F. Toxicity Impacts

Previous resource and environmental profile assessments and other product lifecycle analyses have usually added all the pollutants in a given category to obtain a sum of air pollutants or water pollutants. This procedure ignores the fact that mass is not the only measure of the impact of a pollutant. As manufacturing practices have become more sophisticated, and the use of solvents, small quantity catalysts, process additives, dyes, etc. has become common, another category of materials and wastes has been created for management purposes: toxic materials and hazardous wastes.

This study attempts to catalog the pollutants emitted by diaper manufacturing operations, but reliable data is not prevalent. If data were available, risk assessments would be necessary to quantify the impacts and risks to public health and the environment from the catalogued pollutants, a task beyond the scope of this study. Instead, this section discusses toxicity of emissions from manufacturing and use operations from a qualitative perspective.

Toxic materials and hazardous wastes are regulated by three federal laws, Occupational, Safety and Health Act (OSHA), the Toxic Substances Control Act (TSCA) and the Resource Recovery and Conservation Act (RCRA). OSHA requires employers to create and maintain a safe workplace and provide information to employees regarding the materials they must handle and the health effects of exposure. TSCA requires testing of chemicals to demonstrate that their manufacture and use does not harm public health or the environment. RCRA establishes identification procedures for determining whether or not a waste must be managed as a hazardous or non-hazardous waste. Four criteria exist for determining the characteristic of hazardousness: toxicity, corrosivity, flammability and reactivity. In addition, wastes can be specifically listed as hazardous. Examples of wastes that are so listed are spent solvents, some specific process waste waters and sludge, and specific industry wastes.

In order for a chemical or compound to be toxic, it must be present in sufficient quantity (dose) to cause adverse health effects, and there must be a pathway of exposure to the substance. Improper use and storage at a manufacturing facility are pathways of exposure, as are improper disposal and subsequent migration through air or water.

In 1981, 71 percent of hazardous wastes generated in the U.S. were generated by SIC groups 28 and 29, which include the petroleum refining, petrochemical and chemical manufacturing industries. Manufacture of fertilizers, pesticides and plastics, as well as the production of petroleum products for energy, all contributed to hazardous waste generation.

Specifically, manufacture of plastics involves the use of organic solvents, metal catalysts, pigments and other additives which, along with unreacted monomer and feedstock, can end up in waste water effluent grouped under the broad parameters of BOD, COD, TDS and TSS.

Manufacture of pulp involves extensive use of chlorine and alkalies which often end up in effluent and result in the synthesis of other potentially harmful substances like dioxins and furans. Other by-products of pulp manufacture include phenols, mercaptan, acids (acetic, formic, oxalic, benzoic), chloroacetones, chloroform, toluene, benzene and many others. Organochlorine compounds have special environmental significance because of their toxicity to aquatic species, their ability to resist biological degradation, their persistence and mobility in the environment, and the proclivity for bio-accumulation in the fatty tissues of a number of organisms.[79]

While the concentration of any one compound from paper mills may be low, the large number of compounds emitted is of concern because of the potential for cumulative or synergistic effects. Given the facts that in 1977 a significant number of mills had only primary treatment facilities[80] and that discharge guidelines remain relatively lax, the potential for release of a large number of different organochlorine compounds to the environment is significant. There are documented cases of release of 2,3,7,8-TCDD (dioxin) and TCDF (furans) from pulp and paper mills to the Great Lakes region, with associated bio-accumulation in lake fish.

Growth and manufacture of cotton entail the use and release of potentially toxic materials. Toxaphene, trifluralin and other compounds are pesticides used in the cultivation of cotton. The manufacture of these pesticides uses chlorine, hydrogen cyanide, and concentrated acids and caustics as raw materials. Waste waters generated from pesticide manufacture contain volatile aromatic hydrocarbons such as benzene, toluene, and chlorobenzenes; cyanide; halomethanes such as carbon tetrachloride, chloroform, and methylene chloride; metals such as mercury, arsenic, and zinc; as well as COD, BOD and TSS. Because of the large number and types of pesticides used, data was difficult to quantify for the purposes of this study.

Even as single-use diapers have been found to contain 2,3,7,8-TCDD (dioxin) in the paper component, so too have cotton diapers, but at a lower concentration. Wiberg et al.[81] analyzed consumer products and found that single-use diapers contained 0.54 pg/g (10^{-12}

---

[79] Leena R. Suntio, Wan Ying Shiu and Donald Mackay, A Review of the Nature and Properties of Chemicals Present in Pulp Mill Effluent, Institute for Environmental Studies, (Toronto: University of Toronto, 1988), pp. 1249-83.

[80] Marshall Sittig, Pulp and Paper Manufacturing: Energy Conservation and Pollution Prevention, (Park Ridge, NJ: Noyes Data Corporation, 1977).

[81] K. Wiberg, K. Lundstrom, B. Glas and C. Rappe, "PCDDs and PCDFs in Consumers' Paper Products," Chemosphere, vol. 19, no. 1-6, (1989), pp. 737.

grams dioxin per gram of diaper) of 2,3,7,8-TCDD, while cloth diapers contained <0.1 pg/g 2,3,7,8-TCDD. For parents concerned with their children's health and welfare, these numbers are not negligible.

Energy production has toxicological implications for air emissions as well. Nitrogen oxides are an irritant in the upper respiratory tract, and a powerful oxidant in the lung alveoli, leading to edema, dyspnea, and death at high concentrations. Sulfur oxides cause eye and lung irritation. Carbon monoxide is a highly toxic gas which lowers tissue oxygen levels due to competition for binding sites with hemoglobin. Ammonia is an irritant, a caustic, and lethal at high concentrations. Hydrocarbons is a broad term for a large group of compounds with unpredictable acute toxicity, and subcategories such as aliphatics and aromatics are suspected carcinogens.

Lave and Seskin performed regression analyses on epidemiological and air pollution data and determined that 50 percent of the bronchitis, 25 percent of lung cancer, 25 percent of emphysema, 15 percent of other respiratory disease in the country was attributable to air pollution.[82]

The Superfund Amendment and Reauthorization Act (SARA), Title 3 and the community right-to-know laws require industry to report annual releases of specified toxic chemicals, but reporting is done on the state level, and little data is available on a nationwide basis. The majority of potentially toxic compounds are generated during manufacturing operations for both diapering modes. Since the production of potential toxins from cotton production are distributed over the many uses of a reusable diaper, the relative contributions are significantly lower than for single-use diapers. From a relative resource perspective single-use diaper manufacturing contributes greater quantity of potentially toxic compounds to the environment than does reusable diaper manufacturing.

G. Conclusions

The central conclusion of this study is that single-use diapers have a greater overall environmental impact than reusable diapers when all aspects of diaper production and use are taken into account. Comparison over the lifecycle of these two products shows that single-use diapers generate more solid waste, and consume greater quantities of energy and resources. Both types of diapers are responsible for air and water emissions, but emissions from single-use diaper manufacturing are more toxic, and more expensive to manage. With respect to overall environmental burden, therefore, reusable diapers are superior.

---

[82] Lester B. Lave and E.P. Seskin, Air Pollution and Human Health, (Baltimore: Johns Hopkins University Press for Resources for the Future, 1977).

VIII. ECONOMIC IMPACTS

A. Industry Profiles

Two central facts about businesses producing or servicing diapers stand out. First, the market is demographically driven, since it depends on the numbers of infants and older incontinents. Second, lifestyle factors have an important influence on the type of diaper product chosen by consumers.

The current baby "boomlet" underway in the United States is good news for diaper makers and laundry services. In 1989, the number of births in the United States was higher than in the peak years of the postwar baby boom (the late 1950s). The fact that an average new baby consumes about $6,000 worth of products and services in its first year of life[83] suggests solid business for diaper producers and associated services.

