

# **DIAPERS**

## **IN THE WASTE STREAM**

*A Review of Waste Management  
and  
Public Policy Issues*

**BY**  
**CARL LEHRBURGER**

DIAPERS IN THE WASTE STREAM:  
A REVIEW OF WASTE MANAGEMENT  
AND PUBLIC POLICY ISSUES

By

Carl Lehrburger

December 1988

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Sponsors

National Association of Diaper Services, Philadelphia, Pennsylvania  
Mr. Harvey Tucker, Di-Dee Service, Inc., Syracuse, New York  
Mr. Brian Smithson, Baby Diapers, Inc., Seattle, Washington

The author wishes to thank and acknowledge the contributions of the following:

Energy Answers Corporation, Albany, New York  
Smith & Mahoney, P.C., Consulting Engineers, Albany, New York  
Dovey Dee  
Karen Helgers  
Ethan Snyder Lehrburger  
Dr. Dan Perlman, University of Colorado School of Medicine, Denver, Colo.  
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Dan Smith  
Rachel Snyder  
Kevin Sponable

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## INTRODUCTION

As the cost of solid waste disposal grows and the availability of landfills decreases, society is beginning to recognize the need to reduce, reuse and recycle waste. Too easily overlooked for too long, single-use (disposable) diapers now account for approximately 2% by weight of municipal solid waste (msw). Although composting yard waste (20% of msw) and recycling newspapers (6.3% of msw) and beverage (5.6%) and food containers (6.6% of msw) are the most immediate and generally accepted ways to begin reducing solid waste, the desirability of eliminating single-use diapers from the solid waste stream is gaining recognition.

During the last two years, I have investigated the role that diapers play in our solid waste system. I write as a solid waste management professional who has studied the subject from a materials flow perspective, from a sociological vantage, and from the practical experience of raising an infant.

In pursuit of a more complete picture, I wrote in 1986 a brief paper on the subject entitled "Out of Sight, Out of Mind: The Disposable Diaper Myth". The paper was published in a revised version in the Fall 1988 issue of Whole Earth Review, Sausalito, California.

Near the end of 1987, the National Association of Diaper Services (NADS) indicated interest in helping to fund my research. With the support of that organization and two of its active members, I began in February 1988 a formal study of diapers in the waste stream. Although the sponsors' interest was obvious, the financial commitment was made with no strings attached as to the research content and results.

While Americans value an abundance of time-saving, work-saving products, we also value the environment in which we live. Single-use diapers in the solid waste stream are but one significant aspect of a greater situation facing our consumer-oriented society. As a society, we have been sold on the idea of "disposability" without full recognition of the costs associated with convenience. While single-use diaper manufacturers may promote convenience as a higher social value than reusability or recyclability, few stop to question or to draw the line between ease of disposal and the environmental impacts associated with that convenience.

We have now reached a point where we must question not only the issue of whether alleged "convenience" justifies tossing 18 billion single-use diapers into the solid waste stream annually, but whether the responsibility for safe disposal of single-use products rests with the manufacturer or the consumer.

It is not unusual to wait until we are confronted with the consequence of a problem before we begin to address the cause. Hence, it has been the contamination of wells from leaching landfills that has forced regulations requiring new landfills to have liners, pollution control systems, and daily landfill cover. As well, environmental degradation is forcing us to consider change in the way we package, deliver and consume products. Since the percentage of single-use diapers in the waste stream has been increasing and will probably continue to do so, a critical public policy and health review of this practice is long overdue.

As we become more conscious of options to reduce, reuse and recycle our waste, we can and must begin to integrate these beneficial waste management practices into all aspects of our lives, including diapering of our young and elderly.

This report hopefully will be a beginning point for public policy debate, a reexamination of environmental and economic issues resulting from reliance on single-use diapers, and a stimulus to more thorough investigations into alternatives.

## Section 1. EXECUTIVE SUMMARY AND CONCLUSIONS

In 1988, approximately 18 billion disposable (single-use<sup>\*</sup>) diapers were purchased in the United States. Once discarded, they and over 99% of their contents made their way to the solid waste stream along with household and commercial trash. The overwhelming majority of single-use diapers (92%) were ultimately buried in landfills; the balance incinerated in resource recovery plants.

The impact of single-use diapers on the nation's solid waste disposal system is staggering:

- o On a national average, single-use diaper waste represents 2% of municipal solid waste and 3.5% to 4.5% of household solid waste (by weight). *No other single consumer product--with the exception of newspapers and beverage and food containers--contributes so much to our solid waste.*
- o In 1988, it is estimated that 3,622,500 tons of single-use diaper waste will end up in landfills. There, the comingling of untreated sewage and solid waste will create a potentially unhealthy situation as well as pose a health concern for sanitation workers. *Dramatic shifts in public policy, how we manage waste and manufacture products are needed to put an end to landfilling single-use diaper waste.*
- o Nearly \$300 million is spent annually to discard single-use diapers, which now account for approximately 90% of all diapers sold in this country. Cotton diapers, which are reused 50 to 200 times and then recycled as rags, make up the balance of the diaper market. *For every consumer dollar spent on single-use diapers, an additional hidden cost of over \$0.08 on average must be spent to pay for disposal.*
- o In an ironic twist, the percentage of the waste stream occupied by single-use diapers is destined to increase at the very time that states and municipalities are instituting recycling programs aimed at reducing the solid waste stream. *Even if the number of single-use diapers thrown away stays the same in the coming years, the percentage of solid waste represented by this product will grow as newspapers and glass, plastic, and metal containers are diverted through recycling.*

This report presents the findings and conclusions of a six-month study into the quantitative and qualitative impacts that diaper use has on solid waste management. The topic was addressed from the perspectives of solid waste management, materials reuse, and public policy.

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The author has substituted the term "single-use" for "disposable" in referring to the modern, throwaway diaper, thus defining the product by use patterns and function.



## Diapers as Solid Waste

Viewed from a solid waste management perspective, diaper disposal lends itself to a hierarchy of options encouraging, in order of priority, (1) waste minimization, (2) reuse, (3) recycling and composting, (4) waste-to-energy and (5) landfilling. From this vantage, cotton diaper usage should be encouraged over single-use diapers because it reduces solid waste and relies on reusable fabric.

Although it is the least desirable disposal option for diapers, landfilling is the current option of choice for most municipalities. Nearly 82% of all diapers purchased find their way to landfills; approximately 10% are reused (cotton diapers); and 8% are incinerated. Unless there is a dramatic change in public policy or the direction of waste management services in the near future, most single-use diapers will continue to be landfilled or burned. With the exception of composting, no practical technique is known to recover or recycle single-use diaper material or content.

From the perspective of materials reuse, increased use of cotton diapers represents the most immediate and obvious alternative to single-use diapers. Cotton diapers' reliance on reusable fabric plus disposal of feces to the sewage waste stream, make this diapering mode superior to single-use diapers. Cotton diapering offers long-term savings to consumers and can create jobs within the diaper service industry (currently accounting for 10% to 20% of the cotton diaper market).

The 120 million cotton diapers purchased in 1988 will require 33,435 tons of detergent, 28.6 billion gallons of water, and 82.9 million kilowatts of electricity during their entire product life cycle. In early 1988, diapers washed at home cost \$0.03 each, although the figure increased to \$0.16 per diaper when domestic labor is factored in at \$6.00 per hour. The cost of using cotton diapers with a diaper service was \$0.15, compared to \$0.22 per each single-use diaper.

### "Biodegradable" Diapers

The use of biodegradable plastics in single-use diapers does little to alter the undesirability of diapers entering the solid waste stream because none of the collection, transportation or landfill costs will be minimized. Neither the quantity of diaper waste nor the potential for spread of infection from single-use diapers will be eliminated prior to landfilling. Once landfilled, "biodegradable" single-use diapers may not decompose as rapidly as promoters claim because rapid decomposition requires oxygen, which is in short supply under the surface of a landfill. Using biodegradable plastics in conjunction with co-composting of municipal solid waste would be beneficial. Although well intentioned, the proposed use of biodegradable plastics in single-use diapers will not significantly change the contribution of single-use diapers to mounting solid waste problems.

The only true biodegradable single-use diaper may be a flushable diaper pad. A two-piece diaper employing reusable diaper covers and a flushable pad has many potential benefits over today's line of single-use diapers, including a reduction in quantity of solid waste, a likely reduction in per unit diaper cost, and a reduction in waste processing and transportation costs. Although not commercially available or recognized as feasible, the ultimate solution to the problem of how to dispose of single-use diapers may be solved by developing and commercializing a flushable diaper product that reduces solid waste and concentrates diaper wastes in the sewage waste stream.

### Public Policy

From a public policy viewpoint, reducing the solid waste impacts of diapers in the immediate and near-term future involves encouraging the use of cotton diapers and/or diaper services over single-use diapers, which emphasize materials reuse and waste reduction. The Federal government could act swiftly and thoroughly by authorizing that all Federally-funded or -operated institutions use or dispense cotton diapers. This requirement could extend to military base hospitals, government-operated stores on military bases, and other institutions receiving Federal funds.

On a state or local level, a tax on single-use diapers may be appropriate if directed at alleviating solid waste capacity problems. This policy could also send a strong message to both single-use diaper producers and consumers for the need to develop alternatives to single-use diapers that minimize solid waste. However, from a solid waste management perspective, any contemplated tax or ban on single-use diapers should be put in the larger context of a comprehensive waste management policy that includes all disposable products. As an immediate step, the author recommends educational programs that encourage cotton diaper use as well as a shift from the blatant bias toward single-use diapers in institutional settings.

After encouraging cotton diapers, the most effective reduction of single-use diaper waste will occur at the point of product manufacture. Industries that produce single-use diapers should be encouraged to continue to modify products to generate less solid waste.

In the final analysis, consumers are paying hidden costs for using disposable products, such as single-use diapers. Ultimately, the cost of collection, disposal, any environmental, or medical costs resulting from exposure to these products, is borne by the consumer.

### Public Health

From a public health perspective, single-use diapers are an infectious waste, since their contents often contain contagious viruses. The viruses from the fecal material of babies is a particular source of concern, since babies are effective carriers of enteroviruses and are usually immunized with live poliovirus and other vaccines. Virus-laden single-use diapers will continue to pose a potential threat to the health of those who handle solid waste, and to society at large, as long as improper disposal of solid waste continues.

Although a potential health problem exists due to improper disposal of single-use diapers, the health impacts are relatively small when compared to other problems such as disposal of household hazardous waste, infectious waste from hospitals, and illegal dumping of a variety of wastes. However, the dangers posed to waste-management personnel and the public from exposure to viral and bacteriological infection originating from single-use diapers are, in the author's opinion, underestimated.

Efforts should be made on national, state and local levels to understand the health and environmental impacts of single-use diapers in the solid waste stream. Additional review of the subject is recommended to determine to what degree single-use diapers may pose a public health problem, how this potential health concern compares with other elements of the waste stream, and how solid waste and local health codes could be amended to ensure safe and proper disposal of these wastes.

### Conclusions

The conclusions of this study are that in light of dwindling landfill capacity, growing waste disposal costs and potential public health concerns, the use of reusable cotton diapers should be encouraged over single-use diapers, and the elimination of single-use diapers going to landfills is a desirable and reasonable public policy objective.

The author makes the following recommendations:

1. Solid waste managers should begin to recognize the overlooked impacts that the increasing quantities of single-use diapers have on the solid waste stream, and should seek alternatives to diaper wastes entering landfills and the solid waste stream;
2. Single-use diapers should no longer be ignored and should be addressed in state legislative proposals to minimize or eliminate packaging and plastic waste and disposable, single-use products;
3. National economic policies and subsidies should be shifted from promoting single-use diapers and disposable products and toward encouraging waste reduction by providing economic incentives to diaper services and cotton diaper users to encourage waste reduction;
4. The issue of how best to process diapers should be viewed from a solid waste management hierarchy that emphasizes, in order of priority: waste minimization; product reuse; recycling; waste-to-energy; and landfilling;
5. Increased use of cotton diapers represents the clear and obvious waste reduction approach to minimize solid waste created by single-use diapers;
6. A tax on single-use diapers, as an element of a comprehensive and integrated solid waste management program, is an appropriate public policy to provide incentives for producers and consumers to minimize solid waste and to help raise financial resources to develop and encourage less wasteful alternatives;

7. Local and state health officials are advised to review present public health codes in light of current collection and landfill operation procedures. Determinations should be made as to whether discarding unprocessed, feces- and urine-filled diapers into the solid waste stream and/or landfills poses a health risk and under what circumstances single-use diapers should be defined as "infectious waste";
8. The Environmental Protection Agency should review the definition of both "infectious" and "solid" waste to determine under what circumstances changes in collection and disposal practices for single-use diapers are warranted;
9. Where public health institutions are involved, a policy of reusing cotton and textile products should be promoted instead of reliance on single-use, throwaway products;
10. Research and product development should be encouraged and promoted by diaper manufacturers to develop a flushable single-use diaper as an alternative to the current single-use diaper configuration;
11. Single-use diaper manufacturers could be more effective at educating parents on the proper disposal of diaper contents, and should assume a greater responsibility for promoting proper disposal of their products, and developing products that encourage easier emptying of fecal content into toilets; and
12. Increased educational efforts should be made to provide parents, health care and child care providers with information on proper disposal of, as well as alternatives to, single-use diapers.

