Resource and Environmental Profile Analysis of Foam Polystyrene and Bleached Paperboard Containers

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 requirements and environmental discharges of foam polystyrene (PS) and plastic-coated bleached paperboard containers.

Energy

At zero percent recycling, the foam polystyrene containers require 30 percent less total energy than the paperboard containers. They are essentially equivalent if only the energy from coal, oil and natural gas (fossil fuels) are considered. As recycling rates increase for polystyrene, this difference for energy increases to 50 percent less energy for foam polystyrene than for paperboard.

Environmental

1. The polystyrene container contributes 29 percent more solid waste by volume than paperboard at zero percent recycling. Equivalent volumes of solid waste are at 34 percent recycling of the polystyrene container.
2. The atmospheric emissions from the polystyrene container are 46 percent less than for the paperboard container at zero percent recycling. Atmospheric emissions further decrease as the recycling rate for polystyrene increases.
3. The foam polystyrene container contributes 42 percent less waterborne wastes than the paperboard container at zero percent recycling. This difference increases as the recycling rate for polystyrene increases.

Further conclusions regarding the recyclability, incineration, and landfill of foam polystyrene and paperboard containers were also determined.

Recyclability

Both polystyrene and coated bleached paperboard are recyclable. In fact, manufacturing scrap and trim from the fabrication of containers are routinely recycled.

The only current effort toward post-consumer product recycling is being pursued by the foam polystyrene industry. No targeted recycling activities for coated paperboard food containers from restaurants or cafeterias are now in existence. However, with recent trends in the recycling arena, these conditions may change.

Combustion Impacts

On a per pound basis, polystyrene releases roughly twice as much energy as coated bleached paperboard. However, paperboard containers weigh between two and three times more than the same size polystyrene containers.

Thus, on an equal unit basis, the paperboard containers have a greater potential for energy released from combustion than the polystyrene containers. However, the ash content of bleached paperboard is greater than that of polystyrene containers. Therefore, on a unit-by-unit basis, the paperboard containers have a greater potential for ash from incineration than the polystyrene containers.

Landfill Impacts

*Volume***.** The landfill volume occupied by the paperboard containers is 34 to 46 percent less than the volume occupied by foam polystyrene containers, based on 10,000 units.

These landfill volumes were arrived from landfill densities of general materials determined by experimental studies conducted on-site 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 decomposition. Therefore, the degradability of both paperboard and polystyrene containers cannot be predicted. As a consequence, no estimates can be made regarding the potential for landfill leachate and methane gas production.

Purpose of the Study

The purpose of this study is to determine the energy requirements and environmental discharges of foam polystyrene and bleached paperboard cups, plates and hinged containers.

In this study, the quantities of fuel and raw materials consumed and emissions released to the environment are quantified. The comparative recyclability, combustion, and landfill impacts of polystyrene and paperboard are also addressed for these containers.

Scope

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

16 ounce cups:	a) Foam polystyrene (molded)
	b) LDPE-coated bleached paperboard
	c) Wax-coated bleached paperboard
9-inch plates:	d) Foam polystyrene (extruded)

	e) LDPE-coated bleached paperboard
4-inch hinged container:	f) Foam polystyrene (extruded)
	g) LDPE-coated bleached paperboard

The term "container" is used throughout this study to mean the container itself and all secondary packaging such as plastic sleeves and corrugated boxes. Corrugated boxes and plastic sleeves are required to deliver both the paperboard and polystyrene containers.

For all container types, the polystyrene and paperboard alternatives are the same size. Therefore, it has been assumed that they utilize a 1-to-1 ratio. That is, one paperboard container is the equivalent of one polystyrene container, and vice versa.

The basis for this analysis is the production, use, and disposition of each paperboard and foam polystyrene container.

It has been proven that foam polystyrene containers have better insulation properties than paperboard containers. This may result in the use of two or more paperboard containers to equal the equivalent of one polystyrene container. However, there is no way to quantify the extent of this practice and it is not accounted for in this study.

While each of the three containers were examined, the characteristics for all of these products are similar. Therefore, for the sake of brevity, the impacts of only the hinged containers are reported in this executive summary.

