Appendix C
Overview of Specific Materials

This appendix provides an overview of the specific materials found in the waste stream — specifically, aluminum, aseptics, ferrous metals, glass, motor oil, organic materials, paper, plastics, and tires.

C–1 ALUMINUM[1]

Aluminum is a silvery white metal that constitutes 8 percent of the Earth's crust. It is the third most common element after oxygen and silicon; and it is widely dispersed through most clays and rocks, most commonly as hydrated aluminum oxide. Aluminum is never found naturally in its metallic state.

Aluminum has several characteristics that make it a valuable resource. It is light, strong, and, while flexible, can be made more rigid by alloying it with small amounts of other metals. Because of its affinity for oxygen, it resists corrosion by forming a protective coating of aluminum oxide when exposed to air. Aluminum is a good thermal and electrical conductor.

From What Natural Resources Is Aluminum Made?

The greatest concentrations of aluminum are found in bauxite ore, where it is found as alumina in combination with oxide, titania, and silica. Most of the world's bauxite reserves are located in the subtropics where heat and water weather away silica and other contaminants, leaving a higher percentage of aluminum.

Substantial bauxite deposits are located in Jamaica, Australia, Surinam, Russia, Guinea, France, Yugoslavia, Greece, and Hungary. The limited U.S. reserves are located in Arkansas, Georgia, and Alabama. The U.S. imports 85 to 90 percent of its bauxite.

How Is It Made into Metallic Form?

The oxygen in the alumina is separated out through electrolysis, and subsequently the alumina is combined with small amounts of other metals to strengthen it. The metal is then poured into bars called billets or blocks called ingots. It is then transferred to manufacturing plants that remelt and form the aluminum into various items.

The following resources are used to produce one ton of aluminum: 8,766 pounds of bauxite, 1,020 pounds of petroleum coke, 966 pounds of soda ash, 327 pounds of pitch, 238 pounds of lime, and 197 million BTUs of energy. The pollutants created include 3,290 pounds of red mud, 2,900 pounds of carbon dioxide, 81 pounds of air pollutants, and 789 pounds of solid wastes.

Surface mining of bauxite produces solid waste, waterborne waste, air pollution, and hazardous waste. Once taken out of the ground, it is transported to refineries around the world. It must then be refined into alumina. Approximately 55 percent of the world's aluminum is produced in the United States, Russia, Canada, Japan, and Germany.

What Do We Use It For?

Aluminum is used in packaging, building, and automobile and aircraft construction. Other applications include electrical transmission lines, appliances, and other long-life consumer products.

Why Recycle Aluminum?

Recycling aluminum saves 95 percent of the energy required to produce it from virgin materials. Recycling an aluminum can will save the equivalent in fuel of that can half-filled with gasoline. In addition, 95 percent of the air pollution is eliminated, and 100 percent of the solid waste is diverted from landfills.

How Is Aluminum Recycled?

According to Alcoa Aluminum Company, the turn-around time for an aluminum can is six weeks. This includes manufacturing the can, filling it, delivering it to the store, purchasing the product, consuming the product, having the consumer recycle the can, shipping it to a processing plant, making it into cansheet, making a new aluminum can, shipping the can to the beverage filler, filling it, and shipping it to the store.

[1]This section was reviewed by the California Department of Conservation, Division of Recycling in December, 1998.

Aluminum cans are 100 percent recyclable. Scrap dealers who receive aluminum from recycling centers sell recycled aluminum to smelters. At the smelters the aluminum must be chemically analyzed and then shredded and decontaminated. Steel is removed from shredded aluminum as it passes over magnetized conveyor belts. Contamination of more than 1 percent non-aluminum metals makes the aluminum unusable in a smelter.

Once shredded and decontaminated, the aluminum scrap is melted for 18 hours, during which impurities are removed. The molten metal is then poured into forms and allowed to cool. The resulting ingots are transported to manufacturing plants, remelted, and formed into new products.

A Recycling Outlook

About 60 percent of aluminum cans are currently recycled nationwide. Recycling rates are much higher in states that have bottle bills. Californians recycle approximately 85 percent of their aluminum cans.

For More Information

See Appendix F, section IV, for a list of Web sites related to natural resources.

C–II Aseptics

Aseptic packaging holds liquids in "brick-style" containers frequently referred to as juice boxes or drink boxes. Foods prepared and packaged in this way do not require refrigeration. Aseptic packaging also uses far less energy to manufacture, fill, ship, and store products than other beverage containers. In the United States the most common product packaged in aseptics is fruit juice.

Aseptic packages are manufactured by combining thin layers of paper, plastic, and aluminum. Each material used in drink boxes performs an important function:

- Paper (70 percent) provides stiffness, strength, and the block shape of the package.
- Polyethylene (24 percent) on the inner layer seals the package, making it liquid tight. On the outer layer it keeps the package dry and provides a surface for printing of product information.
- Aluminum foil (6 percent) keeps out air and light to maintain product value and flavor. It is the foil that eliminates the need for refrigeration.

There are six layers of these material types in an aseptic box. The first layer is polyethylene; the second, paper; the third, polyethylene; the fourth, aluminum foil; and the fifth and sixth layers, both polyethylene.

Are Aseptic Packages Recyclable?

Technological feasibility is not the problem in aseptic recycling. The primary barriers to recycling of aseptic packages are collection and contamination. Since aseptics represent such a small fraction of the waste stream, it is difficult to establish recycling programs to collect such small volumes. Recyclers are able to overcome this problem by collecting and recycling aseptic packages with milk cartons, which are also plastic-coated paper. These programs are most successful at schools where juice boxes and milk cartons are used in large volumes. In California hundreds of schools have established milk carton and drink box recycling projects.[2] Some curbside aseptic recycling programs were started in California, but at a slower rate than in other states because of the greater distance to recycling mills.[3]

Contamination of these recyclables has led to problems in collection. Students do not completely empty their milk cartons or juices boxes, and food waste and other items are frequently dumped in the aseptic collection bin. These contaminants interfere with quality recycling and lead to traditional landfill disposal of the containers. However, some schools have found ways to remedy contamination problems and to facilitate recycling. For example, a school in Napa County has been successfully recycling aseptic and milk cartons because the students rinse them prior to recycling.[4] Because of the special problems of contamination, some schools have focused their recycling efforts on composting the milk cartons—not the aseptic packages.

