez
Mulch Film Burner Manufacturer

McConkey-Gleason, Inc.
28055 Southwest Boberg Road
Wilsonville, OR 97070
503/682-8800
fax 503/682-9479
Polystyrene Nursery Tray Washers

Sonoco Products Company
1 North Second Street, 021
Hartsville, SC 29550
803/339-6134
fax 803/332-1277
Keith Williamson
Mulch Film Baler Manufacturer
(Not Commercially Available)

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1225 I Street, N.W.
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Crop Science Society of America
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120 Cockeysville Road
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Hunt Valley, Maryland 21031
410/584-9754
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1000 Johnson Ferry Road, NE
Suite C135
Marietta, GA 30068
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Ann McClure, Exec. VP

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Alexandria, VA 22314
800/336-4743
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Auburn, AL 36831-0009
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205/821-5148
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Lyons, CO 80540-2676
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University of Delaware
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504/766-3471
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406/721-7334
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609/291-7070
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New Mexico Association of Nurserymen
3820 Midway Place, NE
Albuquerque, NM 87109
505/345-7799

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800/647-0384
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Tina Nyce

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California Tomato Growers Association
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Virginia Wood

Puget Sound Flower Growers Association
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Southern Nurserymen's Association
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HORTICULTURAL & AGRICULTURAL INDUSTRY PUBLICATIONS

AABGA Newsletter
American Association of Botanical Gardens and Arboreta
786 Church Road
Wayne, PA 19087
215/688-1120
fax 215/293-0149
Sharon Lee

Agri-Plastics Report, The
American Society for Plasticulture
PO Box 860238
St. Augustine, FL 32086
904/829-1667

American Agriculturist
Farm Progress Companies, Inc.
191 South Gary Avenue
Carol Stream, IL 60188
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fax 708/462-2869

American Nurseryman
American Nurseryman Publishing Co.
77 W. Washington Street
Suite 2100
Chicago, IL 60602
800/621-5727
312/782-5505
fax 312/782-3232

Farm Bureau Focus
American Farm Bureau Federation
600 Maryland Avenue, SW
Suite 800
Washington, DC 20024
202/484-3600
fax 202/484-3604

Florida Nurseryman
Florida Nurseryman & Growers Association
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Orlando, FL 32819
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fax 407/351-2610

Garden Supply Retailer
One Chilton Way
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215/964-4275
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Greenhouse Grower
Meister Publishing Company
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Willoughby, OH 44094
216/942-2000
fax 216/942-0662

Greenhouse Manager
mailing: PO Box 1868
Fort Worth, TX 76101
location: 120 St. Louis Avenue
Fort Worth, TX 76104
800/433-5612
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708/208-9080
fax 708/208-9350

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Vance Publishing Corporation
7950 College Boulevard
Overland Park, KS 66210
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fax 913/451-5821

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fax 617/367-6364

Journal of Production Agriculture
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Madison, WI 53711
608/273-8080
fax 608/273-2021

Nursery Manager
mailing: PO Box 1868
Fort Worth, TX 76101
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Fort Worth, TX 76104
800/433-5612
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fax 817/877-1862

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American Association of Botanical
Gardens and Arboreta
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Wayne, PA 19087
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NEBRASKA

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Estes Park, CO 80517
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MISCELLANEOUS HORTICULTURAL PLASTICS

GREENHOUSE GLAZING

Acrylic
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IRRIGATION TUBING

LDPE Irrigation Ditch Liners
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NON-WOVEN FABRICS

Polypropylene Fiber-Reinforced with PP Netting
Spunbonded Polyester Row Covers
Spunbonded Polypropylene Row Covers

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Expanded Polystyrene Planter and Plug Trays
LDPE Rice Levy Gates
Polyethylene Lawn Edging
Polypropylene Baling Twine

WOVEN FABRICS

Insect Screens
Knitted Polyethylene Shade Cloth
Knitted Polypropylene Shade Cloth
Polypropylene Cotton Bale Wrap
Polypropylene Ground Cover
Polypropylene Landscape Fabrics