Resource and Environmental Profile Analysis of Polyethylene and Unbleached Paper Grocery Sacks

Background

Recently, much attention has been directed at packaging by a variety of interest groups including: environmentalists, government officials, commercial and retail business, and legislators. This attention toward packaging has been the result of two factors:

1. There is an ever-decreasing landfill capacity in this country which is being aggravated by an inability to site new landfills.
2. Containers and packaging account for 31.6 percent by weight and 29.6 percent by volume of the municipal solid waste (MSW) in the United States.

Certain packaging materials have come under particular scrutiny and have been singled out for restrictive measures such as bans or taxes.

Before decisions are made regarding individual packages or materials, a full evaluation should be made of all packaging materials and alternatives.

Objective data regarding the energy requirements, environmental discharges, recyclability, combustion, and landfill requirements of different packaging will be important in determining alternative solutions to our current and future environmental problems.

Conclusions

The following conclusions were reached regarding the energy and environmental impacts for 10,000 equivalent uses of polyethylene (PE) and paper sacks.

Energy

The energy requirements for plastic polyethylene grocery sacks are 20 to 40 percent less than for paper sacks at zero percent recycling for both sacks.

As recycling increases for plastic polyethylene and paper sacks at the 2 PE:1 paper sack ratio, the energy requirements become equivalent at approximately a 60 percent recycling rate.

At the 1.5 PE:1 paper sack ratio, the polyethylene sack continues to require 23 percent less energy than paper even at 100 percent recycling.

Environmental

1. Polyethylene sacks contribute 74 to 80 percent less solid waste than paper sacks at zero percent recycling. Polyethylene sacks continue to contribute less solid waste than paper sacks at all recycling rates.
2. Atmospheric emissions for the polyethylene sack range from 63 to 73 percent less than for the paper sack at zero percent recycling. These lower impacts for the polyethylene sack continue throughout all recycling rates.
3. At zero percent recycling rate, the polyethylene sack contributes over 90 percent less waterborne wastes than the paper sack. This percent difference actually increases as the recycling rate for both grocery sacks increase.

Recyclability

Both polyethylene and paper sacks are recyclable. Manufacturing and scrap trim from the fabrication of the sacks are typically recycled. Post-consumer recycling for both of these has not been significant. In the case of paper sacks, they are most typically recycled during the collection of old newspapers. For polyethylene sacks, efforts are usually concentrated on industrial scrap film. However, significant initiatives have recently begun to collect both polyethylene and paper grocery sacks at the post-consumer level.

Combustion

On a per pound basis, polyethylene releases 2.75 times more energy upon incineration than unbleached paper. However, on an equal use basis, paper grocery sacks weigh 4 to 5 times more than polyethylene grocery sacks. Therefore, on an equivalent use basis, the paper sack has a greater potential for energy released from incineration than the polyethylene sack.

The ash content per pound of unbleached paper is greater than that of polyethylene. Thus, even on an equivalent use basis, the paper sack has a greater potential for more ash from incineration than the polyethylene sack.

Landfill Impacts

Volume. The landfill volume occupied by the polyethylene sacks is 70 to 80 percent less than the volume occupied by paper sacks on 10,000 uses. These landfill volumes were derived by Franklin Associates, Ltd., in conjunction with The Garbage Project, University of Arizona, Tucson.

Degradability. While some degradation occurs in landfills, little data exists regarding what materials degrade and the rate of composition. Therefore, the degradability of both paper and polyethylene grocery sacks cannot be predicted/ As a consequence, no estimates can be made regarding the potential for impact on landfill leachate or methane gas production.

Purpose of the Study

The purpose of this study is to determine the energy and environmental discharges of polyethylene and paper grocery sacks.

In this study, the term impact refers to the quantities of fuel and raw materials consumed and emissions released to the environment. The comparative recyclability, incineration, and landfill impacts of these sacks are also addressed in this analysis.

Scope

The packages examined in this study were chosen due to their predominant visibility and potential for restrictive legislation. The following packages were examined:

1. 1/6 barrel polyethylene grocery sacks; and
2. 1/6 barrel 70-pound base weight single-ply unbleached paper grocery sack.