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[2]Figures were taken from the Aseptic Packaging Council's report, "Milk Carton and Drink Box Recycling Projects as of November 1, 1989."

[3]From a review by California Integrated Waste Management Board staff member Kathy Frevert in December, 1998.

[4]*Ibid.*

How Are These Containers Recycled?

Aseptics and other plastic-coated paper products are recycled using a process called hydrapulping. Hydrapulping separates the paper from the plastic and aluminum so that the paper pulp is recovered. The machine that is used is like a large blender with blades to stir up the water. Since there are no glues or adhesives to hold the layers together, the paper pulp is pulled away easily from the other layers in the packages. A screen then separates the paper pulp from the plastic and aluminum materials.

The paper recovered through this process is of high quality and represents about 70 percent of the aseptic package. Once recovered, the paper pulp is used to make new products, such as writing paper, facial tissue, paper towels, and cardboard boxes. The residual plastic coating (polyethylene) and the aluminum from the aseptic packages are reformed into plastic lumber, which is used for pier pilings and other outdoor equipment.

C–III Ferrous Metals[5]

Ferrous metals are derived from iron, which is a naturally occurring pure chemical element. Steel is produced by adding carbon to iron. Other elements are added to this basic recipe to form different grades of steel. Steel is the most widely used metal today and has a 100-year-plus history as an U.S. export. Iron and steel are the most widely used and recycled metals.

What Are Tin Cans?

What we call "tin" cans are really steel cans with a very thin coating of tin. The tin protects the steel from corroding or rusting. Bimetal cans are tin cans with an aluminum top that used to be common beverage containers throughout the country. Bimetal cans are less expensive to make than aluminum cans and are easily recyclable because they can be recycled with steel cans. You can tell the difference between tin (steel) cans and aluminum with a magnet. Magnets will attract steel but not aluminum. Tin and bimetal cans both attract magnets.

Why Recycle Scrap Metal?

Small mills using electric furnaces to produce specific products from scrap are called mini-mills. Using furnaces to heat the scrap metal, mini-mills bypass the initial stages of mining and processing ore and proceed directly to the fabrication of new products by remolting scrap metal. This process saves energy and expenses. Using scrap instead of iron ore to make new steel reduces air pollution by 86 percent and water pollution by 76 percent, saves 74 percent of the energy and 40 percent of the water that would have otherwise been used, and can reduce the need for virgin materials by 90 percent.

By weight, ferrous metals are the largest category of metals in the municipal waste stream. The largest quantities of ferrous metals are found in durable goods, such as appliances, furniture, tires, and other miscellaneous durables, and in steel cans. In California ferrous metal and steel cans represented about 3.5 percent of the material disposed in 1991, or 1.3 million tons annually.[6] In 1994 California recycled an estimated 202,000 tons of steel cans.[7]

A Recycling Outlook[8]

Large magnets are used to remove ferrous contaminants from aluminum scrap and to isolate ferrous scrap from mixed waste at material recovery facilities. In California curbside collection of steel cans is increasing in residential communities; about 400 programs in California include steel cans in their collection. Most of the cans collected are exported to states like Utah and Montana and are used in the copper mining industry.

Scrap iron found in white goods, such as old stoves and refrigerators, is shredded at California ports and exported to Pacific Rim countries. Approximately 71 percent of the discarded household appliances (such are refrigerators, freezers, and stoves) were recycled in 1991. Approximately 95 percent of the 20 million vehicles discarded in 1994 were recycled; the recycling rate for vehicles is higher than for appliances because of the amount of scrap metal in each vehicle and the relatively well established system for recycling vehicles.

For More Information

See Appendix F, section IV, for a list of Web sites related to natural resources.

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[5]The material in this section was adapted from *Closing the Loop: Integrated Waste Management Activities for School and Home, K-12.* Sacramento: California Integrated Waste Management Board, 1993, p. D-8.

[6]"Market Status Report: Ferrous Scrap." Sacramento: California Integrated Waste Management Board, Publication # 421-96-061, 1996.

[7]*Ibid.*

[8]*Ibid.*

C–IV Glass[9]

Three to four thousand years ago, Egyptians and Mesopotamians were using opaque glass to glaze pots and to make beads and small bottles. The technique of glass blowing produced the first transparent glass and was developed in Syria several hundred years later. The art of glassmaking spread to the Roman Empire and then throughout Europe in the following centuries, becoming a widespread and highly crafted art form. The first known established glass house in America was founded in 1739 in New Jersey. Early glass factories in America produced mostly simple, useful glass objects, such as windowpanes and bottles. The production of glass was not automated until the mid-nineteenth century.

From What Raw Materials Is Glass Made?

Approximately 1,300 pounds of sand, 400 pounds of soda ash, 400 pounds of limestone, 151 pounds of feldspar, and 15 million BTUs of energy are required to produce one ton of glass. Major deposits of white sand suitable for making glass are found in Illinois, New Jersey, the Allegheney Mountains, California, and the Mississippi Valley. Most soda ash comes from Wyoming, and 65 percent of the feldspar in the U.S. comes from California and North Carolina.

Soda ash (sodium carbonate) and cullet (very small pieces of broken glass) are added to lower the melting point of silica and to create a good consistency. Limestone (calcium carbonate) is added to stabilize the mixture and keep it from dissolving in water. Different colored glass is produced by adding small amounts of other substances, such as iron, copper, and cobalt. Green glass, for instance, is made by adding iron.

The eight major types of commonly used glass are: (1) soda-lime glass for containers; (2) ceramic glass; (3) lead glass; (4) borosilicate glass; (5) laminated glass; (6) optical glass; (7) thermometer tubing and semiconductor glass; and (8) glass fiber.

How Are Glass Containers Made?

The entire mixture of ingredients used to make glass is called a batch. The batch is heated at temperatures reaching 2800 degrees Fahrenheit until the ingredients are completely melted and the mixture is made transparent. The molten glass is moved out of the furnace into a glass-forming machine, which presses or blows it into its final shape.