Methodology

A cradle-to-grave approach was used to determine the energy and environmental discharges of the containers 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 material extraction from the earth and proceeding through processing, manufacturing, use, and final disposal, recycle, 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 container.

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

Since this analysis attempts to quantify the total energy impacts associated with each container, the fuel and electric energy conversions 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 discharge from each step were determined. Government documents as well as federal regulations, technical literature, and confidential industry sources form the basis for these data.

These wastes represent actual discharges into the environment after control devices. There are three broad environmental categories considered:

1. Solid wastes

2. Atmospheric emissions

3. Waterborne wastes

These categories include 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 foam polystyrene containers and zero percent recycling for paperboard containers. Polystyrene is currently being recycled to a small degree and is predicted to be recycled at increasing rates.

The polystyrene industry is developing infrastructure for collecting and recycling post-consumer containers contaminated with food. While it is possible to recycle post-consumer bleached paperboard food containers, they currently are recycles as a minor component of mixed office papers.

As the past year has shown, significant changes continue to be observed in recycling and these changes are often difficult to predict. Therefore, recycling conditions could change.

The combustion of both paperboard and polystyrene foam packaging were also included in this analysis. A national average for solid waste combustion of about 14 percent has been determined in the 1990 U.S. EPA Municipal Solid Waste Characterization Study. Thus, the post-consumer solid waste for the containers was adjusted for 14 percent combustion in waste-to-energy facilities.

Solid waste in the form of ash resulting from this combustion of both paperboard and polystyrene was estimated from the ash inherent in the materials. However, the atmospheric emissions that resulted from combustion of the polystyrene and paperboard could not be estimated due to lack of data. However, 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 bleached paperboard or polystyrene.

Most atmospheric emissions from municipal solid waste incinerator 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 paperboard and polystyrene cannot be quantified, the impact of these emissions on scrubber blowdown cannot be determined.

There are a variety of blowing agents used in the production of foam polystyrene such as pentane, isopentane, butane, isobutane, carbon dioxide, and HCFC (non-fully halogenated chlorofluorocarbons).

While HCFC's have 95 percent less impact on ozone depletion than normal chlorofluorocarbons, they are being phased out. For this analysis, isopentane was assumed to be used as the blowing agent, however, emissions data were obtain from fabricators using all types of blowing agents.

The margin of error for this study is believed to be plus or minus 10 percent. Therefore, distinctions in energy and environmental releases will only be noted between containers 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 determined statistically.

Results

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

Energy Requirements

The energy requirements for foam polystyrene and paperboard hinged containers are reported in Table 1-1. These energy requirements are reported in million Btu per 10,000 units at varying recycling rates for foam polystyrene and zero percent recycling for paperboard Figure 1-1 is a graphic illustration of the energy requirements reported in Table 1-1.