## Section 2. DIAPERS

### A. Brief History

It was just 40 years ago that nearly all diapers in Europe and North America were cotton diapers, primarily washed in the home. In the short space of several decades, reusable cotton diapers have been almost entirely displaced by single-use, throwaway diapers.

Probably the first "throwaway" diapers were plants used to swaddle children by early tribal cultures. Records left by many early societies indicate the use of swaddling cloths, although Plutarch reports that Spartan children "had no swaddling bands; the children grew up free and unconstrained in limb and form..."<sup>1</sup>. Egyptian infants, as well, were not constricted in swaddling clothes but allowed to run about naked or carried about in loose, soft wrappings.

The history of modern-day disposable diapers in the U.S. most likely began in the late 1940s, when Johnson & Johnson was marketing Chux brand disposable baby diapers. As reported by Francis J. Bouda, a patent attorney and well-respected industry expert, "The first disposable baby diaper was a multi-ply cellulose-wadding product. (T)his multi-ply crepe paper (similar to kitchen towels) product was coarse and rough, but it still served the purpose of low-cost disposability"<sup>2</sup>.

The Swedes are given credit for developing the forerunner of today's single-use diaper, with a two-piece diaper system made of sheets of cellulose wadding. Later, a rayon fiber mesh for each pad of cellulose wadding material was added. The insert pad was designed to be thrown away after separation from the plastic cover<sup>3</sup>.

One of the first one-piece diaper inventions was disclosed in 1953, but it was in the 1960s that Pampers brand diapers began to be marketed as the first single-piece wing-fold diaper, which was to become the prototypical single-use diaper.

Many developments in diaper construction followed, including the addition of rubber bands in the legs popularized by the Luvs brand diaper in the early 1970s. As super-absorbing materials became available in the late 1970s, diaper manufacturers began to add "super-slurpers" to diaper padding for increased absorbency. When wet by urine these absorbers turn into a gel-like consistency, trapping the fluid away from the baby's skin. The addition of poly-acrylic absorbers into diapers now allow less materials to be used in the diaper, and most baby diapers on the market have super absorbent crystals imbedded in the wood pulp "fluff".

\* The author refers to disposable diapers as single-use diapers throughout this report. See Appendix I., "A Word About Diaper Terminology", for an explanation.

<sup>1</sup>-----  
<sup>1</sup>*Plutarch's Lives*, A. H. Clough, The Modern Library, New York, NY.

<sup>2</sup>*"New Trends In Adult Pads and Infant Diapers"* by Bouda, Francis J., *Nonwovens Industry Magazine*, January 1983.

<sup>3</sup>*"Nonwoven Disposables In Western Europe, Product And Market Characteristics"* Lil D. S. Wettergren, Paper-Lil AB, Inc., Sweden.

Although early single-use diapers were designed to have the inner padding separate from the plastic backing and flushed down the toilet, this practice has been discontinued. Until recently, instructions on the packaging of some single-use diapers called for tearing the diaper padding from the plastic cover and flushing. Now, most diaper manufacturers recommend emptying the "soiled" diaper contents into the toilet, most people changing diapers find this practice too difficult or cumbersome and discard the diaper and contents into the trash.

Although single-use diapers are more costly than washing cotton diapers or using a diaper service, the perceived convenience of not having to wash diapers and the ease with which they are discarded make single-use diapers the most popular diapering mode in the U.S. and Western Europe. The nearly complete conversion of Americans away from cotton to single-use diapers represents one of the greatest marketing and product success stories in recent time.

## B. Market

It is estimated that between 17 and 18 billion single-use diapers were purchased in the U.S. in 1987<sup>4</sup>. This represents nearly 90% of all diapers purchased. The balance is represented by cotton diapers, which account for nearly 20% of all diaper changes. The discrepancy in diaper changes and the 90% market share of single-use diapers is accounted for because cotton diapers are reused many times, and therefore<sup>5</sup> represent a larger percentage of diapers changed than diapers purchased<sup>5</sup>.

The following graphic depicts the U.S. diaper market:

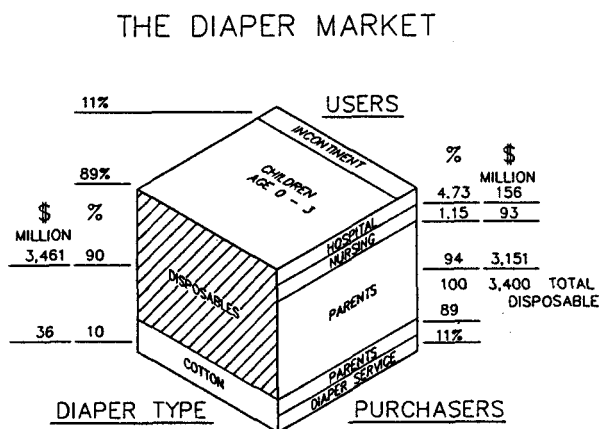


Figure 1. U.S. Diaper Market

<sup>4</sup> "Procter's Gamble--Is Smaller Better?", F. J. Bouda, *Nonwovens Industry*, January, 1986, pg. 18. See also footnote 52 for additional references.

<sup>5</sup> The discrepancy in market share of single-use diapers as defined by sales (89% market share) and by diapers used (81% market share) can be minimized by averaging the two. This results in an estimated 85% market share for single-use diapers, recognizing that sales penetration is a little higher, and the percentage of diapers actually used is a little lower.

Children under three years old account for nearly 90% of the total diaper market, the balance being incontinent adults. Parents, primarily mothers, are the main purchasers of diapers. Institutional purchases of diapers account for less than 6% of the diaper market when cotton diapers are added in.

As the following chart indicates, the projected number of net births in the U.S. is expected to decline. With the near saturation of the market by single-use diapers and the resurgence of cotton diaper services, the growth in the market for baby single-use diapers may now begin to contract. This is contrasted by the market for adult incontinent products, which is a faster growing market segment than baby diapers, growing at an annual rate of nearly fifty percent since 1983.<sup>6</sup>

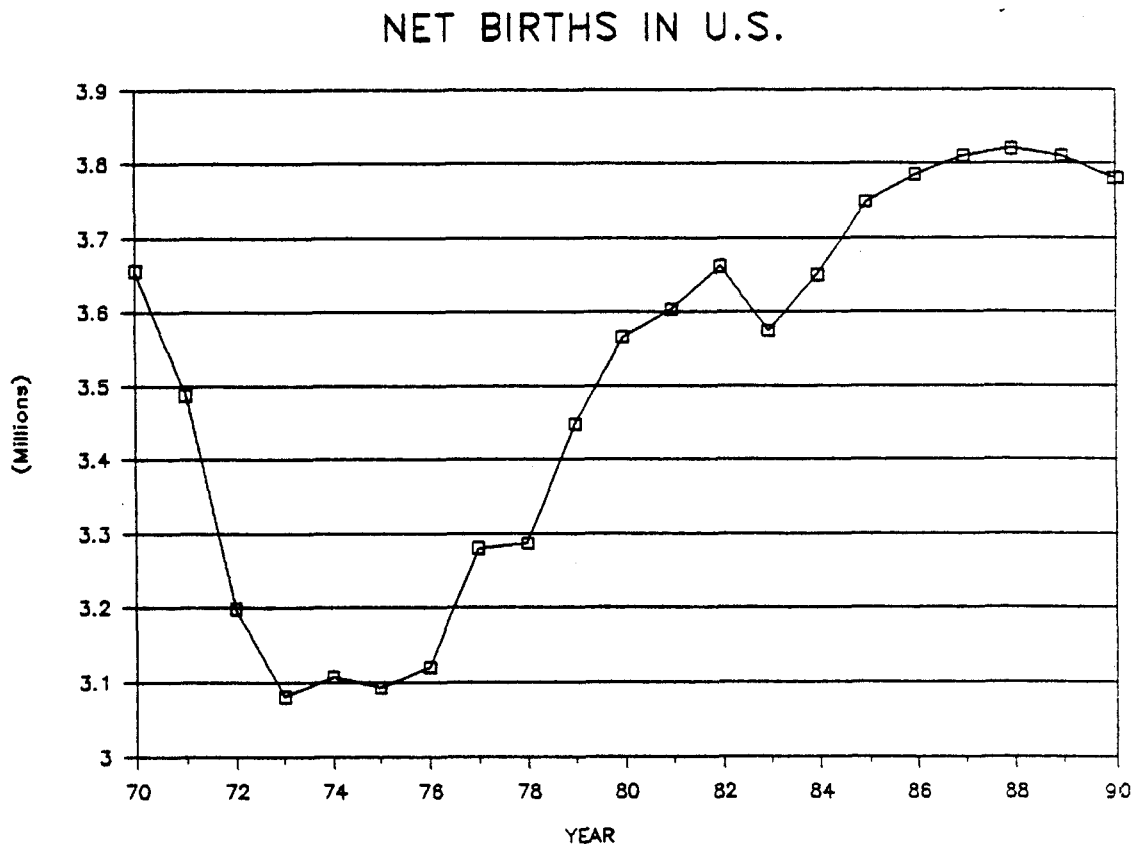


Figure 2. Net Births in the U.S.

<sup>6</sup> "Do Disposable Diapers Ever Go Away", Michael Hinds, *New York Times*, 12/10/88, pg. 33.

The recognition by single-use diaper manufacturers of a potential for a decline in the U.S. baby diaper market is likely to result in an accelerated effort to increase market share in the rest of the world. The U.S. has nearly two-thirds of the world single-use diaper market (see figure 3). The market penetration of single-use diapers will vary widely from one country to another. Sweden, for instance, has a nearly 100% use of a disposable-type diaper, while in Japan, single-use diapers represents an estimated 34% of the diaper market in 1986<sup>7</sup>. Cultural history, product availability and economics all contribute to the equation.

The export of single-use diapers and other disposable products and technology to the Third World means exporting waste disposal problems as well, since most developing nations have less sanitary or regulated waste disposal systems than the U.S. or Western Europe. Although single-use diapers are but one component of solid waste, it is exemplary of a product born out of the "waste ethic" and another example of the exportation of wasteful American consumption habits.

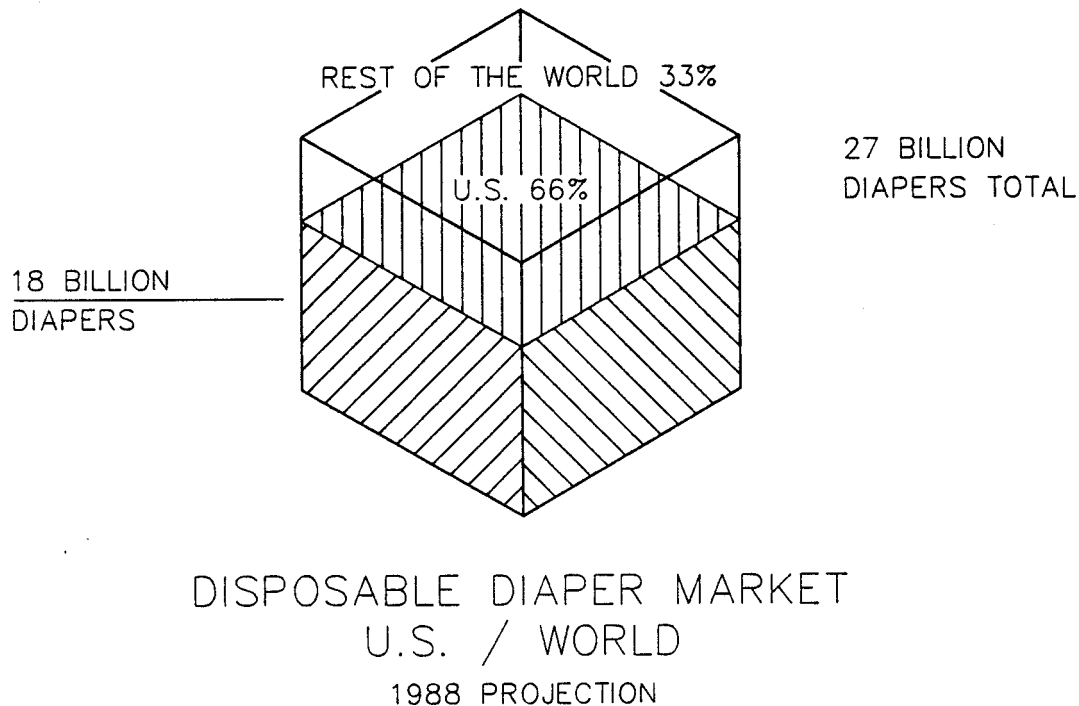


Figure 3. Single-use Diaper Market: World (1988 projection)

<sup>7</sup> *Financial Times of London*, 9/28/87, pg. 22 cites world disposable diaper sales in 1987 as 27 billion units.  
*Pulp and Paper Industry*, 3/88, pg. 82.