This surge in births, however, is not expected to restore the age structure of the first decades of the post-World War II period. Instead, the U.S. Bureau of Census predicts continuing increases in the median age of the population. This points to another demographically driven fact about diapers -- the rising market share for adult incontinent diapers.[84]

Commercial diaper laundry services are a beneficiary of the consumer trend toward reusable diapers during the past several years, because they combine convenience with what is viewed as environmentally responsible behavior.[85] A survey of members of the National Association of Diaper Services indicates a 28 percent growth in business this year and a 20 percent increase in 1989 over 1988.

Consumers have expressed clear preferences for products which have minimum environmental consequences. A national survey conducted by the Gallup Organization in 1990 found that 38 percent of the adults surveyed favored a tax on single-use diapers because of their solid waste impacts.[86]

---

[83] Regina Eisman, "The Booming Baby Market," Incentive, vol.164, issue 2, (February 1990), pp. 39-41.

[84] Mark McLaughlin, "Makers of Adult Diapers Foresee Expanding Market as Population Ages," New England Business, vol.10, issue 2, (February 1, 1988), pp. 37-38.

[85] Lynn Asinof, "Diaper Services Make a Comeback Amid Growing Environmental Concerns," The Wall Street Journal, (November 2, 1989), pp. A1(W), A1(E).

[86] Freeman, "Poll: P & G Seeks to Defend...", pp. 1, 57.

Environmental concerns on the part of consumers are reflected in new marketing trends, such as industry's efforts to market "biodegradable" plastic diapers, and advertising's emphasis on the environmental advantages of one product over another.

B. Job Creation and Employment

From a production standpoint, reusable diapers appear to have higher total employment requirements than single-use diapers. The following calculation supports this.

In August 1988, the employment counts for paper, plastic, and textile mill products, not counting apparel, were 669,190; 793,410; and 699,900 respectively. The portion from paper and plastics for single-use diapers was a fraction of 1 percent of total employment in those manufacturing occupations. Reusable diapers, on the other hand, accounted for about 0.11 percent of cotton production in the U.S. in 1988, and cotton products constituted more than 10 percent of non-apparel textile mill products. Thus, estimating 3.5 billion reusable diaper changes per year, and 17 billion single-use diapers used per year in 1988, reusable diaper production is more labor intensive.

A consumer shift to reusable diapers washed by commercial laundries would create jobs and employment opportunities. The authors' diaper service operator survey indicates that an average of 1 full time job is created for every 284,747 cotton diapers washed per year by a diaper laundry service, or about 1 local job for every 90 to 100 diaper service customers. If total conversion to reusables were achieved, an estimated 72,000 persons would find jobs in the commercial diaper laundry sector.

C. Cost to the Consumer

Out-of-pocket expenses for reusable and single-use diapers include purchase of the diapers, commercial or home laundry expenses for reusable diapers, and disposal costs or charges via the sewer or solid waste disposal system for both diapering modes.

Table P tallies these costs, presenting breakdowns for single-use diapers, cotton diapers washed by commercial laundries, and home laundered cotton diapers.

Table Q. Out-of-pocket expenses by diapering mode

Cost components per diaper change ($)	Single-use diapers[1]	Reusables Diaper Service[2]	Reusables Home Washed	Reusables Home Washed[3]
Diaper cost per use	$0.24	$0.17	0.014	$0.014
Operating costs detergent water energy use labor (imputed wage)			 0.05 0.001 0.01	 $0.05 $0.001 $0.01 $0.06
Capital and maintenance (washing/drying)				0.011
Collection/disposal	$0.018			
Lifecycle costs per diaper change	**$0.258**	**$0.17**	**0.086**	**$0.146**

[1] Cost of single-use diaper: Observed range of diaper purchase price, ADL2 (1990), Table VII-2.
[2] Operating, capital and maintenance, and collection and disposal costs for diaper services are included in the price to the customer. Source: authors' diaper service operators survey (1990).
[3] Imputed labor cost: $6.00/hour.

Out-of-pocket expenses for reusable diapers are between one-third and two-thirds less than for single-use diapers, depending on the method of laundering.

Arthur D. Little calculates unit prices for 11 brands of single-use diapers[87] and develops market share information. Updating this for late 1990 inflation and applying weights equal to estimated market shares suggests an average unit price of $0.24 per diaper. The other out-of-pocket expense for a single-use diaper is its collection and disposal costs. These are conservatively estimated at $75 per ton of used single-use diapers.[88] Total expenses per single-use diaper thus total $0.26.

Lower unit costs were established from the authors' diaper service operator survey. The average cost per diaper change, the relevant unit of comparison, is $0.17 for reusable diapers washed by a diaper service. This estimate incorporates 1.2 diapers per change as determined by a collateral survey of diaper service customers. A figure of 1.2 diapers per change is lower than previous estimates partly because diaper services provide reusable diapers which are thicker and of higher quality.

[87] ADL2 (1990), Table VII-2.

[88] Lehrburger (1990); ADL2 (1990).

The comparable cost estimates for reusable diapers washed at home takes into account the home laundry operation, including depreciation and maintenance costs as well as purchases of detergent, water, and other supplies. This estimate is based on 1.8 diapers used per diaper change.

Allocating 20 minutes total time to preparation, loading, unloading, and folding cotton diapers per wash load adds approximately another penny per diaper for each dollar per hour of imputed value of the householder's time. Thus, when $6.00 per hour is allowed for household services, the unit costs of reusable diapers rise to about $0.15 per diaper, or 11 cents per diaper below total out-of-pocket expenses for single-use diapers. The diapers themselves represent only a fraction of the total overall home laundering costs.

Labor costs for home laundry operations, if computed, are the key element in comparing costs of commercially laundered diapers with costs of home laundered diapers. Both home and commercial laundries, however, provide diapering which is less expensive than single-use diapers.

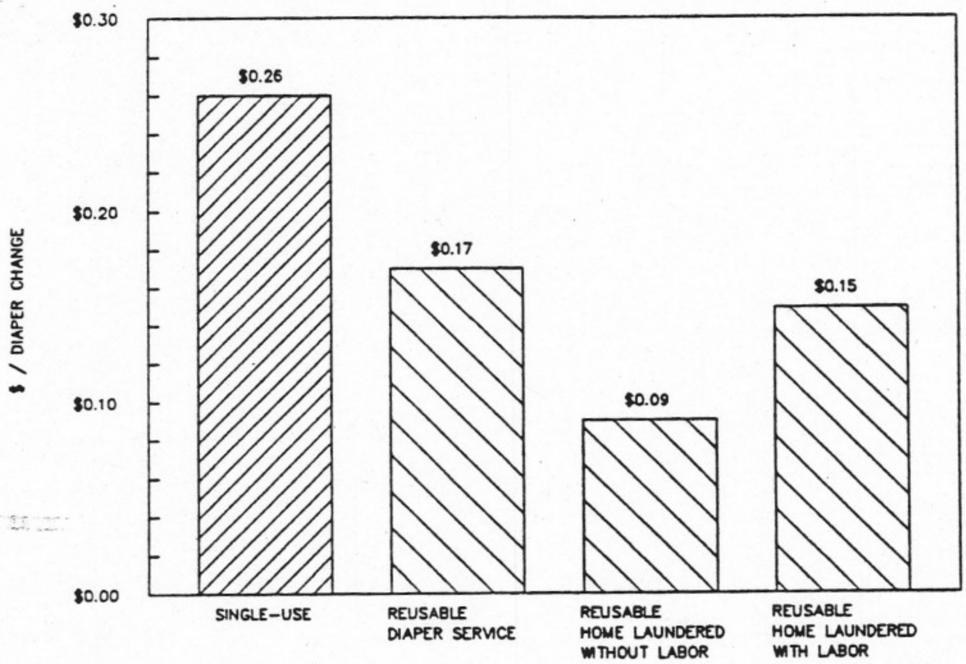

Figure 19. Cost comparison by diaper mode

D. Hidden Costs

"Hidden costs," or out-of-pocket expenses, are not ordinarily recognized as related to a specific product or commodity. Reusable diaper costs are directly related to laundering of diapers. In contrast, the pro rata portion of MSW disposal fees for single-use diapers may be forgotten by the consumer, associated as it is with a larger aggregate of disposed materials. The most significant "hidden cost" of diaper use is the disposal of a used single-use diaper and its contents, with a hidden cost for collection and disposal of nearly $0.02 per diaper.