In the glass-forming machine, compressed air pushes a glob of molten glass down into a mold. More compressed air is forced into the middle of the mold, pushing the glass out against its walls. The container is then transferred to another mold where one last blast of compressed air forms the rough container into its final shape. Finally, the containers are passed through a tunnel called an annealing lehr. If glass containers cool too quickly, they may shatter; annealing prevents breakage by passing the newly formed containers through a tunnel that reheats the glass and allows it to cool slowly.

General categories of glass are flat glass for windows and doors, container glass that is molded into bottles and jars, and pressed and blown glass, such as that used for light bulbs and decorative glassware.

How Much Glass Do We Produce?

In 1997 nearly 9 million tons of glass were produced in the U.S. Of this number, approximately 35 percent was recycled.[10] Each person in the United States uses almost 400 bottles and jars annually.

Why Reuse Glass?

Refillable glass beer and soda bottles, which are likely to survive at least eight round trips from manufacturer to consumer, have become throwaway containers. This means that all the energy and raw materials used to produce the glass bottle are wasted, unless it is recycled.

Reusing glass is usually preferable to recycling one-way containers. It uses less energy and produces less pollution. While returned refillable bottles need to be transported and cleaned, this practice still conserves resources. In Germany and other European countries, over 70 percent of the beverage containers are refilled. In the U.S., where refillable bottles are nearly extinct, we can still conserve resources by reusing glass at home.[11]

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[9] The material in this section was adapted from *Closing the Loop: Integrated Waste Management Activities for School and Home, K-12*. Sacramento: California Integrated Waste Management Board, 1993, p. D-5.

[10] "Americans Continue to Recycle More than One in Three Glass Containers," April 28, 1998, press release from the Glass Packaging Institute.

[11] From a review provided by the California Department of Conservation, Division of Recycling in December, 1998.

Why Recycle Glass?

The next best thing after reusing glass is recycling. Using recycled glass saves energy because it melts at a lower temperature than raw materials. For each 10 percent of recycled glass used in forming glass, the furnace temperature can be lowered 10 degrees. Each batch can be up to about 50 percent recycled glass (up to 90 percent in Europe for specific types of bottles).[12] Using one ton of recycled glass saves 1.2 tons of raw materials. According to one estimate, by using 50 percent recycled glass in manufacturing new glass, water consumption can be cut in half, mining wastes cut 79 percent, and air emissions cut 14 percent.

Bottle bill legislation has substantially increased the amount of recycling of glass containers. In 1981 only one in fifteen of the 46 billion bottles and jars produced was melted down along with fresh material to make new bottles and jars. By 1990 more than one in ten bottles and jars were recycled. In 1997 approximately 67 percent of bottles covered by the bottle bill in California were returned and reused or recycled, while the recycling rate of other glass containers was much lower.[13]

How Is Glass Recycled?

When glass is prepared for recycling, the containers must be rinsed clean of any organic waste, aluminum and plastic caps and lead wrapping must be removed, and the containers must be separated by color. Window glass, ceramics, Pyrex, lightbulbs, mirrors, and other noncontainer glass should never be included, because the different chemical compositions can cause serious (even dangerous) furnace malfunctions as well as visual inconsistencies and structural imperfections in the new glass.[14]

Once collected and separated according to color green, brown, and clear—the glass is broken into very small pieces called cullet. The cullet is sorted to remove remaining contaminants, such as metal and plastic caps, lids, and rings. Organic waste, ceramics, dirt, and rocks are removed to eliminate contamination.

Ideally, glass containers should be sorted according to color, because separating results in a cleaner product. However, in California much of glass recycling is done through single-container collection systems in which the glass is mixed.[15]

Once collected and shipped to manufacturing plants, any remaining contaminants must be removed. Cleaned cullet is added to a batch of raw materials and melted in furnaces. Any remaining paper labels are burned off at this point. Once heated, the molten glass is poured into molds to form the new bottles and jars.

Cullet is used to make fiberglass insulation, concrete, polymer-composite sewer pipe, brick, terrazzo, and new beverage containers. It is also used to make glassphalt, a road surface with a glass filler.

C–V MOTOR OIL[16,17]

In 1998, 40 million gallons of lubricating oil was sold in California to people who change their own oil. If improperly handled, the used oil can seriously harm our environment.

Why Is Used Motor Oil Hazardous?

Motor oil is contaminated by its use with physical or chemical impurities. Used oil can contain such contaminants as lead, magnesium, copper, zinc, chromium, arsenic, chlorides, cadmium, and polychlorinated biphenyls.
Oil poured down drains or onto the ground can work its way into our ground and surface waters and cause serious pollution. One gallon of used oil can foul a million gallons of drinking water, the supply of 50 people for one year. One pint of oil can produce a slick of approximately one acre in area on the surface of water. Federal reports indicate that used motor oil accounts for more than 40 percent of the total oil pollution of our nation's harbors and waterways.

Since the implementation of California's Management of Used Oil Act in 1987, it is illegal to dispose of used oil in sewers, drainage systems, surface or ground waters, water courses or marine waters, by domestic incineration, or onto the land or in the trash.

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[12]From a review provided by the California Department of Conservation, Division of Recycling in December, 1998.

[13]*Ibid.*

[14]*Ibid.*

[15]From a review provided by the California Department of Conservation, Division of Recycling in December, 1998.

[16]Adapted from "California's Used Oil Recycling Program," Sacramento: California Integrated Waste Management Board, Publication # 332-97-001, 1998.

[17]From a review provided by California Integrated Waste Management Board staff member Natalie Lee in December, 1998.

How Is Used Motor Oil Reused and Recycled?

Most used oil is reprocessed into fuel oil and used as fuel for marine vessels and other engines. Used motor oil is also easily recyclable. It can be re-refined to the same quality as virgin oil and used again indefinitely as a lubricant. Two and a half quarts of lubricating oil can be made from one gallon of used oil. According to one estimate, if the oil generated by all do-it-yourself oil changers in America were collected and re-refined, it would provide enough oil for over 50 million cars each year.

Unfortunately, very little used oil is being recycled by individuals who change their own motor oil. In 1997 only 20 percent of the motor oil purchased by do-it-yourself oil changers was recycled in California. That means that tens of millions of gallons of used motor oil was disposed of illegally by the public.