### C. Single-Use Diapers

The U.S. market for single-use diapers is dominated by The Procter & Gamble Company (P&G), manufacturer of Pampers brand and Luvs brand diapers. P&G has over 50% of the market with The Kimberly-Clark Corporation's Huggies brand accounting for approximately 30% of the single-use diaper market .

Single-use diapers are made of an outer layer of waterproof polyethylene plastic. Sandwiched between the plastic and a water-repellent liner is a thick layer of an absorbent cotton-like material made from wood pulp (cellulose). This inner layer of woven cellulose is embedded with super-absorbing crystals made of a poly-acrylate co-polymer. The cellulose is sandwiched between thin layers of tissue-like paper that hold the cellulose in place. The materials in a typical single-use diaper are quantified below:

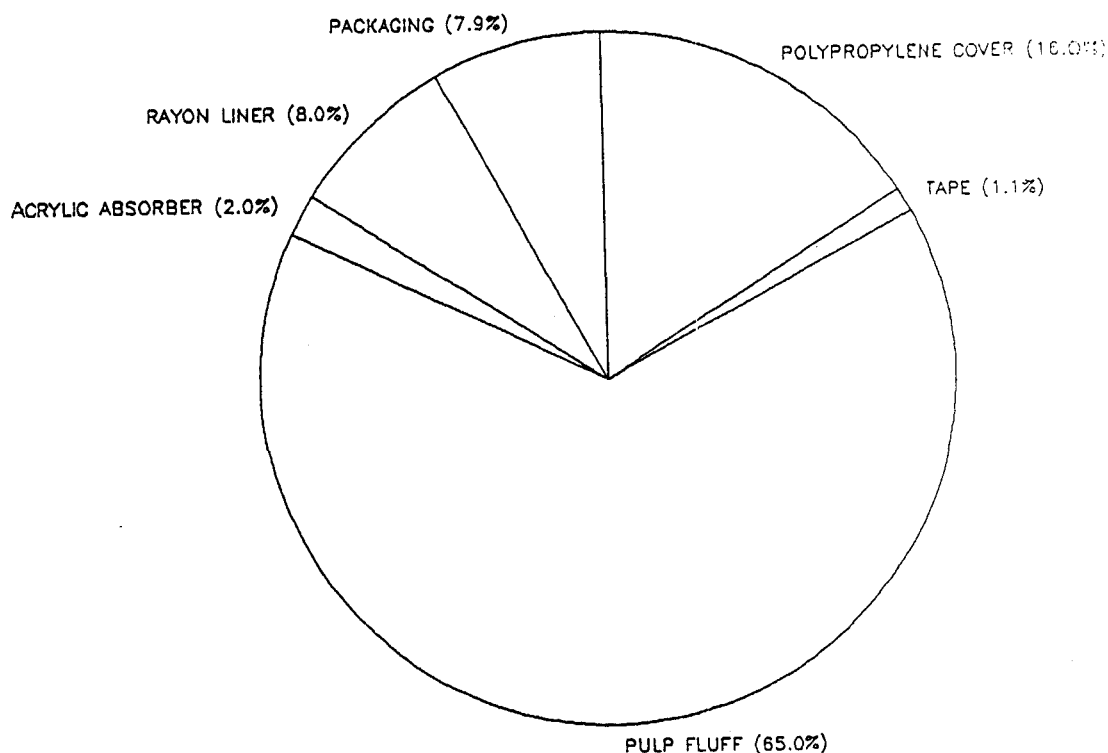


Figure 4. Typical Single-use Diaper Materials Analysis (by weight)

Probably one of the least publicized aspects of single-use diapers is their near total reliance on the solid waste disposal system. Originally, the inner liner of single-use diapers was recommended for sewage disposal via toilets. However, problems caused by plugging of pipes, and the manufacturers' desire for a diaper composed of more absorbent materials rather than less, has resulted in total reliance on the solid waste stream for disposal. Although manufacturers recommend disposing of diaper content in the toilet, this is rarely done by parents (see page 21, 22).

<sup>9</sup> "Diaper Wars", by Brooke Gladstone, The Boston Globe Magazine, 10/18/87.

#### D. Cotton Diapers

The U.S. market for cotton diapers has been declining in direct proportion to the increase in market share by single-use diapers. Today's market is estimated to be approximately 10% of total diaper sales, including cotton diaper cleaned by either home washing or by a professional diaper service.

Most households maintain a supply of cloth diapers on hand, although it is estimated that only 2% use exclusively cloth diapers. Even though retail sales of cloth diapers remained flat during most of 1988, the growth and expansion of many diaper services during the last year indicates a growing trend. Diaper services are available in most large cities, and provide weekly pickup and delivery of diapers. Most parents are surprised to learn that diapers need not be rinsed out, but merely placed in a plastic bag for pickup by a diaper service. Diaper services may account for 10% to 20% of the cotton diapers used.

Cotton diapers, in distinction to single-use diapers, are reused again and again. It is estimated that a typical cloth diaper washed at home may get between 50 and 100 uses, while a diaper service diaper may have 200 life cycles<sup>10</sup>. Nearly 100% of diapers from diaper services are recycled into rags. Although many home-washed diapers are recycled as rags, some undoubtedly find their way into the solid waste stream before secondary or tertiary reuse.

The modern parent using cloth diapers increasingly relies on reusable outer diaper covers or pants. These require an initial investment, which may be as much as \$12 for a wool or cotton diaper cover, with nylon and other synthetics being significantly less expensive (\$1 to \$2 each). A variety of diaper cover products are now on the market, including wool, cotton, rayon and polyethylene products. The natural fiber diaper covers are not waterproof, and often present difficulty in humid or cold-weather climates due to manufacturers' recommendation against machine drying.

The use of cotton diapers, as with single-use diapers, requires attention to hygiene practices. Particularly when home washing of diapers is concerned, the need for hands-on contact may increase the potential for transmission of infection.

<sup>10</sup>-----  
*Lower diaper life-cycles for home washing is a result of using chlorine bleach, which deteriorates the cotton fibers more rapidly.*

From a solid waste management perspective, the major benefits of cotton over single-use diapers are their reusability and reliance on the sewage waste stream. The accompanying chart depicts the flow of waste from single-use and cotton diapers to the solid waste and sewage waste streams.

## DIAPER WASTE MATERIAL FLOW

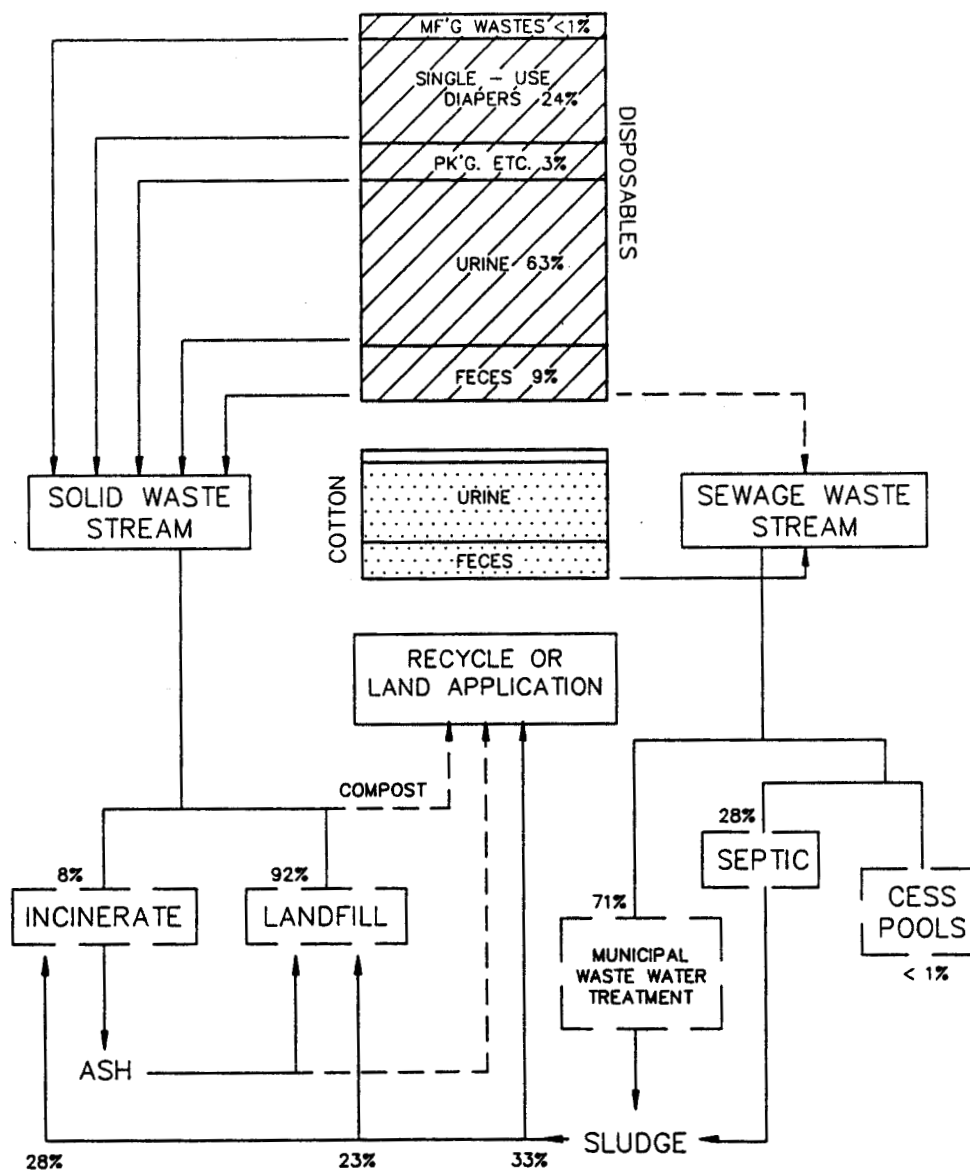


Figure 5. Combined Diaper Waste and Waste Stream Flow Chart

What becomes obvious from this flow chart is that by reusing the cotton diaper, neither the diaper or fecal materials are diverted through the solid waste stream. In addition to this reduction in materials waste, all sewage is concentrated in one place, eliminating the co-mingling of unprocessed sewage with trash, which is the inevitable consequence of using single-use diapers.

Although relying on the sewage waste stream for disposal minimizes waste transportation, processing, and disposal costs, it would be a mistake to assume that these costs are eliminated. After sewage processing is complete, sewage sludge remains, of which nearly one-quarter is currently landfilled. These issues will be discussed in greater detail in Section 4 of this report.

## Section 3. DIAPERS AS SOLID WASTE

### A. The Solid Waste Stream

In seeking to understand solid waste, it is imperative to recognize that waste is not merely a quantifiable commodity, but forms the basis of a materials handling process. This process is called waste management. It includes the collection, transportation, processing, recovery and disposal of discarded materials and products.

Various categories of waste overlap. These are often defined by the content of the waste, including hazardous, radioactive, infectious, construction and demolition, sewage, and sludge. Waste is also defined by its source: commercial, industrial, agricultural, municipal and household.

Since the content and source often overlap, definitions of waste are not uniform. For example, some states and localities allow construction and demolition materials to be disposed in municipal landfills, where it is considered a municipal solid waste, while in other areas, these wastes are clearly defined as non-municipal waste and requires special landfills. The same may be said of some types of non-hazardous industrial waste, sludges, incinerator residues and bulky wastes (i.e., tires and white goods).