E. Worldwide Issues

As the battle for market share in a shrinking infant single-use diaper market intensifies, single-use diaper companies in the U.S. are seeking foreign markets. Overseas sales of single-use diapers are said to be one of Procter & Gamble's most profitable lines.[89]

The implications of widespread use of single-use diapers in developing nations with rudimentary solid waste disposal systems at the village or even city level are staggering. Plastic diapers will accumulate along roadsides, outside household walls or boundaries, or simply in the streets themselves, clogging major watercourses, and causing an undesirable visual as well a potentially negative public health impact.

F. Conclusions

Out-of-pocket expenses for single-use diapers are approximately two-thirds higher than for reusable diapers laundered at home and one-third higher for reusable diapers laundered commercially. Allowing for a value for household labor services of $6.00 per hour for home laundering raises the cost of home laundered reusable diapers to slightly below the cost of commercially laundered reusables. However, both are well below the unit costs of single-use diapers, especially when solid waste disposal and collection costs are taken into account.

---

[89] Laurie Freeman and Laurel Wentz, "P & G On a Roll Overseas," Advertising Age, vol.59, issue 27, (June 27, 1988), p. 30.

IX. PUBLIC POLICY ISSUES

Since 1989, over 24 state laws have been proposed concerning diapers, of which at least five were passed.[90,91] This level of activity indicates a willingness on the part of policy makers to effect waste reduction by encouraging changes in consumers lifestyles. A surprising 38 percent of 1,029 people surveyed said they favor a tax on single-use diapers and 43 percent favored a ban in a Gallup Organization poll conducted in June, 1990.[92]

As Product Lifecycle Analysis becomes more common, diapers and other single-use and reusable products are likely to receive increased attention from the public policy arena. The conclusions of this study are that reusable diapers create significantly less solid waste and, overall, are less damaging to the environment than are single-use diapers. To encourage the use of reusable diapers, the following public policy recommendations are made:

Solid Waste Management: Reusable diapers produce less solid waste than single-use diapers and their use should be promoted as a component of integrated solid waste management programs.

1. Reusable diapers are a waste reduction opportunity, and should be encouraged over single-use diapers in states developing source reduction programs. Proposals relating to diapers should be integrated into an overall solid waste management program that gives highest priority to two solid waste management approaches: 1) encouraging waste reduction and 2) emphasizing the reuse of materials, such as diapers.

   Some states have already included and evaluated diapers as part of their solid waste management plans. For example, the Senate and House of the General Assembly of Virginia requested that the Virginia Department of Waste Management give appropriate consideration to the environmental, economic and consumer impact of single-use diapers in the development of its statewide comprehensive

[90] Center For Policy Alternatives, "Update On Diapers (Revised)," (Washington, DC: Center for Policy Alternatives, September 1990).

[91] Kristin Rahenkamp and Frank Kreith, State Legislative Report: A Comparison of Disposable and Reusable Diapers: Economics, Environmental Impacts and Legislative Options, Vol. 15, no. 8, (Denver: National Conference of State Legislatures, April 1990).

[92] Laurie Freeman, "Diaper Image Damaged: Poll," Advertising Age, (June 11, 1990).

program for waste management.[93]

2. The waste water treatment system is a more appropriate and more economical disposal pathway for diaper waste than the solid waste stream. Reusable diapers rely on the waste water treatment system, and therefore have significant environmental and economic advantages over single-use throwaway diapers.

   The most significant public policy statements to date concerning diapers are concerned with keeping unprocessed urine and feces out of the solid waste stream. A municipal ordinance for Seattle, Washington prohibits the disposal of untreated human feces in solid waste: "...Human feces must be removed from disposable diapers and placed into an approved sewage system before the diapers are disposed of ..."[94]

   The limitation of untreated sewage in solid waste was recommended in the early 1970s by the World Health Organization (WHO): "...Ideally, solid wastes should contain no fecal matter or urine, and the mixture of these--and of such materials as pathological or slaughterhouse wastes--with household wastes should be prohibited by law." Recommendations for action from WHO included (that) "...National health agencies should be closely involved in forming policy on solid wastes disposal and should promulgate codes of practice for sanitary disposal, emphasizing the control of insects and rodents, faecal matter, and pathological wastes, and the pollution of natural waters."[95]

3. Composting is a waste management process that enhances the beneficial reuse of sewage sludge, and should be encouraged. Preventive measures that will preclude toxic and hazardous materials from entering the waste water treatment system, potentially rendering composted sludge unsafe in agricultural applications, should be adopted. Composting of single-use diapers along with MSW, although a better approach than landfill disposal, does not eliminate the comparatively higher environmental impacts of single-use diapers when contrasted with using reusable diapers many times.

---

[93] Virginia House Joint Resolution no. 145.

[94] Seattle Municipal Code 21.36.025

[95] World Health Organization, "Solid Wastes Disposal and Control," WHO Chronicle, vol. 26, no. 4, (Geneva: World Health Organization, April 1972), pp. 147-151; also World Health Organization Technical Report Services, Solid Waste Disposal and Control: Report of a WHO Expert Committee, (Geneva: World Health Organization, 1971), p. 7.

<u>Encouraging Reusable Diapers</u>: Because reusable diapers reduce solid waste and have other environmental advantages over single-use diapers including use of fewer raw materials, and less energy on an equivalent diaper change basis, their use should be encouraged.

1. Economic incentives to cloth diaper services would help to expand the availability of reusable diapers. An example of an economic incentives is Wisconsin's exemption of diapers services from state sales tax (1990 SB 300).

2. Wherever disincentives exist to using cloth diapers, they should be eliminated. California has proposed a bill which would prohibit child day care centers from refusing to care for a child in reusable diapers (SB 2342). The bill was passed by the legislature but vetoed by the Governor. Similar legislation to allow the use of cloth diapers laundered by an accredited diaper service was signed into law in Maine in 1990 (PL 723).

   On the state and national level, assistance programs that allow use of funds for single-use products but not for reusable diapers, such as the federal WIC program and state medicaid programs, should be changed so they do not discriminate against reusable products in general, and diapers in particular.

3. Government funded and operated institutions may derive distinct benefits from changing to reusable products, such as diapers. Evaluations should be required to assess the economic, environmental and health advantages of making reusables available and/or switching from single-use to reusable products in government funded institutions.

<u>So-Called "Biodegradable" Diapers</u>: State proposals and commercial efforts aimed at promoting "biodegradable" single-use diapers as a waste reduction strategy are misguided and should be challenged.

1. Any proposal to promote the use of so-called biodegradable disposable diapers to reduce solid waste is ill-advised because the product is not likely to break down in a landfill environment. Many state proposals regarding diapers have been concerned with so-called biodegradables. At least ten states have introduced proposals to encourage biodegradables, including Nebraska (LB 325) which in May 1989 passed a ban on non-biodegradable diapers effective October 1, 1993, but conditional on a legislative finding. It is now acknowledged that this proposal was promoted by agricultural advocates of biodegradable plastics that use corn starch as an ingredient, rather than by legislative concern with solid waste problems. In December, 1989, national environmental organizations called for a consumer boycott of biodegradable plastics, including trash bags and single-use diapers.