As a result of The California Oil Recycling Enhancement Act of 1991, there are over 2,300 state certified collection centers and 68 curbside programs that accept used oil for free.

To recycle oil, consumers should:

- Drain used oil into a clean container.
- Not mix any other materials, including water, with used oil.
- Take used oil to a household hazardous waste collection facility or a used oil collection site, or use curbside collection if available in the area.

For More Information

To find the used oil collection center nearest you, call 1-800-CLEAN-UP, contact your local city or county recycling coordinator, or look at the Web site: www.ciwmb.ca.gov/UsedOil/.

C–VI Organic Materials

Over 30 percent of California's solid waste stream consists of what are termed organic materials.[18] These materials include yard or landscape materials, such as leaves, grass clippings, and prunings; wood scraps, including branches and stumps; food scraps; and agricultural crop residue. While this material could be composted, most of it ends up in a landfill.

When waste is buried in landfills with little or no oxygen supply, the materials break down very slowly; newspapers buried in a landfill decompose so slowly that they can still be read a decade later. Waste decomposition results in the production of methane and other gases, which can cause safety problems when not properly collected.

There are several ways that households can reduce the amount of organic materials they put into the garbage. Water efficient landscaping and grasscycling are landscaping techniques that reduce waste; and backyard composting and vermicomposting are two ways to turn yard and kitchen scraps into reusable compost.

What Is Water Efficient Landscaping?[19]

One way to reduce the amount of yard trimmings produced is to practice water efficient landscaping, a way of landscaping for low water needs. Although water efficient landscaping was initiated primarily because of concerns over scarce water supplies, it also reduces waste and energy use.

Trees and shrubs that are native to California or Mediterranean climates are often drought-tolerant and slow growing. In general, these plants need less pruning or mowing. These plants are typically deep rooted and often have leaves specially adapted to reduce transpiration rates.

To maximize waste reduction opportunities, gardeners should choose plants that fit the available space in order to minimize pruning needs, and they should consider the mature size of the plant before making decisions on location. Using both winter and summer perennials can give year-round color without the cost and waste of replacing annual plants. Installing perennial ground covers that do not require replacement every year can be an attractive alternative to turf or annuals and result in a reduction of green waste.

Beyond careful choosing and proper maintenance of plants, the design and operation of irrigation systems can also help reduce unnecessary excess growth, maintenance requirements and subsequent waste. For example, drip irrigation places water next to the plant, enhancing plant health, as well as minimizing weed growth. Less weed growth saves labor costs (and time) and decreases the amount of organic matter in the waste stream.

[18] "Greening Team Plan: Vision Statement of the California Greening Team." Sacramento: California Integrated Waste Management Board, 1998.

[19] This section was adapted from "Xeriscaping for Waste Prevention." Sacramento: California Integrated Waste Management Board, Publication # 344-29-033.

What Is Grasscycling?[20]

Grass clippings make up a surprisingly large portion of California's waste stream during the growing season. "Green waste," such as grass clippings, accounts for 15 percent of the total amount of waste generated in California each year. Many people overwater and overfertilize their lawns to encourage maximum growth. The clippings are then bagged and transported to a landfill.

Grasscycling is a term used for the natural recycling of grass by leaving clippings on the lawn when mowing. These grass clippings decompose quickly and release valuable nutrients back into the soil.

Grasscycling can be practiced on any healthy lawn as long as proper turf management guidelines are followed. Proper watering and fertilizing result in more moderate turf growth, yet still produce a healthy green lawn. Grasscycling means applying water and fertilizer at a rate needed by the lawn. Overwatering is not only wasteful, but also causes lawns to grow faster and require more mowing. Overfertilization can weaken a lawn by causing excessive and succulent top growth.

Proper mowing is required for successful grasscycling: cutting grass when the surface is dry, keeping mower blades sharp, and mowing often enough so that no more than one-third of the length of the grass blade is cut in any one mowing. Frequent mowing will produce short clippings that will not cover up the grass surface. In many areas of California, raising the mowing height in the summer encourages deeper roots and protects grass from drought and heat damage.

Grasscycling can be done with almost any mower. The mower collection bag can be removed to allow clippings to drop on the lawn. However, if the mower does not have a safety flap covering the opening where the bag fits into the chute, contact your local retailer to purchase a retrofit kit. Some lawnmower manufacturers have developed mulching or recycling mowers that cut grass blades into small pieces and force them into the soil. These will also work for grasscycling, but are not necessary.

[20]This section came from "Grasscycling: Send Your Grass Back to its Roots." Sacramento: California Integrated Waste Management Board, Publication #500-94-007, 1994.

What Is Backyard Composting?

Compost has long been a useful soil amendment in gardens and farms, but the drive to use chemical amendments and fertilizers after World War II pushed these methods aside in favor of "scientific" farming.[21] Several years ago organic farmers began the turnaround to "natural" methods to replenish soils with microbiological activity found in compost. Just as farmers are looking to add organic material to the soil, cities are also turning to composting to reduce the tons of yard trimmings that are now being placed in landfills.

In composting the decomposition of organic waste mostly occurs aerobically when oxygen is present. This means that there is constant interaction among microbes, air, and water. The point of composting is to keep bacteria and other compost life forms healthy while they are working hard to break down food and yard wastes into nutritious humus.

Backyard composting is a simple way to reduce organic waste without using expensive technology or large amounts of energy. It can be accomplished by using structures ranging from simple piles to boxed enclosures made of wood, wire, or brick.

Like cooking, backyard composting can be easy, especially if you use the right blends of ingredients. The simplest recipe calls for blending equal parts of "browns" and "greens." Brown materials, such as dried leaves, wood chips, sawdust, and twigs, add carbon to the soil. Green materials, such as grass clippings and fruit and vegetable trimmings, add nitrogen. The mixture of these provides a balanced diet for the organisms active in the composting process.

Layering or mixing the materials in a pile or enclosure and keeping them moist (as moist as a wrung out sponge) allow the decomposing organisms to thrive. In addition the pile needs to be turned periodically to allow air to circulate. A compost pile of 3 by 3 by 3 feet will take anywhere from two to several months to complete the composting process, depending on environmental and climatic conditions.