These sacks are the standard plastic and paper sacks used in grocery stores.

The results for the polyethylene sack represent both high molecular weight high-density polyethylene (HMW-HDPE) and linear low-density polyethylene (LLDPE) resins.

The term "package" is used throughout this study to mean the grocery sack itself and all secondary packaging such as overwrap and corrugated boxes.

The two sacks examined in this study are the same size. However, through surveys of major grocery chains, it was determined that more plastic sacks are used to hold the same amount of groceries. The practice of using more plastic to paper sacks is believed to hold true even after taking into account some stores' practice of using double (one sack inside the other) paper sacks.

One reason for the use of more plastic sacks seems to be inexperience on the part of grocery clerks and consumers on how to pack them so that they may hold their designed capacity.

Another reason for the use of more plastic sacks could also be a mistaken comparison of smaller plastic sacks, for instance, 1/7 barrel plastic to the standard 1/6 barrel paper sack.

Since the ration of polyethylene sacks to paper sacks used is crucial to the results of this study, considerable effort has been made to determine this number. Ratios ranging from 1.2:1 to 3:1 have been reported, but there is no industry-wide agreement on a representative ratio. Therefore, the results of this analysis are presented at ratios of 1.5:1 and 2:1 polyethylene to paper since most estimates fall within this range. These ratios were developed based on data collected from supermarket chains and other industry sources.

For this analysis, an equivalent basis of 10,000 uses was utilized. With a 1.5:1 polyethylene to paper sack ratio this equals 15,000 polyethylene sacks and 10,000 paper sacks. With a 2:1 polyethylene to paper sack ratio, this equals 20,000 polyethylene sacks to 10,000 paper sacks.

Methodology

A cradle-to-grave approach was used to determine the energy and environmental discharges of the packages examined in this study.

This methodology quantifies energy consumption and environmental emissions at each stage of a product's "life cycle," beginning at the point of raw materials extraction from the earth and proceeding through processing, manufacturing, use, and final disposal, recycling, or reuse.

Energy use was quantified in fuel or electrical energy units and converted to British thermal units (Btu) for each of the many stages, or industrial processes, required to manufacture a grocery sack.

Btu consumption was determined for six basic energy sources (natural gas, petroleum, coal, hydropower, nuclear, and wood) as well as the total for each sack.

Since this analysis attempts to quantify the total energy impacts associated with each sack, the fuel and electrical energy conversion factors to Btu include not only the energy content of the fuels, but also an adjustment that accounts for the energy used to obtain, transport, and process that fuel into a usable form.

As with energy, the environmental discharges with each step or process were determined.

Government documents as well as federal regulations, technical literature, and confidential industry sources form the basis for these data.

There are three broad environmental categories considered:

1. Solid wastes

2. Atmospheric emissions

3. Waterborne wastes

These categories include not only those readily identifiable wastes associated with a specific process, but also the pollutants associated with the fuels consumed in power generation or transportation. The solid waste category includes both industrial solid waste and post-consumer solid waste.

Energy requirements and environmental discharges were determined for various post-consumer recycling rates for both the polyethylene sack and the paper sack. In this analysis the recycled polyethylene or paper is assumed to replace virgin materials in producing new products.

Currently, recycled grocery sacks are being made into products that we assume are not further recycled such as food cartons. For this reason, both the paper and polyethylene grocery sacks are considered to be recycled in an "open-loop" recycling system. Consequently only half of the energy savings of recycling is attributable to the sack.

The consequence of combustion was also included in this analysis. A national average for solid waste combustion of 14 percent has been determined in the 1990 U.S. EPA Municipal Solid Waste Characterization Study. Thus, the post-consumer solid waste for the sacks was adjusted for 14 percent combustion in waste-to-energy facilities.

Solid waste in the form of ash resulting from this combustion was estimated from the ash inherent in the materials. However, the atmospheric emissions that result from the combustion of the polyethylene and unbleached paper in solid waste could not be estimated due to lack of data. The known dominant constituents of combustion of both materials are carbon dioxide and water.