2. Rapidly biodegrading single-use diapers that utilize the sewage stream (flushables) would be a significant improvement over conventional single-use diapers, and their development is desirable. As a single-use product, however, flushables that utilize the sewage waste stream would still require more water and materials on a per diaper change basis than reusable diapers.

<u>Public Education</u>: **Public Education is the most direct way to help consumers understand the environmental impacts of diapers.**

1. Single-use diaper manufacturers should assume a greater responsibility for promoting proper disposal of their products, including educating parents on the proper disposal of diaper contents. Educating the public about diapers is the purpose of proposals to mandate environmental warnings on packaging of single-use diapers in New York (#A 8004) and in New Jersey (AB 1813,2227).

2. Governments could either promote or sponsor educational campaigns on the environmental impacts of diapering approaches. For example, the State of New York has proposed that hospitals must provide new mothers a copy of a diaper information pamphlet produced by the New York State Consumer Protection Board (A 10587) that addresses the environmental and economic issues related to disposable and reusable diapers. Similar pamphlets have been prepared by the City and County of San Francisco, the State of Vermont and a host of other government agencies.

<u>Discouraging Single-Use Diapers</u>: **To help make the transition from a throwaway society to a conservation oriented society, use of single-use diapers should be discouraged and use of reusable diapers should be encouraged as a long term policy.**

1. Taxes or other economic disincentives can be used to reduce solid waste and to encourage the use of reusable products. Several states have introduced proposals that seek to tax single-use diapers in order to encourage reusable diapers, although none have passed to date (Colorado HB 1157, Iowa HS 3831, Illinois HB 3634, New Jersey AB 3412, South Dakota HB 1302, 1308, Wisconsin SB 300). Tax revenue from those measures should be directed to public education programs or to fund economic incentives provided to reusable diaper services or products.

2. The possibility of banning the sale of single-use diapers has been raised several times since it was first proposed in Oregon in 1979. Ten states proposed bans in 1990, mostly applying to "non-biodegradable" diapers. Although this approach has merit in locales faced with solid waste crises, a ban is likely to create resentment among consumers deprived of the choice to use throwaway diapers. A comprehensive public policy that seeks to discourage single-use diapers and infectious and

hazardous wastes going to landfills within a set time frame offers a better prospect for increased public awareness of diapering environmental impacts than outright banning the sale of single-use diapers.

Rather than an immediate ban, localities and states should adopt a phased, comprehensive approach, which includes educating the public about benefits of reusable products, providing incentives to diaper services and/or users of reusable diapers, as well as developing a timetable for conversion to reusable diapers.

In conclusion, there are multiple legislative initiatives encouraging consumers to use reusable diapers and to require single-use diapers to bear their associated social and environmental costs. These range from directives to include and evaluate diapers in state solid waste plans (Virginia), exempting cloth diaper services from state sales tax (Wisconsin), and prohibiting unprocessed urine and feces in the solid waste stream (Seattle, Washington). Other legislation is under development or has been proposed, like efforts to mandate environmental warnings on packaging (New York), and required labeling on single-use diapers (Colorado, Iowa, Illinois, New Jersey, South Dakota, and Wisconsin).

METHODOLOGY APPENDIX

This diaper lifecycle assessment addresses the manufacturing processes involved in the production of single-use and reusable diapers, including: electrical energy generation; water use, treatment and discharge; raw materials refining; primary and secondary product manufacture; process and post-consumer waste management and disposal; and phases of waste and emissions generation including air, water and solid wastes.

Not included in this assessment are: capital equipment in primary and secondary product transformation; energy consumed in space heating and cooling; transportation impacts; air pollution generation impacts of direct combustion of fossil fuel on manufacturing sites; or impacts of detergent manufacturing. Heat and noise emissions are difficult to quantify due to a lack of available data and are not addressed in this study.

Figures 3 and 4 in section IIC define the systems and their boundaries for single-use and reusable diapers for the purposes of this study.

The base year for most of the data is 1988, unless otherwise indicated; 1988 is the most recent year for which the quantity and quality of data necessary to perform this magnitude of assessment are available.

There are several considerations with respect to the data used in this report:

Accuracy and Precision

In gathering data and performing the calculations necessary to produce the information on the six impact categories, the best available information was used. The authors believe this study to be accurate within 15 percent. However, due to the nature of the analysis, possible errors are systematic and cumulative, not random.

Completeness of Data Sets

Secondary and tertiary data are used in many cases in this study. Primary data direct from manufacturing operations is often proprietary, or not kept in discrete detail for each process of interest. Wherever possible, verifiable data was extracted from the literature. Government documents and government agency publications were a major resource, as were industry trade association publications, technical journals, and other public domain documents.

Data is often not available in the literature, or is reported for some but not all components of the study. Wherever possible, an indication of the completeness of the data set is provided to enable readers better to assess the validity of the information contributing to a given conclusion. Sensitivity analyses are used in some instances to indicate how the results vary with large and small changes in one or more pieces of input.

Old Data

In some cases, recent data was not available for a specific process or pollutant. Old data is considered better than no data, and is used where no other data is available.

Omissions

As discussed above, missing data is always a problem in an analysis of the magnitude of this study. Where details are omitted, it is the result of either the unavailability of proprietary information, or the incompleteness of secondary and tertiary data (as opposed to direct manufacturing data).

The Weighting or Valuation problem in Environmental Assessment

Because the various approaches of reports comparing diapering modes are controversial, a discussion of valuation methods -- how specific types of pollution are evaluated -- is necessary. Clearly, listing the relative values of various pollutants is not easy, and must be highly approximate in view of the episodic and geographically specific nature of high pollution events. Nevertheless, society does make relative evaluations of different types of pollution (various air pollutants, air pollution versus water pollution) insofar as expenditures on mitigation measures are mandated. Furthermore, because the market penetration of diapers is probably 99.99 percent in the United States, consideration is given to national averages and statistics in adducing evidence for the value of environmental impacts, at least with respect to usage and disposal.

The valuation in some areas of comparison is straightforward. Single-use diapers require more materials to fabricate, place greater stress on waste disposal systems, and utilize more energy in production and use than reusable diapers. This is consistent whether 1.2 reusable diapers per change or 1.8 diapers per change are used in the calculation.

With respect to air pollution, however, the picture is mixed. On an equivalent change basis, single-use diapers create significantly more carbon monoxide (CO) and particulate emissions, while reusable diapers produce slightly higher levels of nitrogen oxide (NO_x) emissions. Sulphur oxide emissions are in the same range.

Ascribing values or rankings to various impact categories is difficult. In this report, relative ranking of different diapering modes became evident as a result of the tables presented. Additional assessment of the impacts of single-use and reusable diapers on the environment was advanced based upon the relative resource impact analysis outlined below.

Relative Resource Impacts

There are different ways to compare "apples and oranges" in an environmental assessment. We can (1) develop damage or dose-response functions for various pollutants, (2) survey the public as to their "willingness to pay" for pollution abatement or environmental quality, and (3) impute values to pollutants from actual abatement expenditures, or estimated hardware and process costs of pollution control. These methods supply data to a lifecycle cost analysis, and can be synthesized into a common sense approach, based on relative resource impacts. Analysis of the relative resource impacts contributes insights to the evaluation of the total costs and environmental impacts of diapering modes.

Damage and Dose-Response Relationships: Air pollutants affect human health[96]; accelerate processes of physical wear and tear on buildings, structures, and objects[97]; and have adverse aesthetic and amenity effects. Accordingly, one way of valuing the composition of air pollution in the atmosphere is to total up the probable damages associated with component pollutant categories. Generally, this involves imputing a market value to human life, as well as opportunity costs of missing work due to sickness, degradation of property values and the effects of shorter useful lives of buildings and structures, and survey research concerning aesthetic valuation.