What Is Vermicomposting?

Vermicomposting is a method of using worms to recycle food scraps into exceptionally rich fertilizer for gardens or houseplants. Vermicomposting can be done year round, indoors or outdoors.

[21]"Fact Sheet: Urban Compost Makes Soil Sense." Sacramento: California Integrated Waste Management Board, Publication #422-95-070, 1995.

It is ideal for small spaces in the cool garage or under the kitchen sink. Worms are actually quite clean, and with proper care, the worm box will have a pleasant odor, like that of freshly dug earth. A medium-sized worm box can process more than five pounds of food scraps each week, producing a valuable soil amendment good for growing just about anything.

Vermicomposting can be done with a plastic storage bin, wash basin, or sturdy wooden box, which can be easily fashioned into a home for red worms, also called red wigglers. Worms will eat all types of organic matter, such as fruit and vegetable peelings, coffee grounds, tea bags, crushed eggshells, and other leftovers. Feed worms a vegetarian diet and avoid meat and dairy scraps to keep odors to a minimum. The bin used for the worms should have holes in the bottom for ventilation and drainage. One pound of worms (about 1,000 worms) is enough to start a bin. Eight or ten inches of bedding inside will provide the worms with a damp, aerated place to live. Common bedding materials include strips of newspaper, shredded cardboard, manure, leaves, or peat moss. The bedding should be moist like a well-wrung sponge. In a few months rich, dark worm "castings" (worm feces) replaces the original bedding. This compost is ready for the garden or house plants as fertilizer.

For More Information

See Appendix D for information on constructing a wire mesh composting bin, on vermicomposting, on maintaining a vermicomposting system, and for finding suppliers of worms and worm bins.

See Appendix F, section VI, for a list of Web sites related to vermicomposting; and section II, for a list of Web sites related to composting.

See the following publications from the California Integrated Waste Management Board: "Composting: Nature's Way to Recycle," Publication # 55-94-014, 1997. *Worms, Worms and Even More Worms: A Guide to Vermicomposting,* Publication # 322-98-008, 1998.

See the book *Worms Eat My Garbage* by Mary Appelhof, Flower Press, 1982.

C–VII PAPER[22]

The first paper was made about 300 million years ago by wasps. Wasps chew wood into a pulp and use the paste to make the walls of their houses. Humans began experimenting with paper-like substances only a few thousand years ago in an effort to find a more convenient writing and drawing surface than stone. For example, animal skins were cleaned and pounded and stretched to make parchment. The inner bark from trees were peeled and pounded into thin sheets, silk woven into fabric was used as a painting surface, and papyrus reeds were layered and pounded together to form lightweight sheets.

Today paper gets its name from papyrus, but wood-based paper is made quite differently. The key element in both wood and papyrus is cellulose. Cellulose is the major building block of all plant cell walls. A sheet of wood-based paper is produced by breaking cellulose down into individual fibers by beating them and mixing them with water. The water is then drained away, leaving an interwoven mass of fibers in a thin sheet.

The first real paper was probably made by the Chinese in 105 A.D. out of mulberry tree bark, hemp, fishnets, and rags. The first European paper mill was built in Xativa, Spain, in 1151 A.D. The use of linen and cotton rags for making paper became commonplace in Europe.

Paper was made by hand by dipping screens into large vats of paper pulp and drawing out and draining a thin sheet of fibers. In 1801 the Fourdrinier brothers patented a machine that produced an endless roll of paper. The papermaking machinery used today is basically the same as what was developed two centuries ago.

About the same time that the Fourdriniers were developing their machine, Matthew Lyon of Fair Haven, Vermont, had developed a method for making paper, not from used clothing fibers, but from the bark of the basswood tree and sawdust. Most of the paper we use today comes from trees, and the United States has become the largest producer and consumer of paper and paper products in the world.

[22]The material in this section was adapted from *Closing the Loop: Integrated Waste Management Activities for School and Home, K-12.* Sacramento: California Integrated Waste Management Board, 1993, p. D-3.

From What Natural Resources Is Paper Made?

Wood is the primary natural resource used to make paper. Most trees harvested for papermaking are grown specifically for that purpose on "tree farms." However, about one third of the trees harvested specifically to make paper are harvested from public and private forestland. In addition to trees that are used specifically for papermaking, byproducts from lumber operations, such as wood chips and sawdust, are also used to make paper. About 28 percent of the wood used to make paper comes from the byproducts of lumber.

Most of the wood used for papermaking in the U.S. comes from fir and pine forests of the Northwest, South, and Southwest. Hardwood forests of the north central U.S. and New England are also used.

The number of trees necessary to produce a ton of paper varies with the size and type of tree, but 17 trees is a widely accepted average. Approximately 3,688 pounds of wood, 28 billion BTUs of energy, 216 pounds of lime, 76 pounds of ash, 360 pounds of salt cake, and 24,000 gallons of water are used to make just one ton of paper.

How Is Paper Made Commercially from Trees?

To save transportation costs, paper mills are usually located near the forests and tree farms where the wood is harvested. The trees are debarked, chipped, mixed with chemicals, and processed in a large steam-heated pressure cooker called a digester. This helps to break the wood down into cellulose fibers. The fibers are then rinsed with water to remove chemicals, unwanted wood contaminants, and dirt. The remaining water-wood mixture, called pulp, is blown onto a screen and shaken to intermesh the cellulose fibers. Water is drained through the screen, and the remaining sheet of paper passes through a series of rollers where it is pressed and dried. Continuous rolls of paper up to 16 feet wide are produced by the machines at a rate of 30 feet per second.

What Effects Does Paper Manufacturing Have on Our Environment?

Nearly half of the world's annual commercial wood harvest is used to produce paper. Although wood is a renewable resource, we are presently using more of our forests' resources than we are replacing. A federal subsidy of timber harvesting keeps the cost of wood products artificially low, encouraging their continued overuse.

In addition to depleting natural resources, paper manufacturing pollutes the environment. According to one estimate, producing one ton of paper creates 84 pounds of air pollutants, 36 pounds of water pollutants, and 176 pounds of solid waste. Disposing of used paper pollutes again, as litter, as air pollution from burning, or as potential groundwater contamination from the leaching from landfills of inks containing heavy metals.