While emissions from municipal solid waste incinerators have been characterized, we have no way to attribute these emissions back to a given material. Some studies have characterized the changes in emissions of average MSW to those of MSW "spiked" with specific materials. However, these types of analyses have not been done for unbleached paper or polyethylene.

Most atmospheric emissions from municipal solid waste incinerators will be treated in the gas scrubbers used in these facilities. These atmospheric emissions will eventually be disposed of in scrubber blowdown as solid waste.

Since the atmospheric emissions for paper and polyethylene cannot be quantified, the impact of these emissions on scrubber blowdown also cannot be determined.

For both sacks, the corrugated boxes (for the polyethylene sacks) and paper sleeves (for the paper sacks) are assumed to be recycled because grocery stores typically bale and market their corrugated cardboard (the paper sleeves are included with the corrugated material). Because this material is assumed to be recycled, no secondary packaging materials are available for incineration or land disposal.

The margin of error in this study is believed to be plus or minus 10 percent. Therefore, distinctions in energy and environmental releases will only be noted between packages if the difference is greater than 10 percent.

It must be noted that the nature of error in this analysis is systematic and not due to randomness. Thus the margin of error cannot be statistically determined.

Results

The results of this analysis are organized by two categories: energy requirements and environmental impacts.

Energy Requirements

The energy requirements for polyethylene and paper grocery sacks are reported in Table 1-1. These energy impacts are reported in million Btu per 10,000 uses for both 1.5 to 1 and 2 to 1 polyethylene to paper sack ratios at varying recycling rates.

Figure 1-1 is a graphic illustration of the energy requirements reported in Table 1-1.

Table 1-1 and Figure 1-1 show that at zero percent recycling, polyethylene sacks require 20 to 40 percent less energy than paper sacks depending on the use ratio. Considering only the fossil energy sources, the two are essentially equivalent.

As recycling rates increase for both sacks, this energy difference decreases. This is because the recycling energy savings occur at a greater rate for paper than for polyethylene. At a 1.5 polyethylene to 1 paper sack ratio, the polyethylene sack requires less energy if both sacks are recycled at a 100 percent rate.

Even at a use ratio of 2 polyethylene to 1 paper sack, polyethylene sacks consume less energy until a 60 percent recycling rate is achieved.