However, this method is difficult to apply to a lifecycle analysis because of the large geographic regions involved in manufacturing of commonly used products and geographically specific sensitivities to pollution loading. Emissions are quantified on a mass basis, without information on rate of release or concentration. Both rate and dose data is necessary to understand toxicology and environmental degradation. Therefore, relative resource impact analysis is more readily applied.

Consumer Attitudes: Survey techniques have been developed to elicit consumer attitudes and valuations regarding various kinds and levels of air pollution. These techniques have coalesced under names like "bidding games" and the more recent term "contingent valuation surveys."[98] Monetary measures for abatement of selected criteria pollutants in

---

[96] Lave and Seskin (1977).

[97] U.S. EPA, Damage Cost Models for Pollution Effects on Material, by Edward F. McCarthy et al., (Research Triangle Park, N.C.: U.S. Environmental Protection Agency, Environmental Sciences Research Laboratory; Cincinnati, Ohio: Center for Environmental Information, 1984).

[98] For a review of this literature, see R.G. Cummings, D.S. Brookshire, and W.D. Schultze, Valuing Environmental Goods: An Assessment of the Contingent Valuation Method, (Totowa, New Jersey: Rowman & Allanheld, 1986); Robert Cameron Mitchell and Richard T. Carson, Using Surveys to Value Public Goods: The Contingent Valuation Method, (Washington, D.C.: Resources for the Future, 1989).

various air basins across the United States are summarized by Chestnut and Rowe.[99]

The essence of such survey approaches is to ask how much a consumer would be willing to pay (accept) to avoid (endure) a given level of pollution, made salient, perhaps, by photographs of its occurrence in a familiar area. An indication that consumers are willing to spend more money for a cleaner environment is evidenced by the surge in "green" marketing of products, which emphasize environmental benefits.

Abatement costs: Actual money expenditures on air or water pollution abatement, together with information on the quantity of emissions removed, also provide some guide to the relative values accorded by society to different categories of pollution. In a democratic society and market economy, money allocated to pollution abatement will tend to go to the highest value use. Section 312(a) of the Clean Air Act Amendments of 1970 requires annual reporting of the prospective costs and impacts of governmental and private efforts to implement the act. This report has come to be known as "the cost of clean air report" and suggests unit costs of air pollution abatement by industry.

Alternatively, costs for reducing the emissions of various pollutants can be calculated from engineering data.[100]

Relative Resource Impacts: Since all three methods are beyond the resources of this project to encompass, relative resource impact comparisons have been applied. It is easy to compare the two diapering modes in terms of tons of solid waste generated, or to compare the cost of each diaper type on a per-change-basis in dollars. Once the methodology and boundaries of the inquiry have been identified, the analysis is straightforward in these examples.

However, when comparing unlike resource categories like sewage and solid waste, a relative resource analysis must be expanded. Reusable diapers rely on the waste water treatment system (i.e. laundering) while single-use diapers rely on the solid waste system (i.e. landfills, incineration, etc.). A relative resource analysis should be able to consider the overall impact of single-use diapers on the waste disposal system. In the case of diapers, if all diapers were single-use diapers, they would make up approximately 3 percent of municipal solid waste. Contrasted to the overall impact of reusable diapers on

---

[99] Lauraine G. Chestnut and Robert D. Rowe, "Economic Measures of the Impacts of Air Pollution on Health and Visibility," in Air Pollution's Toll on Forests & Crops, ed. by James J. MacKenzie and Mohamed T. El-Ashry, (New Haven: Yale University Press, 1989), pp. 316-42.

[100] U.S. EPA, A Standard Procedure for Cost Analysis of Pollution Control Operations, by Vincent W. Uhl, (Research Triangle Park, N.C.: U. S. Environmental Protection Agency, Industrial Environmental Research Laboratory, Springfield, Virginia, 1979).

the waste water treatment system, if all diapers were reusables, they would contribute less than 0.5 percent of the U.S. municipal waste water treatment volumes.

In addition to comparing "apples to apples" in specific environmental categories, this approach permits a comparison of "apples and oranges" to arrive at a relative perspective on the impacts on different diapering approaches which utilize distinctive waste processing systems. Single-use diapers have a greater quantitative impact on the solid waste system than reusable diapers have on the waste water treatment system.

ABBREVIATION GLOSSARY

ADL	Arthur D. Little, Inc.
ADL1	"Comparative Analysis of Selected Characteristics of Disposable and Reusable Products", Arthur D.Little, Inc., 1977.
ADL2	"Disposable Vs. Reusable Diapers: Health, Environmental, and Economic Comparison", Arthur D. Little, Inc., 1990.
AGM	Absorbent gel material
BAT	Best available technology
BOD	Biological oxygen demand
BTU	British thermal unit
CO	Carbon monoxide
CO_2	Carbon dioxide
COD	Chemical oxygen demand
DWS	"Diapers In The Waste Stream", Carl Lehrburger, 1988
HC	Hydrocarbons
LDPE	Low-density polyethylene (plastic)
MRI	Midwest Research Institute
MSW	Municipal solid waste
NADS	National Association of Diaper Services
NH_3	Ammonia
NO_x	Nitrogen oxide
O&G	Oil and grease

P&G	Procter and Gamble Company
PLA	Product lifecycle analysis
PPM	Parts per million
RCRA	Resource Recovery and Conservation Act
SIC	Standard industrial classification
SO_x	Sulfur oxide
TCDD	Tetra-chlorinated dibenzo-p-dioxin
TCDF	Tetra-chlorinated dibenzo-p-furan
TDS	Total dissolved solids
TSCA	Toxic Substances Control Act
TSS	Total suspended solids
WHO	World Health Organization
WIC	Women, Infants and Children

GLOSSARY

Absorbent Gel Materials: A polyacrylate gel produced by the polymerization of acrylic acid using a cross-linking agent. Super absorbent materials embedded in single-use diapers to increase absorbency.

Ash: The noncombustible material that remains after a fuel or waste has been burned.

Backyard Composting: The composting of organic material, such as leaves, garden material, and grass clippings by a homeowner or tenant.

Biodegradable: Material capable of being readily decomposed by biological means, especially by bacterial action.

BOD: Biological oxygen demand.

Bottom Ash: The non-airborne combustion residue from burning pulverized coal or municipal solid waste. The material falls to the bottom of the boiler and is removed mechanically.

Bulky Waste: Large items of waste materials, such as appliances, furniture, large auto parts, trees, branches, stumps, etc.

Carding: Method of treating fibers to produce yarn.

Caustic: Throughout this report, refers to sodium hydroxide, a material used to raise the pH of a solution to aid in chemical reaction in textile finishing, paper industries and super absorbent gel manufacture.

Co-Compost: A process designed for the simultaneous composting of two or more waste products. This term is typically used to describe the composting of mixed municipal solid waste and sludge.

COD: Chemical oxygen demand.

Commercial Solid Waste: All types of solid waste generated by stores, offices, restaurants, warehouses, and other non-manufacturing activities.

Composting: A solid waste management technique which utilizes natural processes to convert many organic materials to humus by micro-organism activity in an aerobic environment. Composting is not effective on plastic and rubber.

Construction and Demolition Waste: Waste building materials, dredging materials, grubbing waste and rubble resulting from construction, remodeling, repair and demolition operations on houses commercial buildings and other structures and pavements.

De-inking: The process of extracting the ink from newspaper or high-grade paper to allow use of recyclable fiber in new white-paper products.

Difficult-to-Manage: Solid wastes which, because of their chemical or physical composition, pose particular challenges to environmental protection and require special management consideration.

Dioxins: High molecular weight organic compounds consisting of two benzine rings attached by oxygen with chlorine about the exterior of the structure. Extremely toxic substance produced during the manufacture of pesticides and bleaching processes. Suspected carcinogen, responsible for the evacuation of Times Beach, Missouri.