What Do We Use Paper For?

Paper is used for three main purposes: (1) as a lightweight, durable surface for writing and printing; (2) as wrapping and packaging for food and other items; and (3) for sanitary products, such as paper towels and tissue. In 1996 the United States consumed about 80 million tons of paper and paperboard products. Of that amount approximately 47.3 million tons were thrown away.

Why Recycle Paper?

According to one estimate (which does not take into account the transporting and processing of the materials), when paper is made from recovered paper instead of trees, 60 percent less water and 70 percent less energy are used, and 50 percent fewer pollutants are added to the environment. Recycling also helps extend the life of our landfills. Paper represents nearly one-third, by weight, of the materials we dispose in the U.S. and over half by volume. Recycling one ton of this waste saves an average of three cubic yards of the space in a landfill.

How Is Paper Recycled?

Paper intended for recycling must be sorted prior to recycling to ensure the best quality end product and to eliminate adhesives and other contaminants that can damage machinery. Care must be taken to store the paper out of sunlight and away from water, which can break down cellulose fibers and make the paper unusable.

At recycling centers paper is first baled and then transported to one of over 600 paper mills in the U.S. At the mills, bales of recovered paper are dumped into a pulper, where a rotor mixes it with warm water and breaks the cellulose fibers back down into pulp. Once the rotor has thoroughly mixed the paper-water solution, a screen catches contaminants, such as paper clips and staples. The mixture then travels on through centrifugal cleaning tanks and is bleached and de-inked. Once cleaned, the slurry is deposited on screens, sent through dryers, and formed into finished rolls of recycled paper in much the same way the original paper was made.

What Is Recovered Paper Used For?

Recovered paper cannot be recycled perpetually, because with each recycling, the cellulose fibers become smaller and weaker. Eventually, the fibers become too small to screen into paper. Therefore, "virgin" wood fibers from trees or other cellulose sources are necessary in the papermaking cycle. Recovered paper is used to make a wide variety of recycled paper products. The following are just some of the products that are made from recycled fibers: writing and printing paper and newsprint; roofing felt, insulation board, fiberboard, and other construction materials; fruit trays, flower pots, egg cartons and other products molded from paper pulp; craft paper; tissue; corrugated cardboard; and cardboard boxes.

Besides being recycled into newsprint, recovered newspaper is shredded and reused as animal bedding or packing material. It is also shredded, defibered, and treated with fire-resistant chemicals for use as building insulation.

Is Recycled Paper as Good as Paper from Virgin Fibers?

Most of today's recycled paper products perform just as well and look just as good as virgin paper. While recycled packaging and tissue papers for many years were largely indistinguishable from those made from virgin paper, recycled printing and writing papers (such as copier paper) were considered inferior to those made from virgin materials. Over the past ten years, however, the quality of these papers has improved considerably, and most copier manufacturers acknowledge that recycled papers perform just as well in the machines as do virgin papers. Still, some prejudices toward recycled paper remain.

A Recycling Outlook

Recycled paper manufacturers operate in an economic and political environment that still favors virgin paper production. For example, freight taxes are lower for virgin materials than for recycled fiber, and the forest industry is heavily subsidized through government tax policies and the leasing to loggers of public land below cost. These artificial structures give virgin paper production a competitive edge over recycled paper production.

In spite of the benefits extended to using virgin wood fiber, the use of recovered paper in U.S. paper and paperboard manufacturing is on the rise, driven largely by the nation's increasing awareness of the need to recycle. In 1990 recovered paper made up 26.1 percent of the total fiber used to make paper and paperboard; this number grew to 36.5 percent in 1998.[23] Recovered paper use is projected to continue to grow faster than virgin fiber use in the foreseeable future.

For More Information

See Appendix F, section IV, for a list of Web sites related to natural resources.

C–VIII Plastics

What Are Plastics?[24]

Plastic is a term generally used to describe any of numerous materials that can be molded, cast, drawn, extruded, or laminated into many types and shapes of parts, products, housings, containers, coatings, tubing, films, or fibers. Plastics are widely used because they are durable, lightweight, waterproof, chemically resistant, convenient for the consumer, and inexpensive to produce and transport. Their chemical structures are malleable to achieve just the right combination of properties for most applications. Some plastics are also recyclable.

The very first plastics were made from cornstarch, but most plastics today are made from nonrenewable resources—natural gas and crude oil. They are made by linking together in repetition relatively small molecules, called monomers, to build one large molecule, called a polymer. Polymers can be thought of as big buildings, and monomers as the bricks that go into them. These synthetic polymers vary in composition, depending on the type of polymer. The most common ones are made from hydrogen and carbon elements, with some also containing oxygen, nitrogen, and other organic and inorganic matter. Synthetic polymers fall into two basic categories: thermoplastics and thermosets.

Thermoplastics. Like wax, thermoplastic polymers liquefy at high temperatures and solidify when cool. This property makes it easy to melt

[23]Figures provided by the American Forest & Paper Association's publication "Paper, Paperboard, & Pulp Capacity and Fiber Consumption: 39th Annual Survey," December, 1998.

[24]From a review provided by the Director of Corporate Environmental Health and Safety with the Raychem Company, Jerry L. Jones, in January, 1999.

the plastic and reform it several times into new objects. Thermoplastics are used in packaging, such as milk, soda, and juice containers; bags for frozen foods, and bottles for detergents. They are also used in durable goods, such as electronic equipment, automobile components, and white goods. Polyethylene, polystyrene, polyvinyl chloride, polyethylene terephthalate, and polypropylene are types of thermoplastics.

Thermosets. Like concrete, once thermoset polymers are formed, they cannot change shape. Formed by combining different polymer molecules, thermosets cannot be melted and reformed into new shapes and are difficult to recycle. Thermoset resins are widely used in producing tires and in making plywood, fiberglass, furniture, toys, tableware, and other permanent uses requiring a hard plastic. Some types of polyesters, epoxies, certain rubbers, and melamine are all thermoset polymers.

In What Ways Are Synthetic Polymers a Problem?