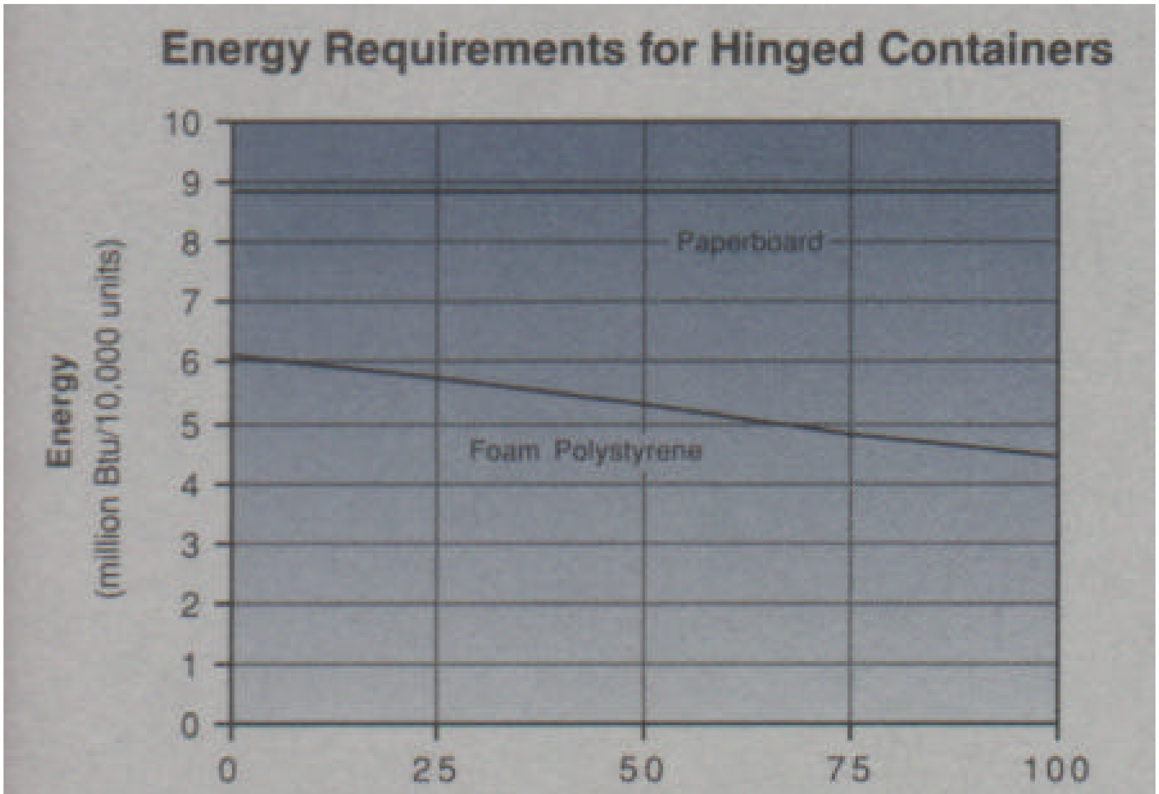


Figure 1-1

Both Table 1-1 and Figure 1-1 show that at zero percent recycling, the polystyrene hinged container requires 30 percent less total energy than the paper board hinged container.

Figure 1-1 also illustrates that with increased recycling of the polystyrene container this margin increase; at 100 percent recycling of the polystyrene container 50 percent less energy is required. In the case of the polystyrene package the recycling is considered to be "open loop;" the recovered material is recycled into some other useful application but not into the same product. Consequently, only half of the environmental savings is attributed to the original cycle.

The hinged container itself requires more than 90 percent of the total energy. The other parts of the system only account for 10 percent of the energy.

Of the total energy for the polystyrene container, 90 percent is derived from natural gas, petroleum, and coal. Approximately half, or 45 percent of the total, is included as inherent energy of the hydrocarbon feedstock. The remainder is process and transportation energy. Of the total energy for the paperboard container, approximately 65 percent is derived from natural gas, petroleum, and coal for processing and transportation. The balance is derived from by-products of wood in the paper making process.

A major difference between these products is there use of a wood-derived energy, commonly referred to in the paper industry as self-generated energy. Wood-derived energy accounts for 30 percent of total energy of the paperboard container and 4 percent of the polystyrene container. Thus if only the fossil energy sources are compared they are essentially equivalent for the two products.

Table 1-1

Energy Requirements for Foam Polystyrene and Paperboard Hinged Containers by Recycling Rates

(million Btu per 10,000 units)

	Recycling Rate				
	0%	**25%**	**50%**	**75%**	**100%**
Foam PS	6.1	5.7	5.3	4.8	4.4
Paperboard	8.8 (1)				

Environmental Discharges

The environmental discharges for the containers are divide into three groups:

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

These discharges are reported in summary form in Table 1-2.

(1) Recycling not considered for the paperboard hinged container.

Source: Franklin Associates, Ltd.

Solid Waste

The solid wastes generated by the hinged containers are reported in Table 1-2 in cubic feet per 10,000 units and includes both post-consumer and industrial waste.

Post-consumer solid waste volume was determined from weight by applying previously determined density factors based on general categories of solid waste. For industrial waste, a density of 50 pounds per cubic foot was used. A density of 6.7 pounds per cubic foot for foam polystyrene and 29.6 pounds per cubic foot for paperboard under landfill conditions were used for this study. Post-consumer solid waste is adjusted for 14 percent incineration of materials not recycled.

The solid waste data reported in Table 1-2 are also illustrated in Figure 1-2. Both show that at zero percent recycling, paperboard containers contribute 29 percent less solid waste by volume than foam polystyrene containers.