Waste composition and quantity is affected by numerous factors, including demographics, economic activity, technological innovations and public policy. Two different approaches to determining quantities of waste are available: the first approach relies on scientific sampling at a specific site; the second relies on an understanding of material flows and extrapolates based on data projections. The sampling method is best suited for a single location, and is often required when a recycling or resource recovery project is to be built. However, since waste practices and composition vary dramatically at different locations, a materials flow analysis is often better suited for understanding quantities and qualities of waste on a national scale.

This section examines examples of available waste characterization studies that include diapers, and a materials flow analysis to provide a macro perspective of diapers in the waste stream.

The main source of information on waste characterization and quantities has been the United States Environmental Protection Agency (EPA)<sup>11</sup>. In 1986 under contract to EPA, Franklin Associates completed Characterization of Municipal Solid Waste in the United States 1960-2000<sup>12</sup>, which is currently used throughout the solid waste industry for obtaining base information on waste characterization, quantities and trends.

Generally speaking, when waste managers refer to municipal solid waste (msw), they are referring to household and commercial waste delivered to a landfill or resource recovery facility. Often, but not always, this includes yard waste, institutional waste, construction and demolition materials, wastewater treatment sludges, and some light non-hazardous industrial waste. Msw specifically excludes radioactive waste, used oils, most infectious waste from hospitals, and hazardous materials (with the exception of household hazardous wastes).

Franklin Associates uses a materials flow analysis, which does not clearly delineate the source of discarded materials. Selected data from their study are shown in the next table.

<u>Material</u>	<u>1986</u>		<u>1990</u>	
	<u>%</u>	<u>Millions of Tons</u>	<u>%</u>	<u>Millions of Tons</u>
Paper and paperboard	35.6	50.1	36.8	54.9
Glass	8.4	11.8	8.3	12.3
Metals	8.9	12.6	8.9	13.4
Plastic	7.3	10.3	7.9	11.8
Other (rubber, leather, wood, textile, other)	8.9	12.6	7.9	11.9
TOTAL NONFOOD PRODUCT WASTE	69.2	97.4	69.9	104.2
Food Waste	8.9	12.5	8.4	12.5
Yard Waste	20.1	28.3	19.8	29.5
Misc. Inorganic Waste	1.8	2.6	1.9	2.8
TOTAL WASTE DISCARDED	100%	140.8	100%	149.0
* Waste discarded after materials recovery has taken place				

Figure 6: Material Discarded into the U.S. Municipal Waste Stream  
Source: Franklin Associates, Ltd., 1988, Table 2<sup>12</sup>

<sup>11</sup> U.S. EPA, Office of Solid Waste Management Programs; Second Report to Congress (1974, SW-122), Third Report to Congress (1975, SW-161), and Fourth Report To Congress (1977, SW-600).

<sup>12</sup> Characterization of Municipal Solid Waste in the United States, 1960-2000, Franklin Associates, LTD., Prairie Village, Kansas, upgraded March 30, 1988, EPA Contract No. 68-01-7310.

Although Franklin Associates segments "tissue paper and towels" as a product category, consistent with most waste characterization studies to date, they do not break out single-use diapers. This may be due to unavailable data, underestimated volumes, or because single-use diapers contain overlapping categories of waste, including plastic, cellulose (paper), and organic materials. Based on Franklin Associates data, the author has estimated single-use diapers as a category in the municipal solid waste stream in the following pie chart.

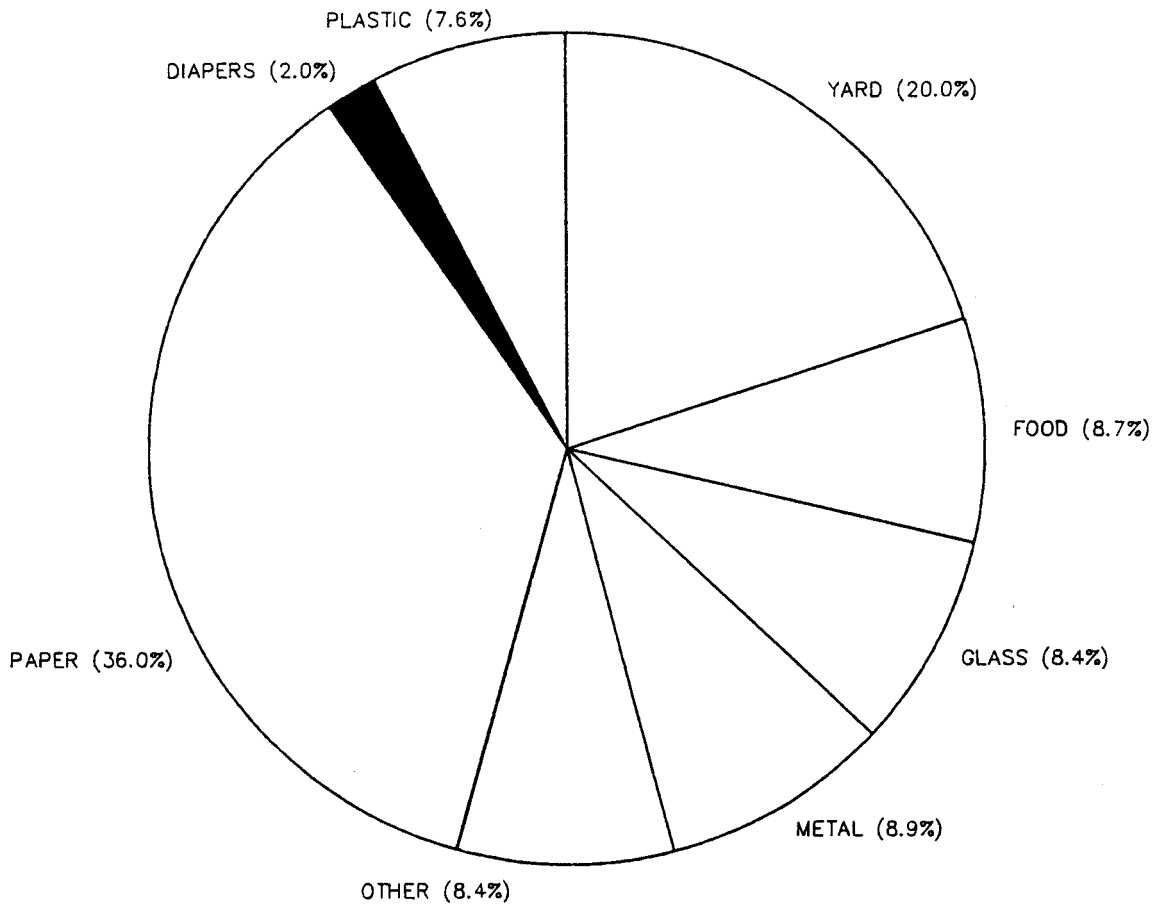


Figure 7. The Municipal Solid Waste Stream (1988)

The household solid waste stream refers to materials discarded from residences and does not include commercial waste. Because most single-use diapers are purchased by consumers, they occupy a larger segment of the household waste stream than the municipal waste stream, as shown below.

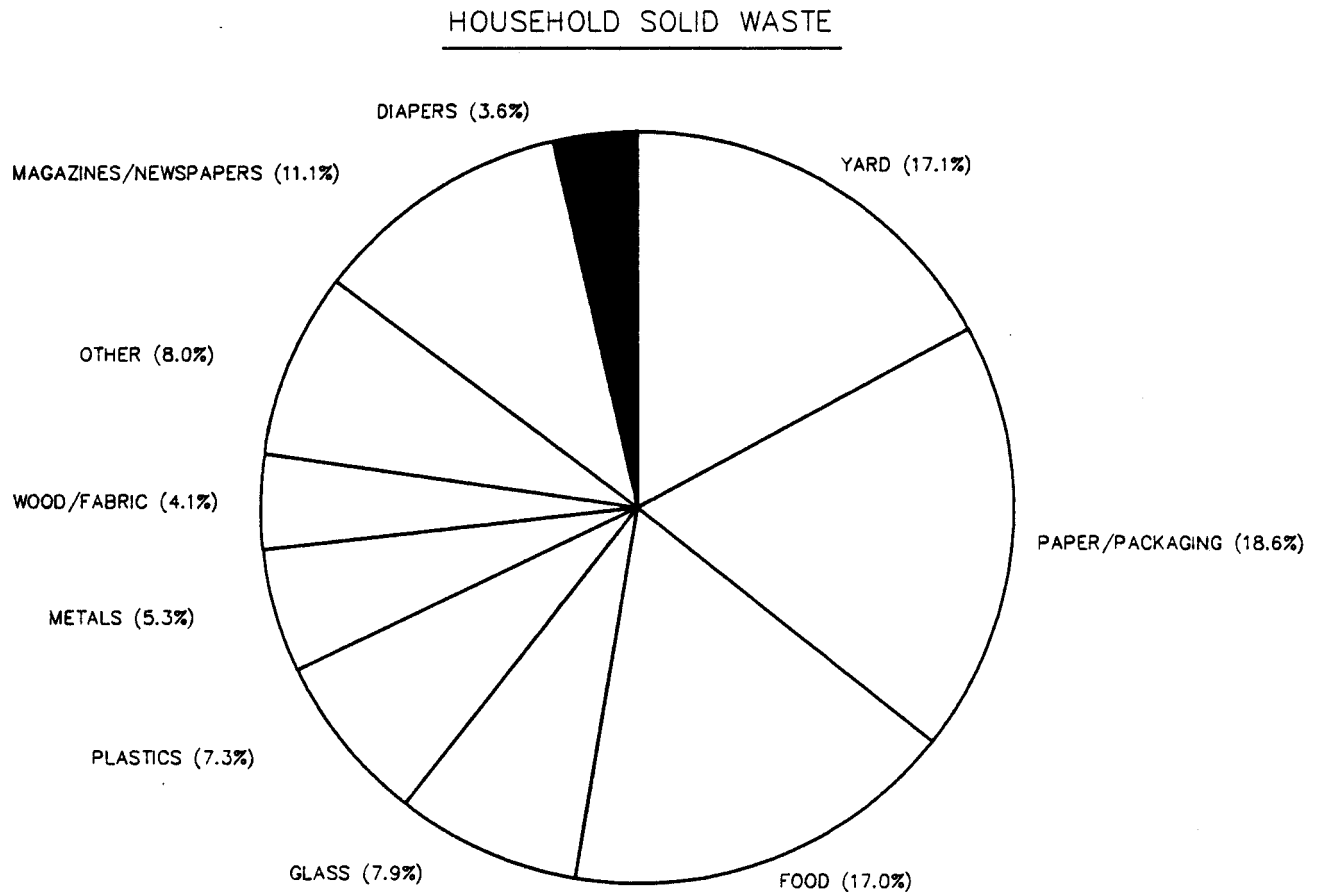


Figure 8. The Household Solid Waste Stream<sup>13</sup>

<sup>13</sup>-----  
Source: *The Garbage Project, University of Arizona, Tucson*



Americans are throwing away more and more trash each year. Franklin Associates report that per capita discards have increased since 1960. For the year 1960, each individual was estimated to have discarded 2.65 pounds per day, or 964 pound per capita per year. By 1990, this is expected to increase to 3.94 pounds per capita per day, or 1,336 pounds per capita per year. This trend is corroborated by other national and local waste studies, and is shown below:

	<u>1960</u>	<u>1970</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
Total Waste Discarded (Pounds/person/day)	2.65	3.22	3.43	3.67	3.94

Figure 9.

Total Discards Of Municipal Solid Waste By Individuals, 1960-2000  
Data Extracted From Table 6: Franklin Associates (1988)

These estimates are considerably less than 1960's estimates of 5.3 pounds per capita per day by EPA, and slightly higher than the 1986 Franklin Associates estimates.

Even as total discards into the municipal waste stream are growing every year, net discards to landfills are expected to begin to flatten out due to the increase in materials recovery (recycling) and projected energy recovery (incineration). These will be discussed in sections 4A and 4B.

Diminishing landfill capacity, the rising cost of solid waste disposal, and a growing awareness of the long-term environmental problems caused by polluting landfills, has resulted in a dramatic change in the public policy sphere during the last 10 years. The emergence of new waste processing techniques and the growth in consumer and environmental activism have also impacted the public policy agenda. What has emerged is:

- o a recognition of the need to properly close old landfills and enforce strict new environmental laws for current and new ones;
- o a growth in the number of operating and planned resource recovery plants;
- o the reemergence of the need to recover and recycle materials currently being discarded; and,
- o the emergence of state proposals that seek to reduce waste.