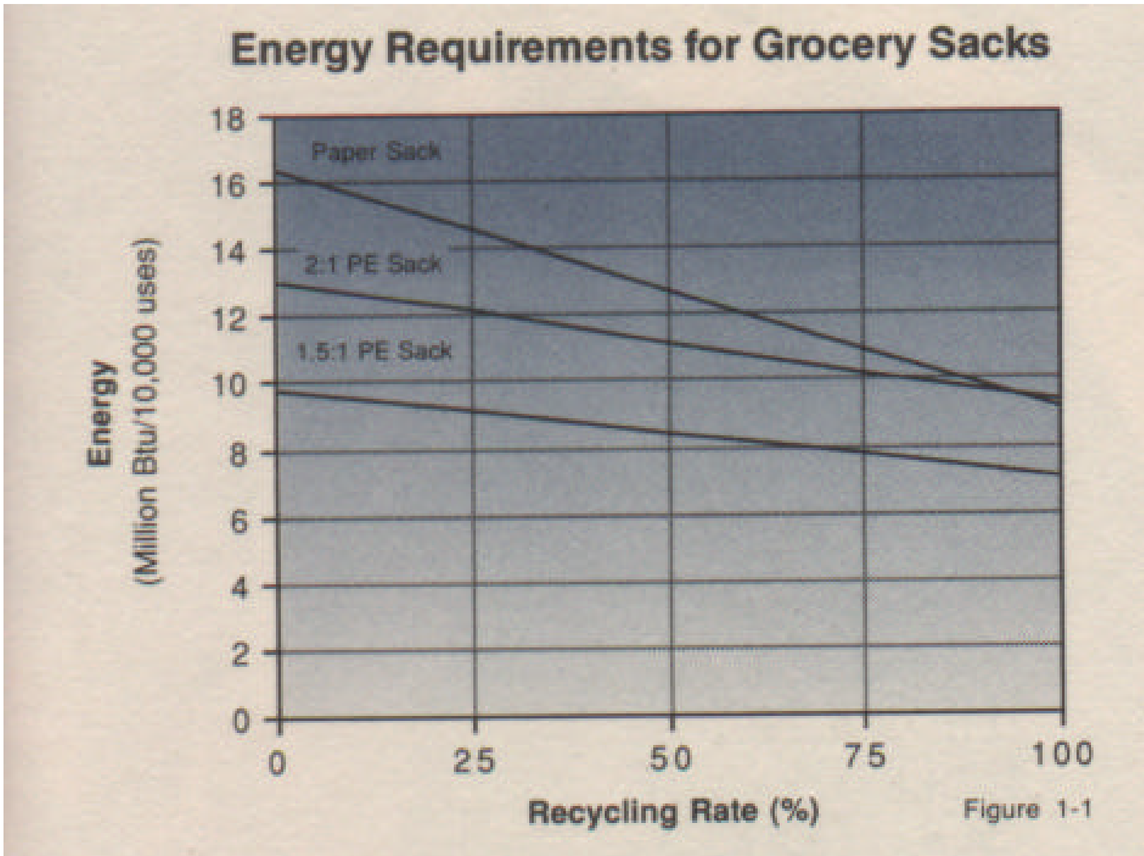

Table 1-1
Energy Requirements for 1/6 Barrel Polyethylene and Paper Grocery Sacks at Various Recycling Rates (1)
(Million Btu per 10,000)

	Recycling Rates				
	0%	25%	50%	75%	100%
1.5 PE to 1 Paper Sack Ratio (2)					
Polyethylene	9.7	9.1	8.4	7.7	7.0
Paper	16.3	14.5	12.7	10.9	9.1
2.0 PE to 1 Paper Sack Ratio (3)					
Polyethylene	13.0	12.1	11.1	10.2	9.3
Paper	16.3	14.5	12.7	10.9	9.1

Environmental Impacts

The environmental impacts for the sacks are divided into three groups and reported in Table 1-2:

1. Solid wastes
2. Atmospheric emissions
3. Waterborne wastes

(1) Assumes 14 percent of post-consumer wastes are burned

(2) Ratio indicates the number of polyethylene sacks used per one paper sack
(3) Ratio indicates the number of polyethylene sacks used per one paper sack.

Source: Franklin Associates, Ltd.

Solid Wastes

The solid wastes generated by the grocery sacks are reported in Table 1-2 in cubic feet per 10,000 uses and include both post-consumer and industrial solid waste.

Post-consumer solid waste volume was derived from weight by applying pre-determined density factors. A density of 24.8 pounds per cubic foot for polyethylene sacks and 27.4 pounds per cubic foot for paper sacks under landfill conditions were used for this study.

Post-consumer solid waste is adjusted for 14 percent incineration of all materials not recycled. For industrial solid waste, a density of 50 pounds per cubic foot was used.

The solid waste data reported in Table 1-2 are also illustrated in Figure 1-2. Both show that at zero percent recycling, polyethylene sacks contribute 74 to 80 percent less solid waste by volume than paper sacks.

Figure 1-2 also illustrates that the percent difference decreases as recycling increases. However, polyethylene sacks continue to contribute less solid waste than paper sacks at all recycling rates.