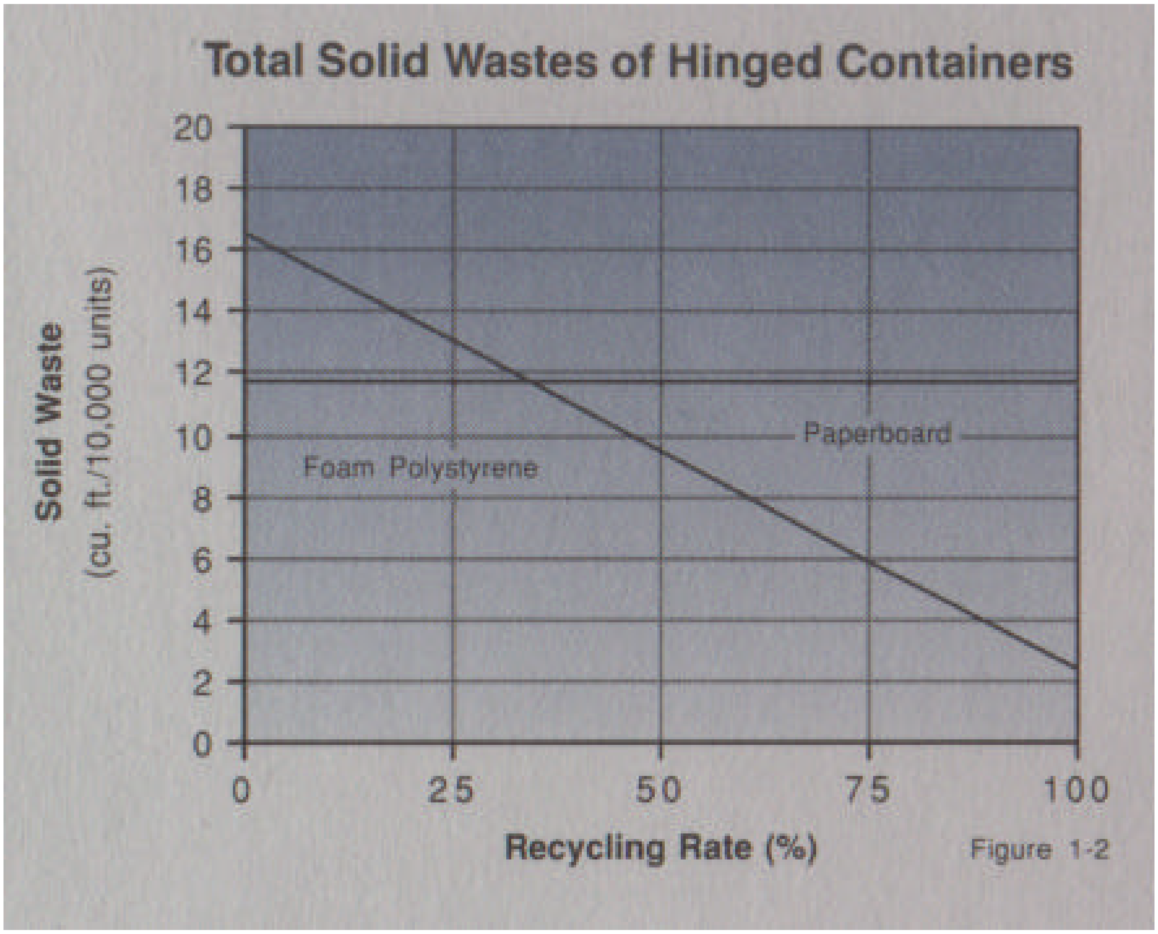


Figure 1-2 also illustrates that the solid wastes generated by polystyrene foam containers, at a 34 percent recycling rate, reach the equivalent volumes of the paperboard containers.

Table 1-2
Environmental Release Data for Foam Polystyrene and Paperboard Hinged Containers by Recycling Rates
(for 10,000 units)

	Total solid waste (cu. ft.)	Atmospheric emissions (lb.)	Waterborne wastes (lb.)
Foam Polystyrene			
0% recycling	16.5	13.8	2.5
25%	13.0	13.3	2.3
50%	9.4	12.8	2.1
75%	5.9	12.3	2.1
100%	2.3	11.8	1.7

Paperboard (1)			
0% recycling	11.7	25.7	4.3

(1) Recycling not considered for the paperboard hinged container.