The widespread use of synthetic polymers is a problem for two main reasons: plastics are made from a nonrenewable resource, and they cause special problems in the waste stream. Although some plastics are relatively inexpensive to manufacture, the crude oil and natural gas from which they are made come from limited supplies. As the extraction of these oil supplies becomes increasingly complicated, negative environmental and political consequences also increase; for example, oil spills and U.S. dependence on foreign oil become greater issues. In the process of extraction, other natural resources, like water and salt, are used and may be harmful to the environment.

The percentage of synthetic polymers, especially thermoplastics, in the waste stream is increasing in both real and in relative terms. Specifically, the amount of disposable plastic products manufactured is increasing each year, thus increasing the amount of plastic disposed of in real terms. In addition, materials (like paper, glass, and organics) are diverted from the waste stream in greater amounts, so that the relative amount of plastic in the waste stream is also increasing.[25]

Plastics cause several special problems in the waste stream. The same characteristics that make plastic an attractive packaging material make it difficult to deal with as a waste. Though lightweight, plastic is bulky and difficult and expensive to compact for shipping to reprocessors or for burial in landfills. Another problem with the disposal of plastic is that it does not biodegrade and can persist in the environment as a litter problem. Although photodegradable plastic may break down into smaller pieces when exposed to enough sunlight, it never disintegrates completely.

Plastic litter causes particular problems in our oceans and on our beaches. Thousands of fish, sea mammals, and birds have died because they have eaten or gotten tangled in discarded fishnets, six-pack rings, plastic bags, and other packaging material. Virtually all beaches and waterways are now polluted with plastic waste. In 1997 the California coastal cleanup effort collected over 1,000,000 pieces of debris, 63 percent of which was plastic.[26]

Foam packaging also creates problems. If expanded with chloroflourocarbon (CFC), both the manufacturing of the foam and the packaging itself release into the atmosphere certain CFCs, which deplete the Earth's ozone layer. While manufacturers in the United States were required to stop using CFCs in 1990, CFCs are still used in other parts of the world. Rigid foam products account for one-quarter of the world's use of the two most ozone-threatening CFCs.

Plastics also cause problems in incineration. While they are made from fossil fuels and have a high energy (BTU) value, some plastics emit toxic fumes when burned. Burning polyvinyl chloride, for instance, can release chlorine compounds into the atmosphere, contributing to the depletion of the ozone layer. Other plastic ingredients can clog the inner workings of incinerators.

How Are Thermoplastic Polymers Recycled?

For recycling, thermoplastics are first sorted by resin type and color. They are baled or shredded for transportation to a reprocessing plant where the material is washed, dried, and extruded into pellets.[27] The pellets are then used as a raw material in the manufacturing of products containing recycled content.

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[25]From a review provided by California Integrated Waste Management Board staff members Mike Leaon and Edgar Rojas in December, 1998.

[26]"1997 International Coastal Cleanup Data Report: California." Center for Marine Conservation, 1997.

[27]From a review provided by California Integrated Waste Management Board staff members Mike Leaon and Edgar Rojas in December, 1998.

The polyethylene terephthalate (PETE) used in soda bottles is shredded and processed to make fibers, which can be woven back into threads to make clothing or used to stuff sleeping bags, quilts, and parkas. The high density polyethylene (HDPE) used in plastic milk jugs, juice jugs, bleach bottles, and detergent bottles is commonly recycled into construction materials, such as railroad ties, parking blocks, and piping, or back into detergent and soap bottles.

Because plastic materials used for containers may absorb some chemical substances–like motor oil– from the contents of the container, recycled plastics are used very seldom for food containers.[28] They are sometimes used as a filler layer in food packaging as long as they do not come into direct contact with food.

The quality of recycled plastic depends on how well the scrap is separated prior to recycling. The less control there is over separation and contamination, the poorer the quality of the resulting product. The success of recycling plastics depends in part on the proper identification and separation of plastics. There are hundreds of different kinds of plastics, more than 46 of which are in common use. Just by looking at the plastic container, a person may be unable to distinguish the chemical recipes.

Why Are Plastics Difficult to Recycle and What's Being Done to Encourage Recycling?

The cost of collecting, transporting, sorting, processing, and washing postconsumer plastics makes recycling difficult, because it often puts recycled resin at a cost disadvantage to virgin resins. The very low prices of virgin resins, caused by their oversupply, make the economical situation of plastic recycling businesses critical.[29]

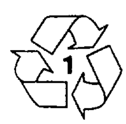
The Society of Plastics Industry (SPI) developed a coding system (see next page) that helps to identify and separate by sight the most commonly used thermoplastics, and thus facilitate recycling. A small number of companies have developed automated identification and sorting technologies, thus decreasing the cost of recycling plastics.[30] Research is also being done on melding unsorted plastics into a composite material, primarily for use as building material.

In California some types of plastics are being recycled in significant amounts. Because of the California Beverage Container Recycling and Litter Reduction Act, for example, the percent of PETE soda bottles that was recycled increased from 4 percent in 1988 to 71 percent in 1994.[31] However, the overall recycling of plastics is still very small; only about 3.5 percent of waste plastic in California is recycled or diverted from the waste stream.[32]

The California Integrated Waste Management Board has implemented several programs to develop markets for postconsumer resin. For example, one law specifies that trash bags intended for sale in California contain at least 10 percent recycled postconsumer plastic material, or the manufacturer must ensure that at least 30 percent by weight of all the manufacturer's plastic products intended for sale in this state be recycled postconsumer plastic. The Rigid Plastic Packaging Container Act requires that specific plastic containers be source-reduced by 10 percent, contain 25 percent postconsumer resin, reusable or refillable, or meet specified recycling rates.[33]

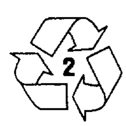
These efforts, along with advances in sorting and processing technologies, offer the potential to increase the amount of plastic recycled in California and in the United States.

Different Types of Plastics and Their Resin Identification Codes[34]



PETE

Polyethylene Terephthalate: Used for soft drink bottles, salad dressing bottles, cooking oil bottles, mouthwash bottles, peanut butter jars, and clear food tray containers.