Furans: Relative of dioxin with similar molecular structure and health impacts.

Garbage: Solid waste resulting from animal, grain, fruit, or vegetable matter used or intended for use as food.

Gin: A machine that separates cotton lint from seed and removes most of the trash and foreign matter from the lint. The lint is cleaned, dried, and compressed into bales weighing approximately 500 pounds, including wrapping and ties. There are about 2,000 gins located throughout the Cotton Belt.

Hazardous Waste: Any waste defined and regulated under 310 CMR 30.000 (Hazardous Waste Regulations).

High Density Polyethylene (HDPE): A type of plastic resin used to manufacture tough, flexible, yet relatively hard plastic products. Plastic milk jugs are made from HDPE.

Household Waste: See Residential Waste.

Incinerator: Any structure or furnace in which combustion takes place and refuse such as paper, wood, and animal and vegetable matter from restaurants is used as fuel, alone or with fossil fuel.

Industrial Wastes: Unwanted materials produced in or eliminated from an industrial operation. They may be categorized under a variety of headings, such as liquid wastes, sludge wastes, solid wastes.

Infectious Waste: All surgical, obstetrical, pathological or biological wastes.

Intermediate Processor or Recyclable Material: A company or individual that processes post-consumer recyclable materials in preparation for use as an input for a manufacturing process.

Landfills: A conventional landfill is "a land disposal site employing an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading solid wastes in thin layers, compacting the wastes to the smallest practical volume, and applying cover materials at the end of each operating day."

Leachate: The fluid which issues from a pile or cell of solid waste and which contains water, dissolved solid and decomposition products of the solid waste. Leachate can enter and mix with the groundwater and contaminate drinking water supplies.

Liner: A continuous layer of natural or man-made materials installed beneath or on the sides of a landfill to restrict the downward or lateral escape of solid waste or leachate.

Mass Burn: Combustion of municipal solid waste without any pre-processing of the waste except for removal of bulky waste.

Municipal Solid Waste (MSW): Solid wastes generated by residential dwellings, institutions and businesses.

Non-point Source Pollution: Pollutants dispersed over a large area with no immediately identifiable source.

Organic: Chemical compounds containing carbon and hydrogen, often in combination with other elements. Many organic compounds are formed by living creatures: thousands of others have been synthesized by chemists. Many synthetic organic compounds, such as pesticides and gasoline, are biologically active, often toxic.

P & G: Procter and Gamble Company, the largest manufacturer of single-use diapers.

Packaging: Material, typically comprised of paper or plastic, used to protect products during transport. Typically discarded once the product is opened for use.

Pathogen: A specific causative agent, such as a virus or bacterium, of disease.

PLA: See Product Lifecycle Analysis.

Polyethylene: A family of thermoplastic resins obtained by polymerizing the gas ethylene. Low molecular weight polymers of ethylene are fluids used as lubricants: medium weight polymers are waxes miscible with paraffin: and the high molecular weight polymers are the materials used in the plastics industry.

Polypropylene: Thermoplastic resins made by polymerizing propylene and in the case of copolymers with monomers, with suitable catalysts, generally aluminum alkyl and titanium tetrachloride mixed with solvents. The monomer unit in polypropylene is asymmetric and can assume two regular geometric arrangements.

Pretreatment Standard: Industrial waste effluent quality required for discharge to a publicly owned treatment works.

Product Lifecycle Analysis (PLA): A cradle to grave analysis of a product, that includes manufacturing, transportation, processing, consumer use and disposal. It is designed to take account of effects and costs which are not obvious to the consumer when he or she buys or uses a product.

Pyrolysis: The chemical decomposition of material by heat in the absence of oxygen.

Raw Waste Characteristics: A description of the constituents and properties of a waste water before treatment.

Recovered Materials: All types of materials handled by dealers and brokers that have fulfilled their useful function, and materials that occur as waste from the manufacturing or conversion of products.

Recyclable Materials: Materials that can be technically and economically recycled.

Recycling: As commonly used, reusing discarded materials and objects in original or changed form rather than wasting them. Precisely used, refers to sending recovered material back into the process by which it was first formed.

Refused Derived Fuel (RDF) System: RDF systems process municipal waste into a combustible product called refuse derived fuel. RDF processing involves removing non-combustible materials and shredding burnable materials, thereby increasing combustibility. Energy is recovered when the refuse derived fuel is burned. The non-combustible materials are either landfilled or further processed for sale.

Relative Resource Impacts: A comparison of the impacts that different products or processes have on equivalent or analogous environmental categories. For example, a relative resource impact analysis of diapers as waste would include a correlation between the percentage of reusable diaper waste in the sewage system compared to the percentage of single-use diapers in the solid waste stream.

Residential Waste: Waste generated by homeowners or tenants. The collection and management of residential wastes typically is provided by municipal government.

Resource Recovery: The extraction of useful materials or energy from solid waste. Recoverable wastes include paper, glass, and metals which can be reprocessed. "Resource recovery" is usually used to describe mechanical methods.

Reusable Diapers: Cotton or cloth diapers.

Simple Processing of Cotton Fabric: Woven or knit fabric finishing operations that may consist of fiber preparation, scouring, functional finishing, and one of the following processes applied to more than 5 percent of total production: bleaching, dyeing, or printing.

Single-use Diapers: Disposable diapers.

Solid Waste: Useless, unwanted, or discarded materials intended for disposal, processing, or combustion, or as stored until then. Commonly referred to as refuse, garbage, trash, or rubbish.

Solid Waste Stream: See Solid Waste and Municipal Solid Waste.

Source Reduction: Actions taken to reduce the volume or toxicity of waste generated.

Source Separation: The separation of recyclable materials from waste at the point of collection, e.g. residential separation of paper, metal, and glass from the rest of household wastes. Source separation makes recycling simpler and cost-efficient.

Special Wastes: Solid wastes requiring special handling or processing technologies or methodologies to protect public health or safety or the environment.

Super Absorbents: See Absorbent Gel Material.

Toxic Pollutants: All compounds specifically named or referred to in the Consent Decree, as well as recommended specific compounds representative of the nonspecific or ambiguous groups of compounds named in the agreement. This list of pollutants was developed based on the use of criteria such as known occurrence in point source effluent, in the aquatic environment, in fish, in drinking water; and through evaluations of carcinogenicity, other chronic toxicity, bio-accumulation, and persistence.

BIBLIOGRAPHY

American Paper Institute. Patterns of Fuel and Energy Consumption in the U.S. Pulp and Paper Industry, 1972-1984. Washington, DC: API, 1985.

________. Pulp and Paper Fact Book. Washington, DC: API, 1988.

Arthur D. Little, Inc. (ADL1). "Comparative Analysis of Selected Characteristics of Disposable and Reusable Diapers." Report to Tissue Division, American Paper Institute, Inc. Cambridge, MA: Arthur D. Little, Inc., January 1977.

________. Overview of U.S. Pulp and Paper Industry. Volumes 1 and 2. Cambridge, MA: Arthur D. Little, Inc., January 1988.

________ (ADL2). "Disposable Versus Reusable Diapers: Health, Environmental and Economic Comparisons." Cambridge, MA: Arthur D. Little, Inc., March 16, 1990.

Asinof, Lynn. "Diaper Services Make a Comeback Amid Growing Environmental Concerns," The Wall Street Journal. November 2, 1989, pp. AI(W), A1(E).

Casey, J.P., ed. Pulp and Paper: Chemistry and Chemical Technology VII. New York: Wiley, 1983.

Center for Policy Alternatives. "Update on Diapers (Revised)." Washington, DC: Center for Policy Alternatives, September, 1990.