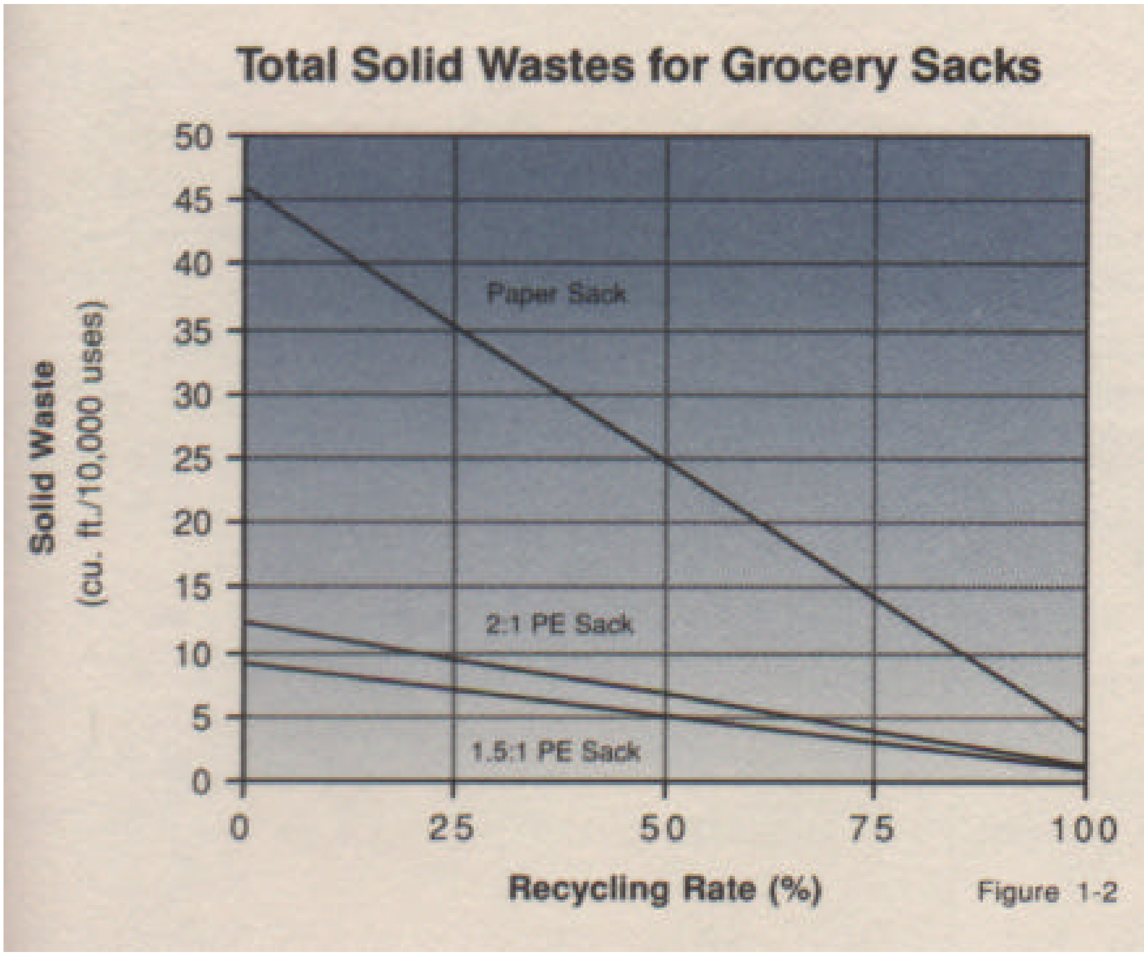

Figure 1-2

Atmospheric Emissions

Six components dominate the category of atmospheric emissions for paper and polyethylene sacks: particulates, nitrogen oxides, hydrocarbons, sulfur oxides, carbon monoxide, and odorous sulfur.

For five of these six components, the polyethylene sacks produce less of each emission than do the paper sacks. Hydrocarbons are generated in greater quantities by the polyethylene sacks.

Table 1-2 lists atmospheric emissions for the grocery sacks in pounds per 10,000 uses. Figure 1-3 also illustrates these releases for both packages.