Source: Franklin Associates, Ltd.

Atmospheric Emissions

Five components dominate the category of atmospheric emissions for paperboard and polystyrene foam containers: particulates, nitrogen oxide, hydrocarbons, sulfur oxide, and carbon monoxide.

The polystyrene container produces less emissions in four of the five categories. Only hydrocarbons are generated in higher quantities by the polystyrene container.

Table 1-2 lists atmospheric emissions for the hinged containers in pounds per 10,000 units. Figure 1-3 also illustrates these releases for both containers.

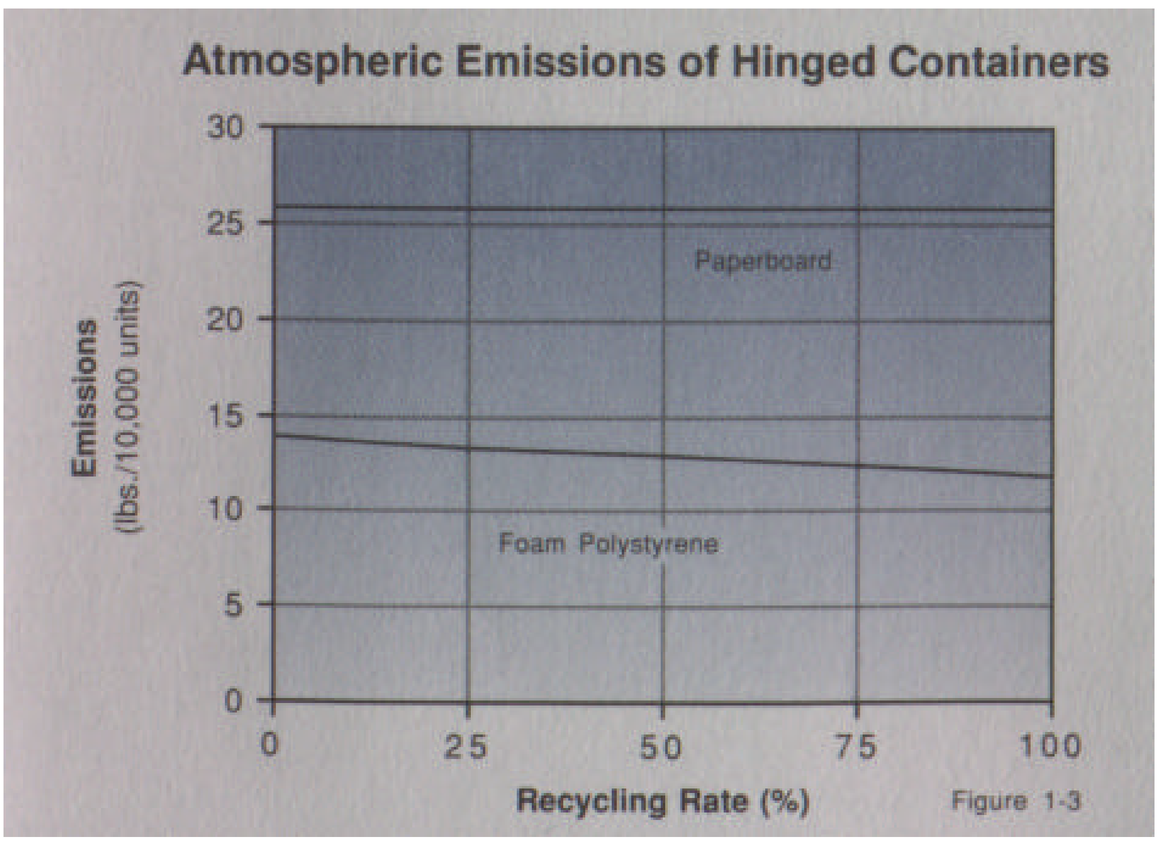
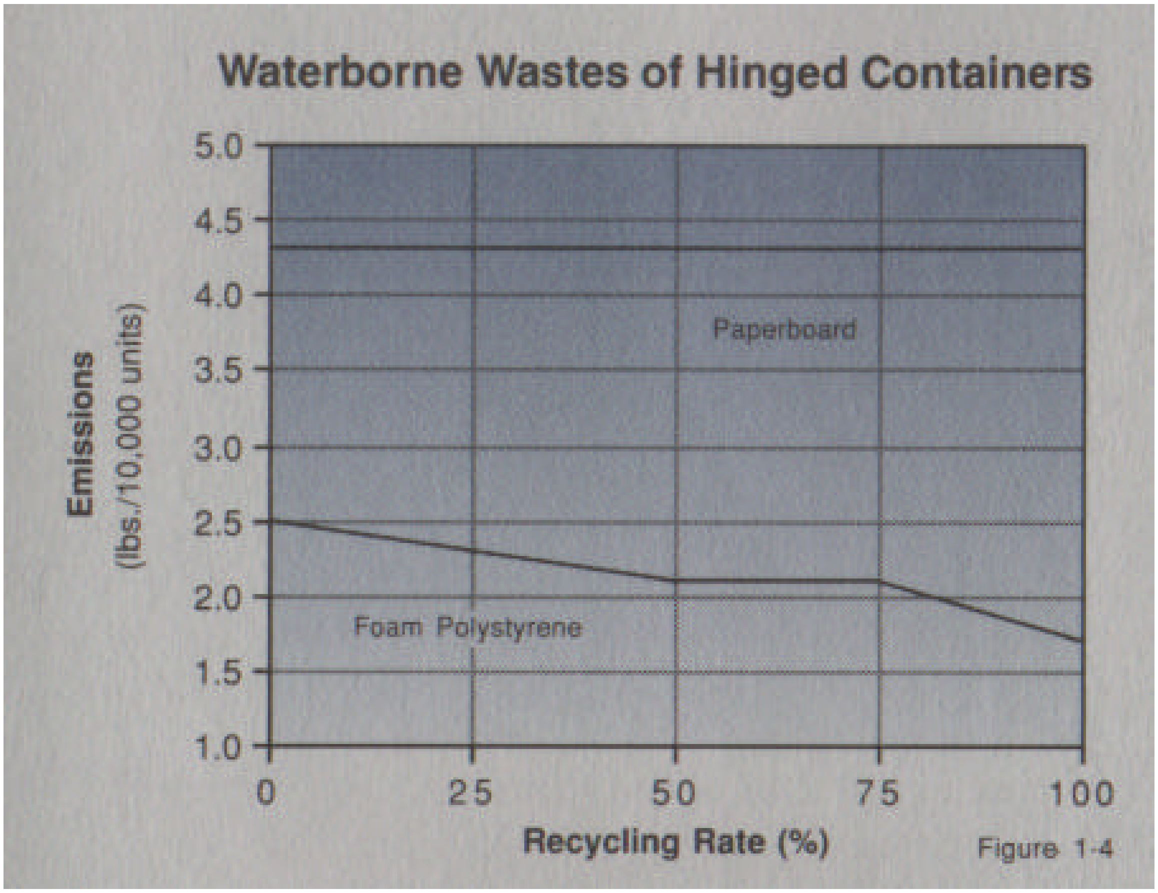


Table 1-2 and Figure 1-3 show that at zero percent recycling, atmospheric emissions are 46 percent less for the polystyrene container than for the paperboard container. With increased recycling if the polystyrene container this difference is only marginally increased to 54 percent at 100 percent recycling.

Waterborne Effluents

Four components dominate the category of waterborne effluents from the paperboard and polystyrene foam containers: dissolved solids, biological oxygen demand (BOD), suspended solids, and acids.

For three of the four components polystyrene foam containers produce less waste than the paperboard containers. Dissolved solids are generated in lower quantities by the paperboard container.



The waterborne waste reported for 10,000 hinged containers in Table 1-2 are also graphed in Figure 1-4. Both show that at zero percent recycling, the foam polystyrene container contributes 42 percent less total waterborne effluents than the paperboard container. As the recycling rate increases for the polystyrene container, this difference becomes greater.