Chestnut, Lauraine G. and Robert D. Rowe. "Economic Measures of the Impacts of Air Pollution on Health and Visibility." In Air Pollution's Toll on Forests and Crops, James J. MacKenzie and Mohamed T. El-Ashry, eds. New Haven: Yale University Press, 1989, pp.316-42.

Chigier, Norman. Energy Combustion and Environment. New York: McGraw Hill, 1981.

Corbitt, Robert A., ed. Standard Handbook of Environmental Engineering. New York: McGraw Hill, 1990.

CRC Handbook of Environmental Control, 1st ed. "Air Pollution Petroleum Industry." Vol. I. Cleveland: CRC Press, 1972.

________. "Pest Management in Agriculture." Vol. III. Cleveland: CRC Press, 1972.

________. "Wastewater." Vol. IV. Cleveland: CRC Press, 1972.

Cummings, R.G., D.S. Brookshire and W.D. Schultze. Valuing Environmental Goods: An Assessment of the Contingent Valuation Method. Totowa, NH: Rowman and Allanheld, 1986.

Edgar, Thomas F. Coal Processing and Pollution Control. Houston: Gulf Publishing Co., 1983.

Eisman, Regina. "The Booming Baby Market." Incentive, Vol. 164, Issue 2, pp.39-41. February 1990.

Energy Information Administration. Manufacturing Energy Consumption Survey, Consumption of Energy. Washington, DC: EIA, 1985.

Environmental Quality. Washington, DC: U.S. EPA, 1988-89.

Feachem, Richard G., David Bradley, H. Garelick, and D.D. Mara. "Appropriate Technology for Water Supply and Sanitation." New York: World Bank, 1980.

Federal Register. "Draft Regulatory Impact Analysis of the Proposed Regulation for Sewage Sludge Use and Disposal." Vol. 54, No. 23, Feb. 6, 1989. November 1988.

First Boston Equity Research. "Shift in Diaper Usage Immaterial for Kimberly-Clark and Procter & Gamble." The First Boston Corp. July 30, 1990.

Fluck, Richard C. Agriculture Energetics. Westport, CT: AVI Publishing Co., 1980.

Foreign Agricultural Service. World Cotton Situation: October 1989. Washington, DC: Foreign Agricultural Service, 1989.

Franklin Associates, Ltd. "Characterization of Municipal Solid Waste in the U.S. (1990 Update)." U.S. EPA 530/SW-90-042. Washington, DC: U.S. EPA, June 1990.

_______ (Franklin Associates Diaper Profile). "Energy and Environmental Profile Analysis of Children's Disposable and Cloth Diapers (Final Report)." Prepared for American Paper Institute, Diaper Manufacturers Group, July 1990.

Freeman, Laurie. "Poll: P & G Seeks to Defend Its Diapers." Advertising Age, vol. 61, issue 24, June 11, 1990.

_______. "Diaper Image Damaged: Poll." Advertising Age, vol. 61, issue 24, June 11, 1990.

Freeman, Laurie and Laurel Wentz. "P & G On a Roll Overseas." Advertising Age, vol. 59, issue 27, June 27, 1988.

Hamilton, Patricia. "Emptying the Trash." Dun & Bradstreet Reports, vol. 37, issue 6 (Nov/Dec 1989), pp. 34-37.

Helsel, Z.R. Energy in Plant Nutrition and Pest Control. New York: Elsevier, 1987.

Jarvisalo, J., ed. Proceedings of the International Symposium on Occupational Hazards Related to Plastics and Synthetic Elasatomers. New York: AR Liss, 1984.

Jones, A.R. "The Environmental Impact from Oxygen Bleaching Hardwood Kraft Pulp." TAPPI Environmental Conference Proceedings, 1983.

Jones, H.R. Pollution Control in the Textile Industry. Park Ridge, NJ: Noyes Data Corp., 1973.

Kimberly-Clark 1989 Annual Report. Kimberly-Clark Corporation, 1989.

Kirk, R.E., and D.F. Othmar. Encyclopedia of Chemical Technology. Vol. 9. New York: Wiley, 1980.

Lave, Lester B. and Eugene P. Seskin. Air Pollution and Human Health. Baltimore: Johns Hopkins University Press for Resources for the Future, 1977.

Lehrburger, Carl. "Diapers in the Waste Stream: A Review of Waste Management and Public Policy Issues." December 1988.

________. "Diapers: A Waste Management Perspective." Nonwovens World, February 1990.

Lentz, Dr. Roland, Marina Franke and Karl J. Thome-Kozmiensky (LENTZ). "Does the Use of Cloth Diapers Instead of Disposable Diapers Cause Less Environmental Impact?" Paper presented at the International Recycling Congress. Berlin. November 28-30, 1989.

Marshall, Duane W. and Nicholas Bock. "TAPPI Characterization of Leachates from Solid Wastes of Pulp and Paper Manufacturers Origin." TAPPI Environmental Conference Proceedings, 1981.

Mathur, John R. Water Resources: Distribution, Use, and Management. New York: John Wiley and Sons, 1984.

McKean, William T., ed. Energy and Environmental Concerns in the Forest Products Industry. New York: American Institute of Chemical Engineers, 1978.

McKetta, John J., ed. Encyclopedia of Chemical Processing and Design. Vol. 34. New York: M. Dekker, 1990.

McLaughlin, Mark. "Makers of Adult Diapers Foresee Expanding Market as Population Ages." New England Business, vol.10, issue 2, (February 1, 1988), pp.37-8.

Metcalf and Eddy, Inc. Wastewater Engineering: Treatment, Disposal and Reuse. New York: McGraw Hill, 1979.

Midwest Research Institute (MRI). "Study of Environmental Impact of Disposables versus Reusables." Draft Report for U.S. EPA. Kansas City, MO: Midwest Research Institute, February 11, 1977.

Mies, Will. "Fluff Pulp Growth Slowing Due to Lower Birthrate, Super Absorbents." Pulp and Paper Magazine, March 1988.

Mitchell, Robert Cameron and Richard T. Carson. Using Surveys to Value Public Goods: The Contingent Valuation Method. Washington, DC: Resources for the Future, 1989.

Modern Plastics. "Materials '90." January 1990.

Modetz, Henry and Michael Murtiff. Kraft Pulp Industry Particulate Emissions: Source Category Report. Research Triangle Park, NC: U.S. EPA, 1987.

National Cotton Council of America. Cotton Counts Its Customers. Memphis, TN: National Cotton Council of America. 1989 edition.

National Council of the Paper Industry for Air and Stream Improvement (NCASI). Pulping Effluents in the Aquatic Environment, Part I. Technical Bulletin No. 572. October 1989.

National Solid Wastes Management Association. Landfill Capacity in the Year 2000. Washington, DC: National Solid Wastes Management Association.

Nemerow, N.L. Industrial Water Pollution, Origins, Characteristics, and Treatment. New York: Addison Wesley, 1978.

Nonwovens Industry. "The Adult Incontinence Products Market," March 1989.

"Nonwovens Markets and Fiber Structures Report." Nonwovens World newsletter, March 16, 1990. San Francisco: Miller Freeman Publications, Inc.

Nonwovens World. "Degrading the Disposable Diaper," vol. 5, no. 2 (February 1990), p. 23. San Francisco: Miller Freeman Publications, Inc.

Organization for Economic Cooperation and Development (OCDE). Petrochemical Industry: Energy Aspects of Structural Change. Paris: OCDE, 1985.

Owen, William F. Energy in Wastewater Treatment. Englewood Cliffs, NY: Prentice Hall, 1982.

Pacey, A. Sanitation in Developing Countries. New York: Wiley, 1978.

Pimentel, David. Handbook of Energy Utilization in Agriculture. Cleveland: CRC-Press, 1980.

Pinkerton, John E. "Significance of PM 10 Regulations for the Forest Products Industry." TAPPI Environmental Conference Proceedings, 1988.