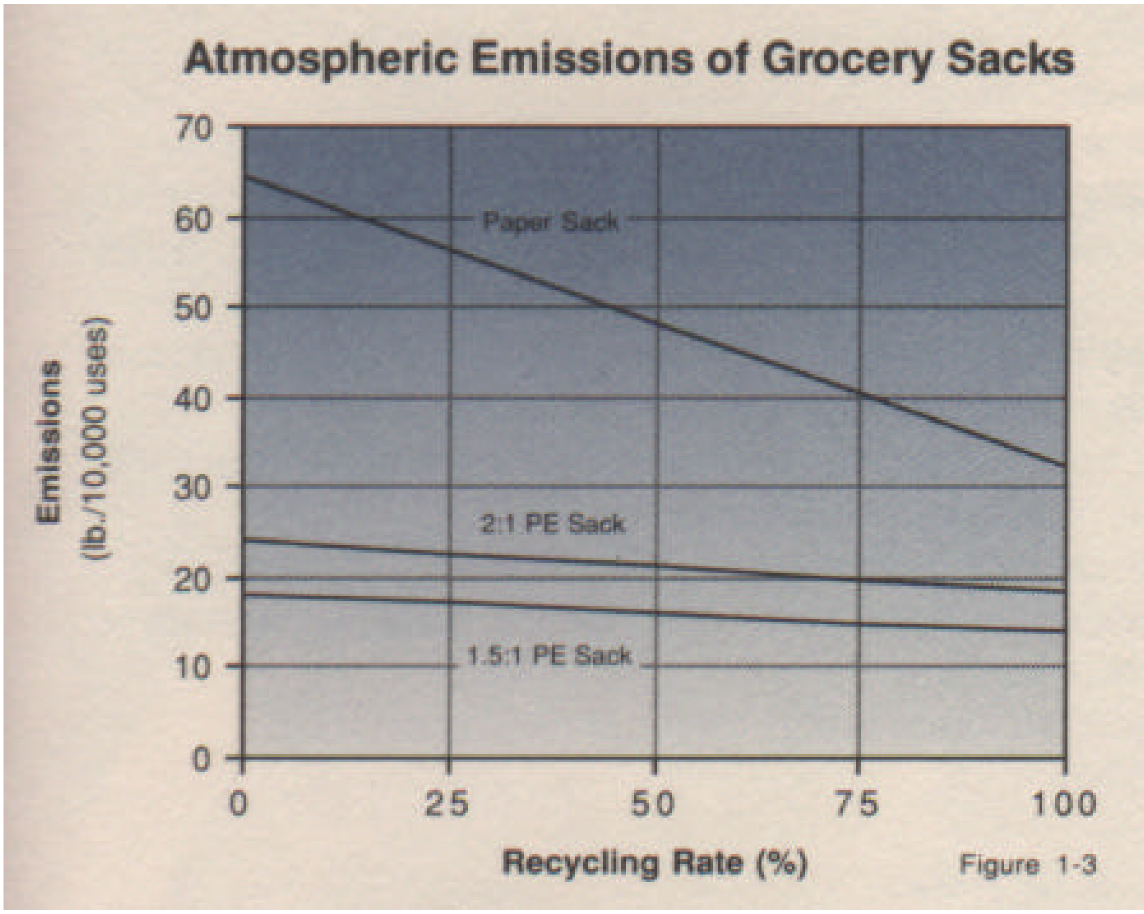

Table 1-2 and Figure 1-3 show that at zero percent recycling the total atmospheric emissions are 63 to 72 percent less for polyethylene than for paper sacks. From Figure 1-3, it can be seen that this difference decreases as recycling increases. However, the polyethylene sack continues to have less atmospheric emissions at all rates.

Waterborne Wastes

Four components dominate the category of waterborne wastes for paper and polyethylene sacks: dissolved solids, biological oxygen demand (BOD), suspended solids, and acids.

The polyethylene sack produces less of each of the four emissions than does the paper sack. The waterborne wastes reported for 10,000 grocery sack uses in Table 1-2 are also graphed in Figure 1-4. Both show that at zero percent recycling the polyethylene sack contributes over 90 percent less total waterborne wastes than does the paper sack.