As these trends evolve, there is a growing consensus that a hierarchy of preferred waste management techniques should guide public policy. In order of the most desirable approaches to managing our waste, they are:

1. Waste reduction at source: eliminating the amount of material discarded as waste;
2. Reuse: reusing a bottle again, for example;
3. Recycling: crushing a glass bottle and using the material to make a new glass product, for example;
4. Waste-to-Energy or "resource recovery": incineration often accompanied by materials recovery; and
5. Landfilling: burying wastes.

This hierarchy is based upon a variety of criteria within the context of diminishing landfill capacity, including environmental impact, economics and common sense.

In regard to diapers, the least desirable disposal option, landfilling, is primarily relied on. Nearly 82% of all cotton and single-use diapers purchased find their way to landfills; approximately 10% are reused (cotton diapers); and 8% are incinerated (with 6% of the original weight of an incinerated diaper being landfilled as ash).

In the following sections, diapers will be discussed from the perspective of waste management practices, beginning with landfill disposal. But first, diapers and their contents are quantified as a discarded waste product.

## B. Diapers As Waste

A little noticed result of the shift from cotton to single-use diapers has been the increased reliance on the solid waste stream. Although several diaper manufacturers introduced flushable products, the problem of blocked sewer lines proved too great of a problem. Since there was little public awareness of the problems of landfill disposal, flushable single-use diapers were never perceived as desirable by consumers and were not a commercial success.

Although modern, single-use diaper packaging recommends emptying feces in the toilet, this is often impractical and, in fact, is discouraged by the one-piece diaper design, which does not allow the diaper to be torn apart easily. In addition, rinsing the fecal material from tremendously absorptive, single-use diapers in the toilet often produces a very full and heavy diaper.

# DIAPER WASTE MATERIAL FLOW UNITED STATES (TONS)

DISPOSAL COST FOR  
18 BILLION SINGLE USE DIAPERS  
\$298 MILLION

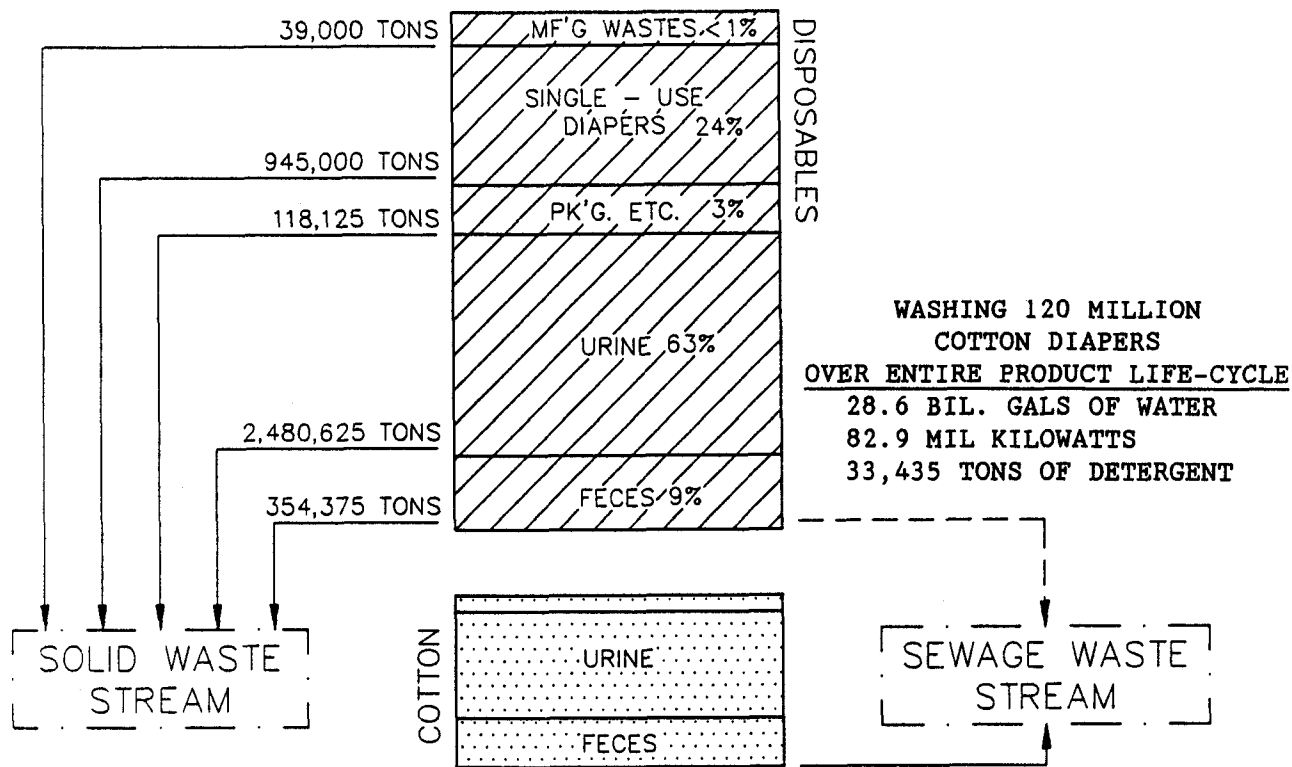


Figure 10. Diaper Waste Materials Flow

The author estimates that less than 5% of parents regularly rinse out single-use diapers containing fecal material. Three studies seem to support this. In an unpublished study conducted by the Garbage Project at the University of Arizona, 102 households in Tempe, Arizona, were studied. 823 diapers were analyzed, of which 281 or 34.1% contained fecal matter. The Garbage Project's Director, Dr. William Rathje, indicates that it is safe to conclude that few, if any, of these diapers had been rinsed or emptied in the toilet<sup>14</sup>.

In another study<sup>15</sup>, 100 diapers were examined for fecal content. 33 were "fecally soiled", and all 33 had fecal matter present. This confirms that 33% is a realistic estimate for diapers containing fecal material, but also shows that none of the parents in this small study rinsed or emptied the diapers.

In another study, Dr. Mirdza Peterson reported that "...approximately 33 per cent of the diapers (analyzed in her study) contained fecal matter" in 1974<sup>16</sup>.

<sup>14</sup>-----  
<sup>14</sup>Telephone interview with Dr. William Rathje, May 1988.

<sup>15</sup>"Biological Properties of Sanitary Landfill Leachate", Engelbrecht, Weber, Amirhor, Foster, and LaRossa, University of Illinois at Urbana-Champaign, Urbana, Ill.

<sup>16</sup>"Soiled Disposable Diapers: A Potential Source of Viruses", Mirdza L. Peterson, Phd, AJPH Vol. 64; No. 9, September, 1974.

Based on the three studies cited above and the author's own estimate, as little as 1% to 2% of single-use diaper waste is diverted from the solid waste stream to the sewage waste stream.

### C. Waste Characterization Studies

Few quantitative studies are available that provide precise data on the amount of diaper waste that end up in the solid waste stream. The author has reviewed eight studies that provide a basis for a quantitative analysis from actual sampling. Of the studies, five examined municipal waste and three examined household waste. These studies are summarized below (refer to Appendix II for references):

Study	Waste Stream	Year	Diaper % of MSW (Weight)	Single-Use Share of Diaper Market Year of Study <sup>17</sup>
1 Oyster Bay, Long Island Consultants Study	Municipal waste from refuse	1988	2	85%
2 Tuscon, AZ Bay Area, CA Chicago, IL	Municipal solid waste (average of three landfills)	1979- 1985	.86	66%
3 Dearborn Hights Michigan	Municipal refuse MSW w/o yard waste	1980 1980	1.43 2.09	54% 54%
4 Cincinnati, OH Kentucky	Municipal solid waste Municipal solid waste	1971 1971	1.03 .71	19% 19%
5 Onondaga Co. New York	Municipal solid waste	1987	1.33	85%
6 East Hampton and Buffalo, New York	"Household waste" composition study	1987	2	85%
7 Tuscon, Arizona	Household waste only	1982	5.1	59%
8 Cincinnati Ohio	Household waste only	1974	3.13	37%

Figure 11. Single-Use Diapers In the Solid Waste Stream  
Summary of Eight Selected Studies <sup>18</sup>

<sup>17</sup> Research Brief - "Kimberly-Clark Corporation", by Goldman Sachs Research, 4/17/86, table 5. Also, refer to next footnote.

<sup>18</sup> Refer to Appendix II. for a description of these studies.

Because some of these studies were conducted when single-use diapers comprised a smaller proportion of all diapers sold and used than today, these numbers must be calibrated to be useful in quantifying diapers as a percentage of today's solid waste stream. The following chart seeks to calibrate the results of the five studies of municipal solid waste.

Study	Year of Study	% of Waste Stream Year of Study	Single-Use Market Share Year of Study	% of Waste Stream Calibrated at 85% market Share <sup>19</sup>
1 Oyster Bay, Long Island Consultants Study	1988	2	85	2
2 Tuscon, AZ Bay Area, CA Chicago, IL	1979- 1985	.86	66	1.23 *
3 Dearborn Heights Michigan	1980	1.43 2.09	54 54	1.87 2.73**
4 Cincinnati, OH Kentucky	1971 1971	1.03 .71	19 19	1.7 1.18
5. Onondaga Co., NY	1987	1.33	85	1.33***
* With the methodological concurrence of Dr. William Rathje who oversaw this survey, the author estimated that the recovered waste from the landfill contained 20% dirt (by weight) from daily landfill cover. In this calibrated calculation, the estimated quantity of dirt was subtracted from the total waste.				
** without yard waste included				
*** Only msw landfills included in authors calculation. "Hardfill sites" included in William Cosulich study were eliminated by the author, which raised the diaper percentage from 1.2% to 1.33% If all sites accepting hardfill are eliminated, diapers would be 1.57% of msw.				

Figure 12. Calibrated Percentage of Single-Use Diapers  
In Five Municipal Solid Waste Composition Studies

These five calibrated studies suggest that a range of 1.23% - 2 % of the municipal solid waste stream is composed of single-use diaper waste, with a value of 1.57% when averaged together (results from the two 1971

<sup>19</sup>-----  
The percentage of diapers contained in the msw stream are computed on a basis of an estimated current 85% market share of diapers used, to arrive at present percentage of diapers in solid waste. Refer to footnote 5 for an explanation of methodology and see previous footnote.

studies in Cincinnati and Kentucky (#4) were treated together and not separately). If the #3 Dearborn Heights, Michigan study, which excluded yard waste, is substituted for the computation with yard waste, the average of the four studies is 1.75% of the municipal solid waste stream.

The following chart seeks to calibrate the results of three studies of household solid waste. The percentage of diapers contained in the household solid waste stream are computed on the basis of an estimated current 85% market share of single-use diapers, to arrive at current percentages of diapers in household waste from each study.

Study	Year of Study	% of Waste Stream Year of Study	Single-Use Market Share Year of Study (%)	% of Waste Stream Calibrated at 85% Market Share <sup>20</sup>
6 East Hampton and Buffalo, New York	1987	2	85	2
7 Tuscon, Arizona	1982	5.1	59	6.4
8 Cincinnati, Ohio	1974	3.13	37	4.6

Figure 13. Calibrated Percentage of Single-Use Diapers  
In Three Household Solid Waste Composition Studies

The three calibrated studies above suggest that anywhere from 2% to 6.4% of the household solid waste stream is composed of single-use diapers, with an average of 4.3%.

#### D. Materials Flow Analysis

Another way to estimate the annual quantity of single-use diaper waste in the solid waste stream is to calculate the percentage based upon data derived from material flow analysis. The following format is utilized to arrive at a percentage of municipal solid waste:

$$\frac{(\text{diaper weight}) \times (\text{number of diapers sold})}{\text{total solid waste discarded (weight)}} = \% \text{ of waste stream (by weight)}$$

Where the average weight of a single-use diaper when discarded is estimated to be 7 ounces, multiplied by 18 billion single-use diapers sold, equals 3,937,500 tons of single-use diaper waste discarded per year. This is divided by 144,900,000 tons of solid waste estimated in 1988, to arrive at 2.71%.

<sup>20</sup>-----  
Refer to previous footnote and footnote 5 for an explanation.

Based on this computation, which is detailed in Appendix III of this report, 2.71% (by weight) of the municipal solid waste stream is composed of single-use diapers.<sup>21</sup>

The estimate of single-use diapers comprising 2.71% of municipal solid waste is above the upper range of the five previously calibrated waste composition studies of 1.23% - 2.0%. This suggests that the actual composition of single-use diapers in the municipal solid waste stream may be lower than the 2.71% derived from the materials flow analysis. However, neither the five studies nor the materials flow analysis took into account other single-use diaper wastes such as packaging waste, manufacturing wastes and baby wipes, which could account for 659,000 additional tons of solid waste in 1988<sup>22</sup>. This would imply that the actual composition of single-use diaper waste in the msw stream is higher than the 1.57% average of the five previously cited and calibrated studies, and is near or above the high end of the studies, or about 2% (by weight), with a statistical deviation of .5%.