Predicasts Basebook. Cleveland: Predicasts Inc., 1989.

Rahenkamp, Kristin and Frank Kreith. State Legislative Report: A Comparison of Disposable and Reusable Diapers: Economics, Environmental Impacts and Legislative Options. Vol. 15, No. 8, April 1990. Denver: National Conference of State Legislatures, 1980.

Rathje, W.L., D. C. Wilson, W.W. Hughes, and T. Jones. "Characterization of Recyclable Materials in Residential Solid Wastes." The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona, May 1989.

Sanders, Charles L. Toxicological Aspects of Energy Production. New York: Battelle Press, 1986.

Sax, Irving, ed. Industry Pollution. New York: Reinhold, VanNostrand, 1974.

Schrodt, J. Thomas. Air Pollution Potentials on the Incineration Products of Disposable Diapers. University of Kentucky, July 1973.

Sittig, Marshall. Environmental Sources and Emissions Handbook. Park Ridge, NJ: Noyes Data Corp, 1979.

Sittig, Marshall, ed. Pesticide Manufacturing and Toxic Materials Control Encyclopedia. Park Ridge, NJ: Noyes Data Corp., 1980.

Smith, Dr. Paul M. and Keith D. Sheeran. "Summary: A Profile of Consumer Preference for Baby Diapers." University of Washington Division of Forest Products and Engineering. Seattle: University of Washington, 1990.

Society of Plastic Industry, Inc. (The). Facts and Figures of the United States Plastics Industry. Washington, DC: SPI, 1989.

Solley, Wayne B., Charles F. Merk, and Robert R. Pierce. Estimated Use of Water in the United States in 1985. U.S. Geological Survey Circular 1004. Washington, DC. 1988.

Statistical Abstract of the United States. Washington, DC: U.S. GPO, 1990.

Statistical Office of the United Nations. Industrial Statistics Yearbook, Vol. II. New York: UNIPUB, 1978-87 editions.

________. Industrial Statistics Yearbook, Vol. II. New York: UNIPUB, 1988.

Stout, B.A. Energy for World Agriculture. New York: UNIPUB, 1987.

Suntio, Leena R., Wan Ying Shiu and Donald Mackay. A Review of the Nature and Properties of Chemicals Present in Pulp Mill Effluent. Institute for Environmental Studies. Toronto: University of Toronto, 1988.

Technical Association of the Pulp and Paper Industry. The Bleaching of Pulp. TAPPI, 1953.

Texas Agricultural Extension Service. Cotton Harvest-Aid Chemicals. College Station, TX: The Texas A and M University System, December 1987.

________. Management of Cotton Insects in the Southern, Eastern, and Blackland Areas of Texas. College Station, TX: The Texas A and M University System, 1989-1990.

________. Cotton Production in the Blackland Prairie & Grand Prairie. Publication B-1628. College Station, TX: The Texas A and M University System, 1990.

Tucker, Harvey. Personal communication. 1990.

U.S. Bureau of Census. Census of Manufacturers-Water Use in Manufacturing. Washington, DC: U.S. Bureau of Census, 1983.

________. Census of State, Local, and Territorial Subtitle D Non-Hazardous Waste Programs. Washington, DC: U.S. Bureau of Census, 1984.

________. Census of Transportation, Truck Inventory and Use Survey. Washington, DC: U.S. Bureau of Census, 1987.

U.S. Department of Agriculture. Organic Farming Study. Washington, DC: U.S. Department of Agriculture, May 1980.

________. Cotton Production Practices and Costs. By W.C. McArthur, F.T. Cooke, R.D. Krenz, and G.D. Garst. Washington, DC: U.S. Department of Agriculture, July 1985.

________. Agricultural Pesticide Use Trends and Policy Issues. Washington, DC: U.S. Department of Agriculture, September 1989.

________. Agricultural Resources Inputs Situation and Outlook Report. Commodity Economics Division, Economic Research Service, CWS-59. Washington, DC: U.S. Department of Agriculture, February 1990.

________. Cotton and Wool Situation and Outlook Report. Commodity Economics Division, Economic Research Service, CWS-59. Washington, DC: U.S. Department of Agriculture, February 1990.

________. Cotton and Wool Situation and Outlook Report. Commodity Economics Division, Economic Research Service, CWS-60. Washington, DC: U.S. Department of Agriculture, May 1990.

U.S. Department of Commerce. U.S. Industrial Outlook. Bureau of Industrial Economics. 1990.

U.S. Department of Energy. Monthly Energy Review. Energy Information Administration. May 1990.

U.S. Department of Housing and Urban Development. Survey of Water Fixture Use. By Brown and Caldwell. Contract H-5230, Office of Policy Development and Research, Building Technology Division. Washington, DC: U.S. GPO, March 1984.

U.S. Environmental Protection Agency. Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Synthetic Polymers Segment of the Plastics and Synthetic Materials Manufacturing Pt. Source Category. Washington, DC: U.S. EPA, 1975.

________. Source Assessment: Plastics Processing State of the Art. By Monsanto Research Corporation. EPA/600/2-78/004C. Cincinnati: U.S. EPA, March 1978.

________. A Standard Procedure for Cost Analysis of Pollution Control Operations. By Vincent W. Uhl. Industrial Environmental Research Laboratory, Springfield, Virginia. Research Triangle Park, NC: U.S. EPA, 1979.

________. Development Document for Effluent Limitations for Textile Mills Pt. Source Category. Washington, DC: U.S. EPA, September 1982.

________. Development Document for Effluent Limitations for Petroleum Refining Pt. Source Category. Washington, DC: U.S. EPA, October 1982.

________. Development Document for Effluent Limitation Guidelines and New Source Performance Standards For The Pulp And Paper Board Segment of the Pulp And Paper Industry. Washington, DC: U.S. EPA, 1984.

________. Damage Cost Models for Pollution Effects on Material. By Edward F. McCarthy et al., U.S. EPA Environmental Sciences Research. Research Triangle Park, N.C.: U.S. EPA, January 1984.

________. National Water Quality Inventory. Report to Congress. Washington, DC.: U.S. EPA, 1984.

________. Development Document for Effluent Limitations for Offshore Segment of Oil and Gas Extraction. Washington, DC: U.S. EPA, July 1985.

________. AP-42: Air Quality Compilation of Air Pollutant Emission Factors. Vol. I EP 4.9:42/985, 1985-Present. Washington, DC: U.S. EPA.

________. Preliminary Compilation of Air Pollutant Emission Factors for Selected Air Toxic Compounds. By A.A. Pope. Research Triangle Park, NC: U.S. EPA, April 1987.

________. "(Draft) Diaper Industry Workshop Report." By Science Application International Corporation (SAIC). Cincinnati: U.S. EPA Office of Research and Development, August 1990.

University of Georgia College of Agriculture (The). Cotton Production Package. Tifton, GA: Cooperative Extension Service, 1990.

Van der Leeden, F., F. Troise and D. Todd. The Water Encyclopedia. 2nd edition. Lewis Publishers, 1990.

Wadden, R.A. Energy Utilization and Environmental Health. New York: Wiley, 1978.

Wiberg, K., K. Lundstrom, B. Glas, and C. Rappe. "PCDDs and PCDFs in Consumers' Paper Products," Chemosphere, Vol. 19, No. 1-6, pp. 735-740, 1989.

Woo, Michael T. Crude Oil Energy Requirements from Exploration to Refinery. Chicago: University of Chicago, 1978.

World Health Organization. Solid Waste Disposal and Control: Report of a WHO Expert Committee. World Health Organization Technical Report Services No. 484. Geneva: World Health Organization, 1971.

________. "Solid Waste Disposal and Control." WHO Chronicle, Vol. 26, No. 4, (April 1972), pp. 147-51. Geneva: World Health Organization, 1972.