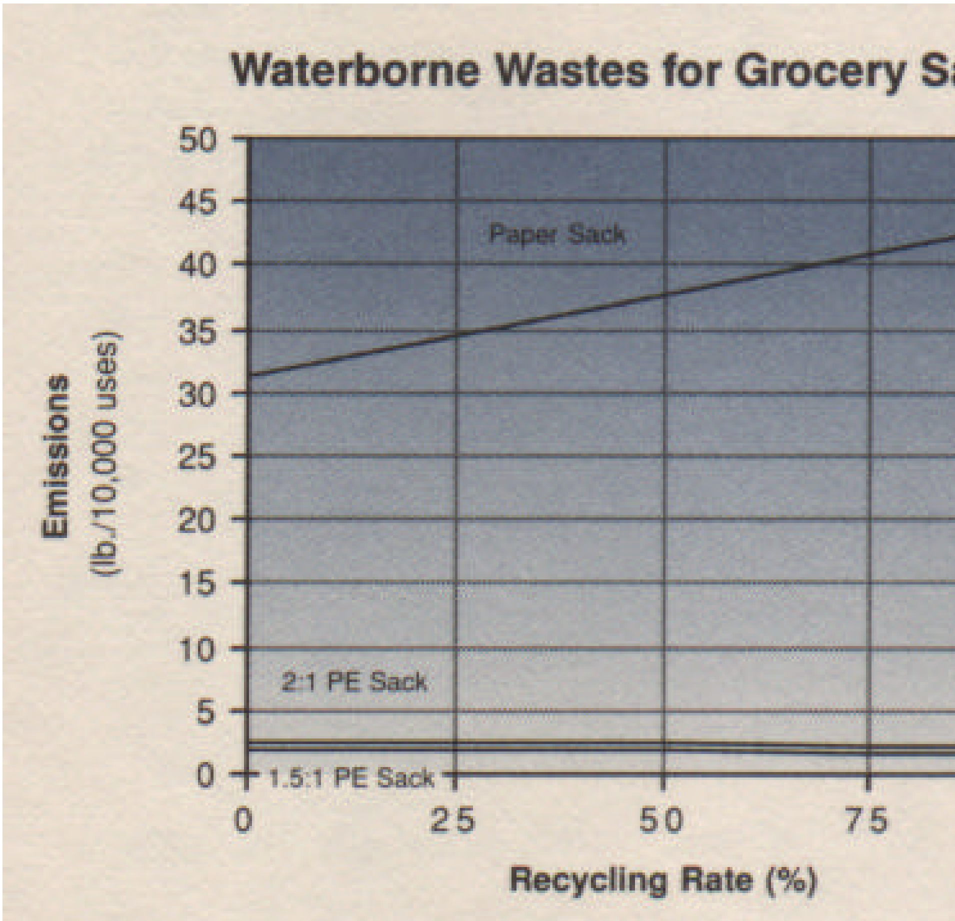

Figure 1-4

Figure 1-4 shows that as the recycling rate increases for both grocery sacks, the difference in waterborne waste becomes greater because recycled paper contributes more waterborne wastes than paper made from virgin material.

Table 1-2
Environmental Discharge Data for 1/6 Barrel Grocery Sacks (1)
(per 10,000 equivalent uses)

	Solid Waste (cu. ft.)	Atmospheric Emissions (pounds)	Waterborne Wastes (pounds)
1.5 PE to 1 Paper Sack Ratio			
Polyethylene sack			
0% recycle	9.1	17.9	1.8
25% recycle	6.9	16.9	1.7
50% recycle	4.9	15.8	1.6
75% recycle	2.9	14.8	1.5
100% recycle	0.9	13.7	1.5
Paper sack			
0% recycle	45.8	64.2	31.2
25% recycle	35.3	56.2	34.3
50% recycle	24.7	48.2	37.6
75% recycle	14.2	40.2	40.7
100% recycle	3.7	32.2	43.9
2.0 PE to 1 Paper Sack Ratio			
Polyethylene sack			
0% recycle	12.1	23.9	2.4
25% recycle	9.4	22.5	2.3
50% recycle	6.6	21.1	2.2
75% recycle	3.9	19.7	2.0
100% recycle	1.2	18.3	1.9
Paper sack			
0% recycle	45.8	64.2	31.2
25% recycle	35.3	56.2	34.3
50% recycle	24.7	48.2	37.6
75% recycle	14.2	40.2	40.7
100% recycle	3.7	32.2	43.9

(1) Ratio indicates the number of polyethylene sacks used per one paper sack.

Source: Franklin Associates, Ltd.