To arrive at a percentage of household solid waste, Franklin Associates table "Products Discarded Into the Municipal Waste Stream"<sup>23</sup> was used to derive 107.29 million tons discarded for 1990. This was done by subtracting non-household waste items, including fractions of commercial discards and yard waste, from the municipal waste stream figures<sup>24</sup>. Based on the computation, which is described in Appendix III, single-use diaper waste represent 3.5% of the household solid waste stream when yard waste is included, and 4.35% when all yard waste is excluded.

Determining the actual composition of single-use diaper waste in the household waste stream is more difficult than the municipal solid waste because it is more subject to varying definitions. The range of the three previously calibrated household studies was 2% to 6.4% of the household solid waste stream, with an average of 4.3%. Considering the above material flow calculation, partially supported by the calibrated studies, a range of 3.5% to 4.5% is estimated for the single-use diaper contribution to the household solid waste stream (by weight), subject to definition and interpretation.

## Conclusion

The conclusion of this analysis is that single-use diaper waste, all of which is discarded into the solid waste stream, makes up 2% of municipal solid waste by weight. When viewing the household segment of municipal solid waste, single-use diapers make up between 3.5% and 4.5% of the household waste stream, dependent largely upon whether yard waste is defined as contributing to household solid waste. These percentages can be significantly higher, as documented by the Tuscon, Arizona study, which

<sup>21</sup>-----  
<sup>21</sup> Refer to Appendix III of this report for a full elaboration of this computation.

<sup>22</sup> Refer to figure 16.

<sup>23</sup> Franklin Associates, Ltd., July 11, 1986 study, Characterization of Municipal Solid Waste in the U.S., 1960-2000.

<sup>24</sup> Refer to Appendix IV for an elaboration of how the total amount of household solid waste was calculated.

yielded 5.1% of the household solid waste in 1982 (which would be 6.4% with today's market share for single-use diapers.)

Since each community's solid waste stream differs, extrapolating to individual communities may prove difficult; a scientific sampling could provide exact information. Differences in location, socio-economic makeup, seasonal fluctuations, and other factors will yield diverse variations from one community to the next. It should also be noted that basing waste composition upon weight as opposed to volume may prove misleading. However this has become a generally accepted practice since most landfills and resource recovery facilities base fees on weight.<sup>25</sup>

Although some may consider 2% (by weight) of municipal solid waste small by comparison, others will be astonished. In fact, this is a startling revelation, in light of previous estimates, which place the number well below 1%. No other single consumer product, with the exception of newspapers and beverage and food containers, contribute so much to solid waste.

<sup>25</sup>-----  
According to Midwest Research Institute, "Study of Environmental Impacts of Selected Disposable Versus Reusable Products With Health Considerations", U.S. EPA, 1987, 50 single-use diapers occupy .285 cubic feet. Assuming 18 billion diapers, this would total over 100 million cubic feet, or 3.8 million cubic yards.



## Section 4. DIAPER PROCESSING TECHNIQUES

### A. Landfill Disposal

The primary solid waste disposal technique practiced today in the U.S. is landfilling. Approximately 92% of municipal solid waste is being buried. Resource recovery accounts for the additional 8%. This means that nearly 92% of single-use diaper waste -- 3,622,500 tons of materials -- will end up in landfills this year. The following chart shows the flow of single-use diapers entering the solid waste stream:

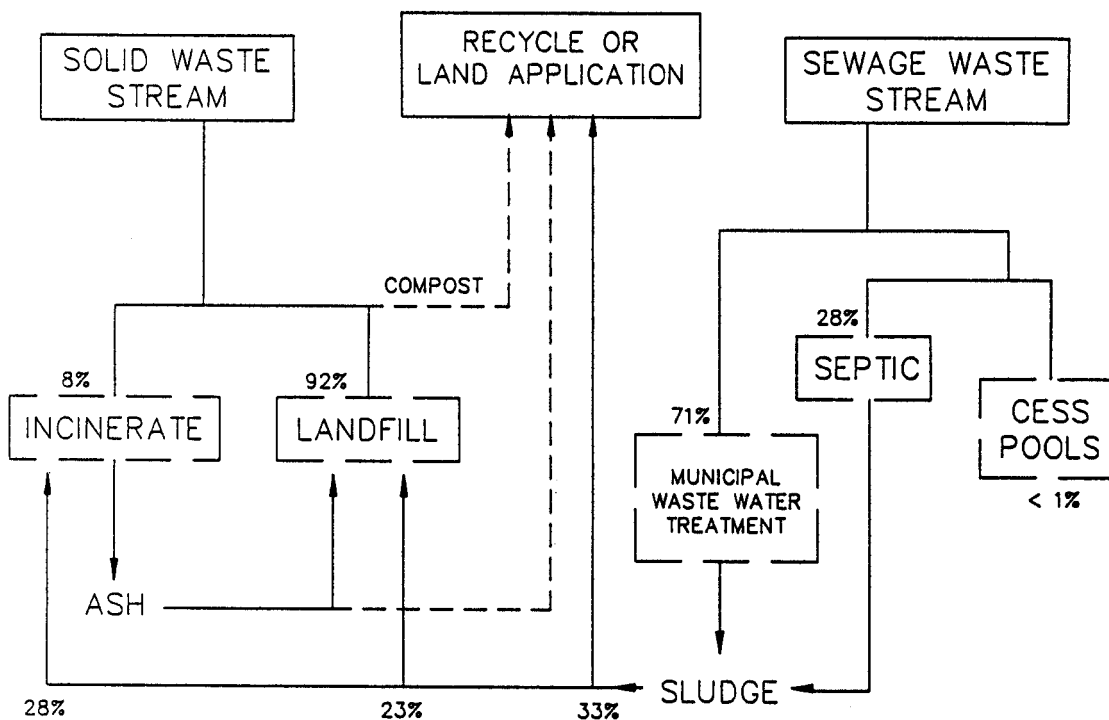


Figure 14. Waste Stream Flow Chart

While landfilling is the most common waste disposal technique today, every year a decreasing percentage of our solid waste will be landfilled. This is due to decreasing landfill capacity, the shortage of suitable land and the growing difficulty in siting new landfills. The development of resource recovery facilities and the increasing amount of materials recovered from the waste stream are reducing the reliance on landfilling solid waste, as the accompanying chart demonstrates:

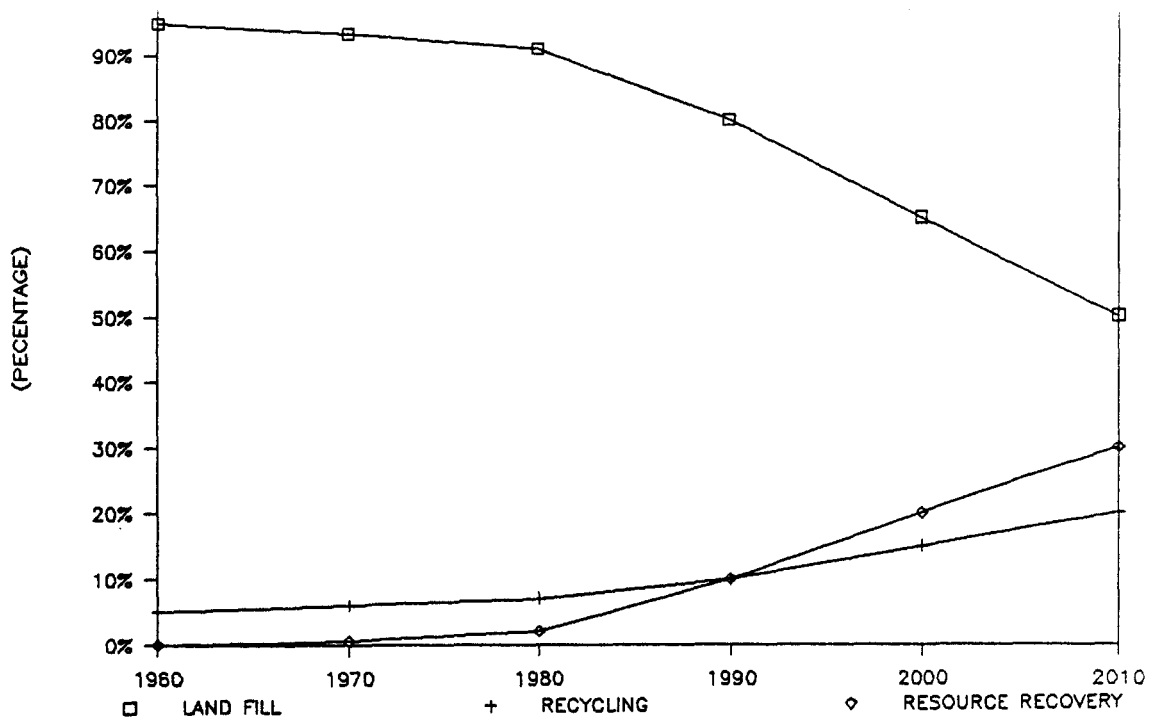


Figure 15. Projected Solid Waste Processing Techniques

Even as the percentage of waste going to landfill decreases, landfills will remain the primary means of solid waste disposal for several decades.

Fortunately, most new landfills are being built with liners and leachate control systems to prevent groundwater contamination. However, most operating landfills, which were built before new environmental requirements were in effect, are not outfitted with modern safety features and pose a threat to underground water supplies. Only 15% of the nations estimated 6,000 municipal landfills have liners, and less than one-third have a system for monitoring groundwater, according to the U.S. EPA.

The situation in Massachusetts illustrates this. Most landfills in Massachusetts were sited and constructed before their impact on underground water supplies was recognized. The Massachusetts Bureau of Solid Waste estimated that over 200 dumps not in use have been improperly closed to prevent groundwater contamination. Of 195 active solid waste landfills in 1985, 174 (89%) had no form of leachate control. Seven landfills had some form of remedial leachate control, but did not have an impervious liner or state-of-the-art leachate collection system. Only 14 landfills of the 195 active sites (7%) had low permeability liners and leachate collection systems under the operating sections. Only two landfills were completely lined<sup>26</sup>. In Massachusetts, forty percent of the sites studied had groundwater contamination resulting from leaching landfills in 1985.

Since single-use diapers are a growing percentage of the waste being landfilled, diaper waste will contribute to landfill leachate. Also, landfill equipment and personnel are coming into increasing contact with discarded single-use diapers. (Potential public health problems from landfilling single-use diapers are addressed in section 5B.)

<sup>26</sup> *Active Landfill Report*, Massachusetts Bureau of Solid Waste Disposal, 1985.

Although a clear potential for transmitting disease exists from discarding single-use diapers into the solid waste stream, from a solid waste management perspective this is but one component of the overall threat to human health resulting from landfilling of solid waste. Some specialized wastes that have been identified as posing an immediate threat to health have been eliminated from landfill disposal in most areas, including infectious hospital waste, untreated sewage, and several grades of industrial and commercial wastes. Attempts are being made to divert other wastes from the solid waste stream, including car batteries and household hazardous wastes such as paints and solvents.

To date the question of whether single-use diapers should be added to the list of materials to be eliminated from landfills has not received complete attention in public health and public policy debate. For example, while eleven states have developed new or amended infectious waste statutes or regulations since 1986<sup>27</sup>, none appear to mention single-use diapers coming from residences. However Pennsylvania and other states do prohibit the landfilling of specific types of single-use diaper waste originating from institutions. Although many experts agree that this presents an unsanitary and potentially unhealthy situation, no presently proposed Congressional or state action would affect single-use diaper disposal.

One approach being advocated to mitigate the solid waste problems of landfilling single-use diapers by some plastic and diaper manufacturers is developing a "biodegradable" diaper. The typical "biodegradable" diaper configuration may have an outer plastic sheeting that more rapidly degrades once in a landfill. Photo-degradable plastics are now commercially available that have an accelerated decomposition time as a result of the sun's effect on plastic. Plastic made with corn starch, which manufacturers claim is a fully biodegradable plastic, is now commercially available as a substitute for the current polyethylene sheeting in most diapers. Several marketers, including Rocky Mountain Medical Corp. of Greenwood, Colorado, and Eco-Matrix of Brookline, Massachusetts, market "biodegradable" diapers.