HDPE

High Density Polyethylene: Used in milk, juice, and water bottles;

[28] From a review provided by California Integrated Waste Management Board staff members Mike Leaon and Edgar Rojas in December, 1998.

[29] "Market Status Report: Postconsumer Plastics." Sacramento: California Integrated Waste Management Board, Publication # 421-96-066, January, 1997.

[30] From a review provided by California Integrated Waste Management Board staff members Mike Leaon and Edgar Rojas in December, 1998.

[31] "Market Status Report: Postconsumer Plastics." Sacramento: California Integrated Waste Management Board, Publication # 421-96-066, January, 1997.

[32] From a review provided by California Integrated Waste Management Board staff members Mike Leaon and Edgar Rojas in December, 1998.

[33] "Market Status Report: Postconsumer Plastics." Sacramento: California Integrated Waste Management Board, Publication # 421-96-066, January, 1997.

[34] Adapted from "How-to-Recycle Polystyrene," National Polystyrene Recycling Company.

bleach and detergent bottles; shampoo bottles; and margarine tubs.

PVC VINYL

Polyvinyl Chloride: Used in bottles for window cleaner, some cooking oil, and detergent powder.

LDPE

Low Density Polyethylene: Used in food packaging bags, shrink wrap, carryout bags, dry cleaner bags, and grocery bags.

PP

Polypropylene: Used in butter and margarine tubs, yogurt containers, screw-on lids, and drinking straws.

PS

Polystyrene: Used in cutlery and plates, foam coffee cups, egg cartons, meat trays, clear food container trays, and yogurt cups. May be clear, hard, or in foam form.

OTHER

Other plastics: includes containers made of more than one resin type, squeezable syrup and condiment bottles, and some microwave food trays.

C–IX TIRES[35,36]

Synthetic rubber and its chemical additives are manufactured in the United States from oil and natural gas. Automobile tires, which constitute 60 percent of the U.S. rubber market, are made from a blend of natural and synthetic rubbers. They also contain a reinforcing fabric made from cloth, plastic, and steel, and a bead of wire around the rim. In 1997 Californians used and discarded some 30.4 million tires. Of these, approximately 17.2 million were burned as fuel, marketed as secondary materials, or used as landfill cover. The remainder were landfilled, stockpiled, or illegally dumped.[37] As the population of California is increasing, the number of discarded tires is expected to increase proportionally.

Why Are Tires a Problem?

Tires cause disposal problems because they are not easy to compact. Unless they are shredded, they tend to work up to the surface of a landfill. Stockpiles of tires attract vectors, such as mosquitoes and rodents, and they are fire hazards.

What Happens When Tires Are Burned?

Tires are currently being consumed as supplementary fuel in cement kilns or for producing electricity. Because of their high carbon and hydrogen content and a high-energy (BTU) value, tires are considered a good fuel source. However, they may produce sulfur dioxide, nitrogen oxides, heavy metals, benzene and other volatile organic compounds, and particulate matter that must be carefully managed by the combustion facility. In California using tires as a fuel requires an air quality permit issued by either the local air pollution control district or air quality management district.

Waste-to-energy incinerators in the U. S. are designed specifically for tire burning. A $41 million facility built in 1987 in California by Oxford Energy, Inc., burns between four and five million tires a year 24 hours a day. This plant was built next to a 42 million tire stockpile, which feeds it. The facility produces 14 megawatts of electricity, enough to supply the electricity needs of about 14,000 homes.

How Can Longer-Life Tires Prevent Waste?

Tires are rated according to their life expectancy, such as 80,000 miles or 35,000 miles. One way to reduce the number of discarded tires is for consumers to purchase longer-life tires, even though these tires may cost a bit more. Tires that need replacing less frequently result in lowering the total number of tires disposed overall.

How Does Retreading Tires Help?

Retreading tires reduces the number of tires requiring disposal by reusing the tires' casings. Retreaded tires are generally 30 to 50 percent less expensive than new tires (although some imports are comparable in price) and consume less petroleum during manufacturing. The lives of retreaded tires are about 90 percent as long as new tires. If all tires were retreaded once, the demand for synthetic rubber would be cut by one-third, tire disposal problems would be cut in half, and substantial energy savings would be realized. The manufacture of a new passenger

[35] "Tires as a Fuel Supplement," Sacramento: California Integrated Waste Management Board Report to the Legislature, January, 1992.

[36] "Overview Report on California's Waste Tire Program." Sacramento: California Integrated Waste Management Board, Publication # 540-98-007, October, 1998.

[37] From a review provided by California Integrated Waste Management Board supervisor John Nuffer in December, 1998.

vehicle tire requires seven gallons of petroleum compared to two and one-half gallons needed for a retreaded tire.

The number of retreaded tires sold on a national basis has declined, due in part to inexpensive domestic and imported new tires and to the low demand for the types of tires retreaded. In 1989 over 35 million retreaded tires were sold nationally, which declined to about 33 million in 1990. If consumers used more retreaded tires, jobs would be lost in the synthetic rubber and new tire industries, but new jobs would be created in the tire recapping business. Retreaded tires are generally 30 to 50 percent less expensive than new tires (although some imports are comparable in price), and they also consume less petroleum during manufacturing.

What Are Other Ways to Reuse Tires?

In addition to retreading, tires can be reused in a number of ways. Tires that are cut into pieces are used as washers, muffler hangers, shoe soles, boat dock cushions, and doormats. Whole tires are used to build artificial reefs, floating breakwaters, and highway crash barriers. Tires are often seen as weights holding down plastic coverings on feed bunkers and are used in combination with sand as a floor base in dairy barns.

Tires are also reprocessed into devulcanized rubber or ground up and sold back to rubber companies for use in new rubber products. Eleven million tires can yield 14 million gallons of oil, 10 million pounds of steel, and 63 million pounds of carbon black. Tires are also ground up into their component parts of rubber, fiber, and metal. The resulting crumb rubber is mixed with hot asphalt and used to pave road, track, and airport runway surfaces. Tires as additives in pavement products are being tested throughout California. Using scrap tires in asphalt concrete for projects, such as paving parking lots and roads, and in asphalt used for roofing materials has the potential to consume a significant number of scrap tires.