Paper Versus Polystyrene: Environmental Impact

One of the most visible forms of environmental activism in recent years has been the drive to replace styrofoam packaging in fast food service. Martin B. Hocking's Policy Forum "Paper versus polystyrene: A complex choice" (1 Feb., p. 504) challenges the wisdom of this substitution. Unfortunately, the most critical argument in the paper appears to be based on a computational error. The study also exaggerates the environmental impact of paper production by citing outdated effluent data and omits discussion of some important factors that should be weighed in the decision.

The most critical number in Hocking's arguments is the 4.1 grams of petroleum fuel he says are required per paper cup. Since this number is in the same range as the number he quotes for the styrofoam cup, he is able to assign the negative impact of petroleum extraction, transportation, and refining to both products equally. This number is much higher than indicated by current data (*1*) or by the reference he cites (*2*). He appears to have converted most of the energy requirement for the process to equivalent petroleum. He also does not consider that, in paper manufacture, petroleum is only a fuel of economic convenience used to make steam. Paper can be and is made without supplemental petroleum fuel in areas where petroleum is not economic or in times of shortage. Oil use for paper manufacture has declined steadily in the United States and Canada since the 1974 embargo and continues to decline.

In the United States today, for an average of all grades of paper, 56% of the energy used is internally produced from waste biomass. Of the 44% purchased energy, only about 8% actually comes from oil and about 15% comes from natural gas (*1*). Statistics for bleached cupstock are unavailable but are presumably better, since bleached board mills have some of the industry's highest cogeneration rates. Taking the overall paper average of 56 million British thermal units (Btu's) per ton of paper and 20,000 Btu's per pound of oil, 8% is 224 pounds of oil per ton of paper or 1.1 gram of oil per 10-gram cup. Inclusion of the gas at 24,000 Btu's per pound gives another 343 pounds of hydrocarbon per ton or 1.7 gram per cup. With the better cogeneration rates for bleached board, the total hydrocarbon fuel use is probably less than 2 grams per cup.

With this error corrected, critical differences between the two products must be faced. First, wood is a renewable resource, while oil is a fossil fuel. Since oil is not renewable on human time scales, the foam cup must be debited for resource depletion. Second, while production and transportation of both materials have an impact, the worst case scenarios for the oil industry (megaspills, war, or both) are more severe.

The paper industry data cited was collected for 1981 and represents Canadian mills only (*2*). These mills represent only about 2% of North American bleached paperboard production, and the data are from a time when few Canadian mills had more than primary effluent treatment. Current North American averages are substantially lower in most categories and much lower in some.

In his analysis of the greenhouse effect of the two products, Hocking does not credit paper for the carbon dioxide fixed by the trees required to support the paper production. Since both the product and the waste biomass that provides most of the energy for production originate from atmospheric carbon dioxide, the process comes close to breaking even in net carbon dioxide even if most of the paper is subsequently incinerated. Under current growth rates and disposal practices, paper production results in a net reduction of atmospheric carbon dioxide.

Hocking states that paper cups are not recyclable because of the adhesives used. In fact, paper cups can and are being recycled as a part of mixed office waste. The technology for recycling paper is far more advanced than that for polyfoam and has been in commercial use for many years. While paper is already recycled at a high rate, one of the main technical barriers to higher rates of reuse is contamination of mixed waste with styrofoam and similar low melting materials (*3*). Styrofoam must thus be debited for both its greater volume per cup in landfills and the volume of waste paper whose recycling is prevented by excess styrofoam contamination.

As Hocking notes, full-system comparisons of the environmental impacts of competing products are difficult. When current, accurate data for both products are used and a broader view of the system is taken, the conclusions of those favoring the use of paper over styrofoam would appear to be at least as supportable as Hocking's.

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2. N. McCubbin, *The Basic Technology of the Pulp and Paper Industry and Its Environmental Practices* (Environment Canada, Ottawa, Ontario, 1983).
3. R. W. Wand, in *Recycling Paper*, M. J. Coleman, Ed. (TAPPI Press, Atlanta, GA, 1990), vol. 1, pp. 47–50.