It is the author's view that this particular diaper configuration will have a negligible impact on the problems associated with landfill disposal and does not minimize diaper waste. None of the collection, transportation or landfill disposal costs will be minimized or eliminated. Neither the waste quantities nor the potential public health problems of single-use diaper waste will be minimized prior to landfilling. Once landfilled, these single-use diapers may decompose more rapidly than conventional diapers, but rapid decomposition requires oxygen, which is in short supply under the surface of a landfill. Although "biodegradable" single-use diaper manufacturers may claim that it will take 2-4 years for the diaper to degrade, it is more likely to be 5-10 times longer. A truly biodegradable diaper might decompose as rapidly as most other organic wastes in a landfill, which at best, would only mitigate the problem of regular single-use diapers' long decomposition time. Although biodegradable diapers could be beneficial in a composting or co-composting process, single-use diapers using photo- or bio-degradable plastic are not a solution to the problems created by collecting, transporting or processing single-use diapers. In addition,

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<sup>27</sup> "Infectious Wastes: A Contagious Concern", World Wastes, July, 1988, pg. 46.

they do not promote product reuse and serve to discourage plastic recycling.

The unsanitary practice of co-mingling untreated sewage from single-use diapers and solid waste is but one consequence of reliance on landfill disposal. Material waste is yet another. From the time a single-use diaper is put on a baby, it may have a useful life of a few hours. Since there is no other application of the single-use diaper,<sup>28</sup> use of this product in the U.S. alone uses nearly 100,000<sup>29</sup> tons of plastic and 800,000 tons of pulp derived from trees per year<sup>30</sup>.

The following chart depicts the estimated 4.123 million tons of all single-use diaper waste that finds its way to the solid waste stream annually:

	Used Diaper	Packaging	Wipes	Manufact- ing Waste	Feces	Urine	Total
Sewage	0	0	0	0	40.2	0	40.2
Landfill	2,011.3	172.4	51.9	82.2	707.1	4,603.5	7,628.4
Inciner- ation	151.4	13	3.9	6.2	56.2	346.5	577.2
TOTAL	2,162.7	185.4	55.8	88.4	803.5	4,950.0	8,245.8

Figure 16. Waste Paths For Single-Use Diapers  
Estimate for 1988 (In millions of pounds)

Packaging waste, baby wipes, and manufacturing waste (which were not included in the materials flow analysis in section 3D), as well as urine and feces, are estimated by the author. 73% of the used diaper and packaging waste materials are considered compostable and will degrade. Ultimately, the plastic fraction will also degrade, although this may take hundreds of years. It is notable that most of the diaper weight that ends up in landfills is urine, which accounts for an estimated 60% of the total estimated weight (with evaporation taken into account).

<sup>28</sup>-----  
<sup>28</sup> Polyethylene film used in disposable diapers (US): derived from Canadian Plastics Magazine, 5/82, with a base figure of 131 million pounds for 1983 with a 4.8% growth rate. Consumption of hot melt adhesive for diapers in 1987 was 34.4 million pounds according to Frost & Sullivan News American Market, 11/87.

<sup>29</sup> Consumption of fluff in single-use diapers (US) derived from Paper Magazine, 11/18/85, page 29, with a base figure of 667,000 metric tons used in 1982 at a 2.8% growth rate. Does not include pulp for packaging.

As disposal costs soar in most communities, the cost of collection and disposal of single-use diapers is receiving increased attention. With the average U.S. landfill tipping fee about \$25.50 per ton of material<sup>30</sup> (some landfills are over \$100 per ton), and the average transportation cost to landfills about \$48 per ton<sup>31</sup>, we pay an average of nearly \$75 per ton or \$273 million annually in the U.S. to get rid of single-use diapers in landfills! When combined with diapers going to resource recovery facilities at an average rate of \$37 per ton, the total annual disposal cost for single-use diapers is \$298 million. For every consumer dollar spent on so-called disposable diapers, an additional hidden cost of over \$0.08 on average is paid by consumers for disposal (not including packaging wastes).

Sending single-use diapers to landfills to be buried is the least desirable processing mode and should be eliminated. It is costly, maximizes waste, and presents a potential health hazard to workers and society. Since the percentage of single-use diapers in the waste stream has been increasing and will continue to do so, a critical public policy and health review of this practice is long overdue.

### B. Incineration

Although most municipal solid waste is landfilled, a growing trend in the waste management industry is the construction of waste-to-energy plants, commonly referred to as "resource recovery". Unlike conventional incinerators, waste-to-energy plants produce steam and electricity and are outfitted with pollution control equipment. Their primary function, however, is the incineration of trash. At least 75 plants currently handle about 8% of total U.S. solid waste after materials recovery has taken place.<sup>32</sup> In 1987, EPA identified 61 plants as being under construction, and at least that many are in various stages of the permitting process. Industry analysts predict that this will grow to 40% of our total solid waste after material recovery has been taken out by the end of the century<sup>33</sup>, although Franklin Associates projects a 19% market share by 2000, which is considered more realistic by the author.

From the perspective of disposal, incinerating single-use diapers is a superior method over landfilling. As a volume-reduction technique, incineration reduces diaper weight, with about 6% of the original diaper weight becoming ash.<sup>34</sup> As a method of eliminating the potential spread of disease, incineration's high temperatures, which can reach over 1800° F., destroy dangerous viruses and bacteria. For example, a clear majority of states name incineration as a recommended treatment for infectious

<sup>30</sup>-----  
<sup>30</sup> Derived from Waste Age Magazine "The 1987 Tip Fee Survey",  
<sup>31</sup> L. Pettit, March 1988.

<sup>31</sup> Estimate of consultant to the author, David Hansen, Vice President, Smith & Mahoney Engineers, Albany, New York. This is based upon analysis of the collection and transportation costs undertaken for several clients.

<sup>32</sup> EPA, Municipal Waste Combustion Study: Report to Congress,  
Washington, 1987

<sup>33</sup> Bucholz, John D., "Waste To-Energy": Analyzing The Market",  
World Waste Magazine, June 1986.

<sup>34</sup> Mr. David Hansen, Vice President, Smith & Mahoney Engineers,  
Albany, New York. Also, Air Pollution Potentials on The  
Incineration Products of Disposable Diapers, J. Thomas Schrodtt,  
University of Kentucky, July 1973.

wastes. An additional benefit of incinerating single-use diapers in waste-to-energy plants is converting waste materials to energy.

Although resource recovery has many benefits, it also presents problems. Two environmental concerns are the potential for air pollution and the hazardous characteristics of incinerator ash. Recent studies suggest that a resource recovery facility outfitted with state-of-the-art air pollution control equipment does not pose a significant risk to the public. Once such study by David H. Minott concluded that, "Comprehensive risk assessments for numerous planned energy recovery facilities consistently indicate the expected risk level to be within the acceptable risk range of 1 to 10 (cancers) per million (people). Air pollutant emissions from planned energy recovery facilities are deemed not to pose a significant health threat."<sup>35</sup> Although some thermal and air pollution will result, these are considered by the author to be relatively low when compared with other sources of industrial pollution (a steel mill or a coal-fired power plant, for example). To achieve a completely acceptable situation, many state regulators are requiring resource recovery plants not outfitted with state-of-the-art air pollution control equipment to add this equipment.

The issue of whether to classify incinerator ash as a hazardous waste is one of the most hotly contested environmental issues of the decade. Actually, there are two ash streams from a resource recovery facility: the fly or top ash, where the highest concentrations of heavy metals and pollutants are trapped, and the boiler or bottom ash, where the heavier materials fall to the bottom of the boiler. Both EPA and Congress are considering regulations regarding the disposal of incinerator residue. The issue is expected to be resolved in 1989 by classifying ash as a "special waste", that may be landfilled at sites only with state-of-the-art landfill liners and leachate control systems.

In the case of both air pollution and ash from waste-to-energy plants, the technology exists to ensure a relative degree of safety to humans and the environment. However, waste-to-energy plants will expell carbon dioxide, create some air and thermal pollution, and disposal of ash in unlined landfills poses a potential for groundwater pollution.

Adding air pollution controls and building adequate landfills to achieve this relative degree of safety will increase the cost of resource recovery as a solid waste disposal option. This means that the price of resource recovery will probably rise at a higher rate than the 10.6% per year seen from 1986-1987. In 1988, the average price of landfill disposal (exclusive of transportation) is projected at \$25.45 while the average price of resource recovery is \$37.21.<sup>36</sup> Thus, even if a greater percentage of single-use diapers are incinerated rather than landfilled, the disposal costs will be high.

In addition to the concerns over escalating costs, resource recovery does little to protect waste collection workers from exposure to single-use diaper wastes, or to eliminate the sheer volume of this product that must be transported to a resource recovery facility.

<sup>35</sup>-----  
*"Comparative Health Risk Assessment of Energy-Recovery and Landfill Facilities", Minott, David H., Concord, MA, presented at New York City Conference on Solid Waste Management, 1/27/88.*

<sup>36</sup>*Numbers extrapolated from "The 1987 Tip Fee Survey", C. L. Pettit, Waste Age Magazine, March 1988.*

The most positive aspect of resource recovery is that it significantly reduces the volume of single-use diaper waste, while ensuring that potentially dangerous viruses are destroyed. These facts alone prove resource recovery superior to landfilling for disposal of single-use diapers, assuming that the water pollution problems associated with landfill disposal are not transferred to potential air pollution problems inherent in any incineration system.

### C: Recycling and Composting

Recycling, material recovery and composting are growing trends in solid waste management. It is estimated that we currently recycle or reclaim about 10% of the total municipal solid waste discarded. Most of this is yard waste, paper, glass and metals.

Recycling is becoming a preferred waste management option over landfilling and resource recovery in many communities. Some advocates of recycling have proposed that recycling with composting be used as the primary method of handling the entire municipal waste stream. Although this is a possible goal, it is not realistic in light of the present direction and capital investment structure of the waste management industry and current public policy governing waste management.

Some states, including New York, Massachusetts, and Connecticut have established recycling goals of 25% or more of the municipal waste stream. Recycling proposals in these states emphasize consumer source-separation of recyclables, including newspaper, beverage and food containers (metal, glass and plastic). Once collected, these materials are transported to facilities where they are processed into usable commodities.

The effect of increasing recycling on the percentage of used single-use diapers going to landfills and resource recovery facilities is noteworthy. Even if the amount of single-use diapers being thrown away remains steady, their composition in the household and municipal waste streams will grow because of the removal of post-consumer recyclables such as newspaper, glass and metals. By 1995, this could increase the total percentage of diapers in the msw stream by 10 to 15%, and increase the total percentage of diapers in the household waste stream by 15% to 25%. The effect on any individual municipal waste stream could be significantly higher, since individual communities are more likely to achieve higher recycling rates.

Strictly speaking, there are no practical ways to recycle single-use diapers. Although the plastic has a market value (in addition to a heating value if incinerated), it is practically impossible to separate it from the rest of the diaper.

Single-use diapers may be composted, however. Composting is the decomposition of organic materials by microorganisms in the presence of oxygen. The end result of composting is a rich, soil-like material called humus or compost. This may be sold and used for top soil or a soil enhancement if the quality of the compost is good.

One of the benefits of composting municipal solid waste is the desirability of adding sewage sludge. Solid waste and sewage sludge are compatible materials to be economically composted together, since the sludge contains quantities of nitrogen and nutrients needed by bacteria to decompose the solid waste. The process of composting solid waste and sewage sludge together is called co-composting. Co-composting is not widely practiced in the U.S. even though it has gained acceptance through-out Europe and many other countries.

Composting has several other benefits, including:

- o Finished compost contains valuable organic nutrients that can help to replace top soil now being depleted by current agricultural practices;
- o Composting municipal solid waste eliminates ground-water pollution and air pollution impacts compared with other processing options (although some composting facilities have had odor problems when improperly operated);
- o A composting facility is significantly less capital-intensive and the solid waste processing cost can be lower on a per ton basis than waste-to-energy;
- o Weight reduction is typically 50% and volume reduction is typically 70%<sup>37</sup> in composting. Rejects to a landfill after composting could amount to 7% of the original tonnage;
- o The composting process kills all pathogens and viruses;.

Single-use diapers are an optimum material for composting with msw and sewage sludge. When composted, the pulp, paper and human feces biodegrade into compost, while most of the plastic may be screened out of the finish material. This plastic may then either be landfilled or used as a fuel for burning in a waste-to-energy plant. Co-composting of single-use diapers would be enhanced greatly by using biodegradable plastics.

This is not to say that composting doesn't have its negative impacts. Sewage sludge and solid waste from the municipal waste streams both contain hazardous materials and these will end up in the compost. Heavy metal concentrations in compost may render it unusable in agriculture and may eliminate its ability to be diverted from the landfill (although the lowest market value of compost would be daily landfill cover, which has an economic value, instead of a disposal cost).

