Environmental Merit

Is Paper Better Than Plastic?

Martin B. Hocking

As consumers become more environmentally conscious they are increasingly concerned about the environmental component of products and services available in their society. Consumer choices are often made instinctively, from necessity, because a detailed analysis of the relative environmental merits of using canned versus fresh versus frozen food, or glass versus paper versus steel versus aluminum packaging would simply be too time-consuming for each purchase.

If, however, the environmental merit question is restricted to a small enough purchase sector it is possible to conduct a complete analysis of relative merit from the initial resource through the manufacturing stages, use attributes, and recycle options through to final use or disposal of the items.

One such analysis was conducted recently, comparing single-use uncoated paper cups and molded polystyrene foam (polyfoam) cups in hot drink applications. This analysis concluded that polyfoam cups have an environmental merit at least similar to that of paper cups.

What Are They Made Of? The major raw material for a paper cup is wood, a renewable resource. However, acquisition of wood for pulpmaking has visibly negative impacts on the landscape from the construction of road access and typical clear-cutting practices. When the clear-cut area occupies an extensive proportion of a watershed, it increases maximum flows and decreases minimum flows of streams draining the watershed, increasing the likelihood of flood and drought in the area served by these streams, although modern management can minimize all of these impacts.

Paper cups are made from bleached pulp, which in turn is obtained in yields of about 50% by weight from wood chips. Bark and some wood waste are also burned to supply a part of the energy requirements of the papermaking process. Thus, an average of some 26 grams (g) of wood plus, for additional energy requirements, an average of about 2 g of residual fuel oil or natural gas, is consumed per paper cup with a finished weight of 10.1 g. More petroleum than this would be needed if the paper cup had a plastic or wax coating, but this option is excluded in this analysis.

A polyfoam cup is made entirely from hydrocarbons (oil and/or gas). Impacts from petroleum exploration and recovery are also significant, from the former particularly in sensitive northern ecosystems and from the latter predominantly from accidental spills during drilling, production, or delivery.

Chemicals Used. Inorganic chemicals are also required for the papermaking process. Relatively small amounts of sodium hydroxide or sodium sulfate are needed for pulping (because much of these chemicals can be recycled), but larger amounts of chlorine, sodium hydroxide, sodium chlorate, sulfuric acid, and other materials are used on a once-through basis in the bleaching process to the extent of 110 to 170 kilograms (kg) per metric ton of pulp. The total non-recycled chemical requirement thus works out to an average of about 1.4 g per paper cup.

The superior properties of polystyrene foam over uncoated paper in a hot drink cup application allow the use of only 15% to 25% as much material to produce a cup. Chemical requirements for polystyrene production are small, totalling about 33 kg per metric ton. This amounts to 0.05 g per cup; or about 4% of the chemical requirement of the paper cup.

Production Needs. The paper cup consumes about 10 times as much steam, 14 to 20 times as much electricity, and twice as much cooling water as a polystyrene foam cup. About 300 times the volume of waste water is produced for the pulp required for the paper cup as compared to the polystyrene required for the polyfoam cup. The contaminants present in the wastewater from pulping and bleaching operations are removed to a varying degree depending on site-specific details, but the residuals present in all categories except mineral salts would still amount to 10 to 40 times those present in the wastewater streams from polystyrene processing.

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Emissions to air total some 14 kg per metric ton of bleached pulp and about 46 kg per metric ton of polystyrene. But because paper cups are four to six times heavier than polyfoam cups, each paper cup results in 1.3 to 1.8 times more mass of air emissions than each polyfoam cup.

Cost. The wholesale price of a paper cup is about 2½ times as much as polyfoam, partly from its greater consumption of raw materials and utilities, and partly from higher labor costs.

Recyclability. The technical side of recycle capability with the polystyrene foam is also straightforward. The restriction that recycled resin may not be used in food applications only partially limits the many possible end uses for recycled polystyrene such as in packaging materials, insulation, patio furniture, etc. Recycle operating problems have largely been solved. An improved infrastructure is all that is required to make this option a more significant reality and convert this perceived negative aspect of polyfoam use to a positive one.

The non water-soluble hot melt or solvent-based adhesive used to bind the parts of a paper cup together makes recycling of this product less straightforward.

Disposal. Polystyrene is relatively inert to decomposition when discarded to landfill. However, there is also increasing evidence that disposal of paper to landfill does not necessarily result in degradation or biodecomposition, particularly in arid regions. If the paper does decompose in a wet landfill, it produces substantial quantities of methane, a potent greenhouse gas, much of which is lost to the air. At the same time, water-soluble substances, which consume oxygen, are contributed to any leachate from the landfill, which also have the potential to cause pollution problems.

Conclusion. It can be seen from this summary of the analysis that even the relatively restricted question of paper versus polyfoam for hot drink cups is complex. But for single-use applications it would appear that polystyrene foam cups should be given a much more even-handed assessment as regards their environmental impact relative to paper cups than they have received during the past few years.

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Paper vs. Plastic Hot Drink Cups

Item	Paper Cup[a]	Polyfoam Cup
Per cup:		
Raw materials		
Wood and bark	25 to 27 g	0 g
Petroleum fractions	1.5 to 2.9 g	3.4 g
Other chemicals	1.1 to 1.7 g	0.07 to 0.12 g
Finished weight	10.1 g	1.5 g
Per metric ton of material:		
Utilities		
Steam	9000 to 12,000 kg	5500 to 7000 kg
Power	980 kWh	260 to 300 kWh
Cooling water	50 m^3	130 to 140 m^3
Water effluent		
Volume	50 to 190 m^3	1 to 4 m^3
Suspended solids	4 to 16 kg	0.4 to 0.6 kg
BOD	2 to 20 kg	0.2 kg
Organochlorines	2 to 4 kg	0 kg
Mineral salts	40 to 80 kg	10 to 20 kg
Air emissions		
Chlorine	0.2 kg	0 kg
Chlorine dioxide	0.2 kg	0 kg
Reduced sulfides	1 to 2 kg	0 kg
Particulates	2 to 3 kg	0.3 to 0.5 kg
Chlorofluorocarbons	0	0
Pentane	0 kg	35 to 50 kg
Sulfur dioxide	≈10 kg	3 to 4 kg
Recycle potential:		
To primary user	Possible Washing can destroy.	Easy Negligible water uptake.
After use	Possible. Hot melt adhesive or coating difficulties.	Good. Resin reuse in other applications.
Ultimate disposal:		
Proper incineration	Clean	Clean
Heat recovery	20 MJ/kg	40 MJ/kg
Mass to landfill	10.1 g	1.5 g
Biodegradable	Yes. BOD to leachate methane to air.	No. Essentially inert.

[a] Uncoated fully bleached kraft paper cup.
[b] Molded polystyrene foam bead (seamless) cup.
[c] Many producers of foamable beads have never used CFCs.

"Updated, complete results of Martin B. Hocking's study, as published in the November 1991 issue of Environmental Management, may be obtained by calling 1-800-288-CARE."