Hocking refers to a report I wrote for Environment Canada in 1982 that included some data on typical Canadian mills in the 1970s (*1*). His estimate of 9,000 to 12,000 kilograms of steam used in the production of one metric ton of pulp is apparently from my table 14. He seems to have overlooked my explanation in (*1*) that much of this is generated from the mill's internal wastes and not from fossil fuel. My own calculations indicate that a typical new bleached kraft mill in 1990 uses about 1.5 to 2 grams of oil (or equivalent fossil fuel) per 10.1-gram paper cup (the example used by Hocking).

Hocking quotes some effluent data for kraft mills, apparently from my report. These data give no indication of the discharges to the environment, since they refer to late 1970s kraft mills with no effluent treatment. Today, any U.S. mill would discharge about 5 kilograms of biochemical oxygen demand (BOD) per metric ton of pulp instead of "30 to 50," about 3 kilograms of organochlorines per metric ton, and so on.

Hocking's comparison of effluent flows is misleading, because flow in itself is of little environmental significance and because he compares pulp mill effluent, which includes cooling water, with polyfoam plant effluent, which does not. I am curious about how a polyfoam plant consuming 154 cubic meters of water can discharge only 2 cubic meters of effluent per metric ton of product.

Finally, Hocking relies on my 8-year-old Air and Water Pollution Control training manual as a source of data on 1991 mill energy consumption and effluent discharges. I have written several publicly available reports since 1983 that are more up to date and suggest that there are many more authoritative sources for both types of data published by various bodies who specialize in such matters.

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According to Hocking, there is increasing evidence that paper does not degrade in landfills. In fact, the rate at which organic products, like paper, degrade in a landfill depends on moisture content and is site-specific. A decade of scientific studies (*1–4*) have shown that significant organic material degradation does take place, which is why landfills emit methane gas. Notably, the methane from landfills is increasingly being captured for use in place of fossil fuels.

Biodegradation is also important for litter management. Food service products account for a small portion of municipal solid waste, but they can pose a litter problem, particularly in waterways, if not properly disposed of. According to the Center for Marine Conservation, 62.7% of the debris collected from the shorelines of 24 states in its 1989 beach cleanup campaign was plastic. Only 9.8% was paper. Not surprisingly, in recent Florida tests (*2*), most paper products exhibited signs of degradation, such as loss of tensile strength, after about 6 to 8 weeks of outdoor exposure.

Hocking ignores the carbon storage attributes of the trees owned by the paper industry on the one hand, and the methane and carbon dioxide (greenhouse gas) emissions that result from producing, refining, and transporting the petroleum and natural gas used in polystyrene manufacture on the other. The paper industry's woodlands alone consume more than the equivalent of all of the carbon dioxide released from its total production of pulp, paper, and paperboard.

Hocking's list of environmental pollutants (table 1) does not include styrene under the column representing production of polystyrene cups. Yet, in terms of total 1988 releases to the environment of the United States' top 25 carcinogens, styrene ranked second at almost 43 million pounds (*3*). Given that two-thirds of all styrene produced in the U.S. goes to make polystyrene (*4*), Hocking's omission is critical and misleading.

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2. "Toxics in the community, 1988: National and local perspectives" (EPA 560/4-90-017, Environmental Protection Agency, Washington, DC, September 1990).
3. *Biodegradation of Paperboard Products* (Research Triangle Institute, Research Triangle Park, NC, May 1990).
4. R. A. Denison, "McDonald's says no to foam: Why and how the environment benefits" (Environmental Defense Fund, New York, December 1990).

Paper can be made from cellulose sources other than wood pulp, at much lower cost to the consumer as well as to the environment. One acre of hemp, in annual rotation over a 20-year period, would produce as much pulp per year as 4.1 acres of trees over the same period (*1*). Hemp pulp can be used in any standard paper mill with only a slight adjustment in temperature and requires only 1/5 to 1/7 as much sulfur-based chemicals because of its lower lignin content (4% compared to 18 to 30% in tree pulp.) In addition, dioxin contamination of rivers is eliminated, as the hemp papermaking process does not require chlorine bleach (*2*).

The only "undesirable" by-product of hemp is tetrahydrocannabinol (THC), which many marijuana smokers find enjoyable. This substance is produced in the flowering tops of female plants. Commercial hemp is grown close together to maximize stem (fiber and pulp) production and is harvested before the buds develop. This problem has also been circumvented by the recent development of a THC-free strain in France.

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2. G. Smith, *Earth Island J.* 5 (no. 4), 32 (fall 1990).

Response: I am sorry that I did not have McCubbin's latest work to refer to. I referred to his 1983 training manual because it provides, in plain language that anyone can understand, one of the best outlines I know of the processes involved in pulping and bleaching. Texts on the subject are more for specialists. The data cited were for Canadian mills only, as referenced.

Wood residues and evaporated spent liquor were estimated in my paper to contribute 50 to 70% of the energy for steam production. I agree with McCubbin's figures for oil or gas consumption by a *current* integrated mill and add that paper (lightboard) from current nonintegrated mills would require a shade more, say 2 to 3 grams of fuel per 10 grams of paper cup, depending on the age of the mill. Only about one-half of the petroleum used to make the polyfoam cup is burned, that is, 1.5 to 2 grams. Half is still available in the finished cup if recycled, or for styrene recovery, or as energy by combustion. Thus, the net nonrecoverable petroleum consumption by the two technologies is about the same.

At least some Canadian mills in the period from 1985 to 1989 had effluent discharges in the amounts listed in table 1 of my paper (*1*). All effluent quantities are probably lower now. McCubbin's estimate of current organochlorine discharge is about right. The reduction is the result of a commendable crash program of research and control brought into action in the last 12 to 18 months. American experience must be somewhat better than this to meet current Environmental Protection Agency regulations of 7.1 kilograms of biochemical oxygen demand (BOD) per metric ton of pulp and 12.9 kilograms of total suspended solids (TSS) (*2*). Measures of organochlorines per metric ton of pulp in the treated effluents of five American mills sampled in 1986 gave a mean of 2.7 kilograms per metric ton of effluent (*3*), but this average is also probably lower now.

I did not examine litter management, and it is certainly a factor that should be considered in the overall picture.

I did not mention "greenhouse" carbon dioxide combustion contributions of the two technologies in my paper. Global warming was only considered for the somewhat more significant pentane blowing agent loss from polyfoam, which was more or less offset by methane loss from landfill anaerobic decomposition of organic matter in landfills (*4*).

The Independent Broadcasting Authority (United Kingdom) does not agree with Wells that carbon dioxide uptake from replanted trees offsets the carbon dioxide release from pulp and paper operations (*5*), but it could be true. I did not consider this question.

Styrene, an emission in polystyrene production, is mentioned, along with (the former) countervailing organochlorines of papermaking, in my full paper (*6*), while the chlorinated "dioxins" and "furans" are not. These chemicals have been virtually eliminated in mill effluents in the last 12 to 18 months in Canada and in the United States. For 3.7 million metric tons [8.13×10^9 pounds (*7*)] of styrene processed in the United States in 1988, Cavaney's reported gross emission of 43 million pounds would calculate to a styrene emission rate of 5.3 kilograms per ton of styrene processed, an easier figure to relate to the other data I cited.

I stand corrected on the recyclability of paper cups. While I understand that the coatings, resins, and so forth make them a less favored source of fiber, they *can* be used. I note, however, that the dislike of plastic waste in recycle stocks by papermakers is probably matched by the dislike of paper waste in the stock by plastic recyclers.

Hemp could well tip the scales in favor of paper over polystyrene. The higher cellulose content and easier pulping and bleaching conditions described by Camo would probably make hemp lower in environmental impact than unbleached kraft from wood. Positive factors like these are probably the motivation for the recent proposal, submitted by the Hemp for Paper Consortium to the Tasmanian government, to plant almost 15,000 hectares for the production of 100,000 metric tons of pulp per year. Any cultivation inputs (fuel, fertilizer, pesticides, and so forth) would have to be considered in a detailed assessment.

Thanks are due to the above (and many others) for their contributions to help expand the scope and refine the detail of the summary. What is needed now to fully assess my simplified catalog is a cost-benefit or eco-risk analysis, or both, of the two technologies that are acceptable to both the paper and polystyrene industries and comprehensible to the public.

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Correction

In Charles Mann's News Profile "Lynn Margulis: Science's unruly Mother Earth" (19 Apr., p. 378), the illustration on page 379 should have been credited to Walter Shearer, in *Scientists on Gaia*, S. Schneider and P. Boston, Eds. (MIT Press, Cambridge, MA, in press), based on measurements and observations of Russell Schnell, L. R. Maki, G. Vali, and their colleagues.