And, as is the case with both landfilling and resource recovery, co-composting has high transportation costs associated with collection. The cost of transporting solid waste exceeds the processing cost on average with landfilling, resource recovery or co-composting.

<sup>37</sup>-----  
*Dano Resource Recovery, Inc., The Dano Process: Washington D.C. Proposal, Alexandria, Virginia, page 11.*



These concerns notwithstanding, composting single-use diapers is an optimum processing technology because it reuses most of the materials and destroys potentially dangerous pathogens. Unfortunately, co-composting of sewage and municipal solid waste is only now gaining acceptance in the U.S., and only a handful of plants are in operation. Based on the dramatic growth in the number of companies marketing composting and co-composting equipment and providing engineering and technical services, and the number of municipalities who are seriously investigating composting alternatives, it is expected to become an increasingly popular waste disposal technique. Its prospects in the long run look much brighter, since it is a less capital-intensive and a simpler approach to solid waste processing than waste-to-energy.

However, unless or until there is a drastic change in public policy or the direction of waste management technology, most single-use diapers will continue to be landfilled or burned in the near future.

#### D. Waste Reduction and Reuse

Approximately 18% of all diapers changed are reusable cotton diapers. They nearly eliminate any contribution to the solid waste stream, since by washing them, their discarded contents are flushed down a toilet or are expelled from a washing machine. This is an advantage over single-use diapers because it channels the diaper excrement into the primary sewage waste system where it can be concentrated and processed. After disposal, the sewage is treated at a sewage treatment plant, where the solids are concentrated into a sludge.

Feces make up a relatively small percentage by weight of average discarded diapers, whether cotton or single-use. If sewage sludge is landfilled, one could theorize that the cost of landfilling the feces portion of cotton diapers is the same as landfilling that same component in single-use diapers -- however, this represents less than 9% of the average diaper weight.

Also, a growing percentage of treated sewage sludge is being used in agriculture as a soil conditioner and fertilizer. It is estimated that between 24% to 31%<sup>38</sup> of sewage sludge and septage is used in agriculture or land applications<sup>39</sup>, and that its probability<sup>39</sup> of increased usage exceeds that of all other organic wastes in the U.S.

Cotton diapers do have other costs associated with them. These include water, use of detergent, and use of energy for washing and drying. The life-cycle costs of cotton diapers are significantly different than single-use diapers. The estimated 120 million cotton diapers purchased in 1988 will yield an estimated 11.52 billion diaper changes over many years, consuming 28.59 billion gallons of water, 33,435 tons of detergent and 82.9 million kwh of energy over their entire life cycle.

<sup>38</sup>-----  
Solid Waste Disposal And Reuse In The United States, Volume  
II, Murarka, Ishwar P., CRC  
<sup>39</sup>Organic Farming Study, U.S. Department of Agriculture, May  
1980.

Figure 17 traces the activity and resources associated with laundering 1988's estimated production of cotton diapers. The total production estimate of 120 million diapers is converted into washloads by allocating 90% of cotton diaper laundering to the home, and the other 10% to diaper services. A typical home washload is assumed to contain 25 diapers, while an industrial laundering averages about 588 diapers per washload. A somewhat higher reuse factor of 150 is assumed for diaper services, compared with 90 washings of a cotton diaper in home laundering. As a conservative assumption, all-electric laundering is assumed with a domestic per cycle requirement of 3.5 kilowatt hours (kwh).

Totals for detergent, water and energy use are on a life-cycle basis for the the anticipated life of the diapers.

	Fraction Washed at At Site	Detergent (Thousand Tons)	Water (Million Gallons)	Energy (Thousand KWH)
Home Wash	90%	30,375	27,216	81,648
Diaper Service	10%	3,060	1,377	1,285
Total	100%	33,435	28,593	82,933

Figure 17. Waste From Cotton Diapers  
Life Cycle Analysis of 120 Millions Cotton Diapers Sold in 1988

Although water is considered a renewable resource, the true environmental impact of the process of diaper laundering is dependent upon the nature and quality of the waste water management approach.

Reliance on the sewage waste stream for diaper waste disposal has inherent advantages over reliance on the solid waste stream. Firstly, it encourages reuse of diaper materials themselves, such as cotton diapers and reusable diaper covers. Secondly it channels the feces into the primary sewage treatment system. Transporting these wastes in this efficient and economical manner does not expose workers or vehicles to potentially infectious diaper wastes. With the growth in land applications for sewage sludge, the opportunities to reuse the resulting sludge is greatly enhanced. Although large amounts of water are used, this is a renewable resource that is processed at a waste water treatment plant and reused again by both humans and nature.

Increased use of cotton diapers represents the clear and obvious waste reduction approach to minimize solid waste created by single-use diapers. It offers economic savings to consumers and eliminates the public cost of disposal associated with single-use diapers. Its reliance on reusable fabric and disposal of feces to the sewage waste stream make this diapering mode superior in almost every respect over current disposal modes for single-use diapers.

It should be noted that the use of super-absorbent materials in single-use diapaers produce a thinner diaper, which has resulted in a reduction in waste volume and a need for less packaging. This may prove to significantly reduce the volume of diaper waste entering the solid waste stream. However, even if all single-use diapers were to be reduced in size by 50%, overall this will reduce diaper waste by an estimated 10-15% by weight. Although use of super-absorbent materials in diapers do represent an example of source reduction by diaper manufacturers, this disposal approach needs to be seen in the context of a +95% solid waste reduction achieved by using cotton diapers.

#### E. Prospects for A Flushable Single-Use Diaper

A potential alternative diapering approach that makes use of the sewage waste stream is a flushable diaper product. Originally, many single-use diapers such as Baby-Scott brand (by Scott Paper), Chux brand (by Chicopee Mills), and White Lamb brand (by Borden) were designed to have the inner liner be separated from the diaper and flushed down the toilet with contents intact. The plastic liner was then to be disposed in the trash can. Problems with plugged sewer lines and the difficulty in convincing parents to rinse the diaper forced diaper manufacturers to take the road of least resistance and to design a diaper made for tossing rather than flushing. This approach also allowed additional materials to be added to the diaper to increase absorbtivity.

Since the last commercial flushable diaper disappeared, a series of super-absorbing materials called "super-slurpers" have been discovered. Super-absorbers are now embedded in the diaper cellulose to increase the absorbency of single-use diapers. The original cotton starch super-absorber discovered by U.S. Department of Agriculture scientists can absorb up to sixty times its weight in urine, while the poly-acrylic absorbers used in most single-use diapers absorb up to eighty times their weight in fluid.

The advent of super-absorbers has resulted in the potential to reduce the amount of cellulose used by single-use diapers, as evidenced by Pampers "Ultra-Thin" line of diapers, manufactured by The Procter & Gamble Company. Other manufacturers quickly followed suit, and now have products with less materials than single-use diapers without these super-slurpers.

This technological development in diapers is theoretically transferable to a new, flushable single-use diaper product anticipated by the author as an eventual alternative to today's throwaway diapers. Such a product would return to a two-piece diaper system, consisting of a reusable diaper cover and single-use flushable inner pad. The flushable pad could be made out of a combination of tissue paper-like material and super-absorbing materials.

Original super-absorbing materials, such as starch-y-polyacrylonitrile (HSPAN) copolymer, is made from cornstarch, an organic product proven to be environmentally safe. This super absorbent material swells up to thirty times its original volume and absorbs up to sixty times it weight of urine. Use of such a highly absorbing material could dramatically reduce the materials needed for a flushable diaper inner pad.

Once in the toilet bowl and if released from its paper lining, the HSPAN co-polymer forms a viscous dispersion, which is easily flushed and should not clog drain lines. After being processed at a sewage treatment plant, the biodegraded organic polymers would serve as a nutrient if applied to land along with the sewage sludge. This would provide food for microorganisms in the soil. Currently, the HSPAN co-polymer is being used in commercial agricultural applications, including a soil ammendment to increase water absorption and retention.

The potential of such a product would have many benefits over the current line of single-use diapers, including:

- o reduction in the amount of solid waste going to landfills;
- o potential reduction in per-unit diaper costs, since less material would be used;
- o dramatic reduction in waste processing and transportation costs.

The flushable diaper could also offer potential benefits over cotton diapers, including:

- o minimize the detergent required for washing (some washing would be required for diaper covers);
- o minimize the total energy expended for washing and drying cotton diapers;
- o eliminate the labor for washing diapers.

However, the problems associated with a flushable diaper include:

- o increased consumption of water;
- o the requirement for developing new materials and a materials configuration that does not clog the sewage system;
- o the difficulty of convincing consumers to flush rather than discard diapers in the trash.

A flushable diaper pad would rely on the sewage waste stream, which as noted above would consume increased quantities of water. However, these increases would be only marginal. The following chart estimates the consumption of water by cotton diapers and a flushable diaper product. Water costs for washing diaper covers are not included.

	Water Used gals/diaper use	Cost (\$)/diaper use
Cotton Diaper Washed at Home	2.8	.004
Cotton Diaper Diaper Service	0.77	.001
Flushable Diaper	4.5	.006

Figure 18. Water Usage for Cotton and Theoretical Flushable Diaper

The U. S. Geological Survey "Estimated Use Of Water In The U.S." in 1980 indicated each person in the U.S. uses 183 gallons per day, or 200,385 gallons per 3-person household per year. Assuming 40 flushable diapers per week with 4.5 gallons of water used per diaper, 9000 gallons of water would be used by a single baby using diapers. This equals approximately 4% of the 3-member family's yearly water usage.

Compared to average landfill disposal cost for a single-use diaper of \$0.0167 each, a flushable diaper would cost approximately \$0.006 for water and waste water treatment. Cotton diapers would cost significantly less than this, although have the additional costs of laundering.

The prospects of developing a flushable alternative to the present line of single-use diapers appears technically feasible and desirable. However, in addition to requiring research, product development and testing, a flushable single-use diaper may require a shift in the manner in which manufacturers produce their products.

Given the status of modern technology, manufacturing capabilities, and the diaper market itself, a change in diaper modes in a relatively short period of time is possible. As an example, the market share of single-use diapers as a percentage of total diapers purchased went from 10% in 1970, to 54% by 1980, to 85% in 1988<sup>40</sup>.

<sup>40</sup>-----  
Research Brief, "Kimberly-Clark Corporation", April 17, 1986, Goldman Sachs Research. Table 5, "Disposable Diaper Market Statistics".

## Section 5. PUBLIC POLICY ISSUES

### A. Diapers as a Public Policy Issue

Diapers become a public policy issue as they interface with the areas of waste management and public health. Increased environmental awareness, rapidly escalating disposal costs, and diminishing landfill capacity are already resulting in increased interest and public policy review of the diaper issue. The methods employed to process single-use diapers and their resulting environmental impacts are dependent upon: 1) the diaper material configuration; and, 2) the available waste processing alternatives. Therefore, efforts to review, change or regulate public policy will focus on these two areas of product alternatives and waste disposal techniques.

Increasingly, public policy in the solid waste management field emphasizes reducing waste and eliminating hazardous and harmful products and materials from the waste stream. Waste reduction initiatives are increasingly taking the form of state proposals to ban or minimize packaging waste. Twenty-one states and many European countries have already introduced legislation to limit or ban plastic packaging waste. Of these, only Oregon and Washington have introduced proposals that would specifically and directly affect single-use diapers.

In 1988 in the State of Washington, House Bill #1684 was introduced ("An Act Relating To Solid Waste Management") that would require a comprehensive state-wide waste stream analysis, giving priority to categories of solid waste that "present a high potential of harm to human health", including disposable diapers. Previous bills introduced in the State of Washington sought to make it "unlawful to sell, offer, or display for sale at retail any diapers designed for single use without the warning: Soiled disposable diapers contain viruses and microbes which may transmit diseases to the general population when disposed of improperly. Fibrous material must not be disposed with garbage or trash"<sup>41</sup>. This proposal did not become law.

In 1987, Oregon House Bill #3315 ("Relating To Solid Waste Disposal") sought to prohibit for sale any non-biodegradable disposable diaper. A bill in 1979 proposed an outright ban on the sale of disposable diapers; those used in the state would have require disposal so as "to prevent the disposal of untreated sewage in an environmentally hazardous manner"<sup>42</sup>. Neither of these two proposals has become law.

Since so many states are now proposing to ban certain types of packaging as the basis for waste reduction programs, an outright limitation on single-use diapers is not out of the question as a means to minimize waste. As highlighted in a recent solid waste survey of New Hampshire municipal officials, 68% of respondents indicated they would favor legislative limits or bans on some plastic products (diapers were not mentioned specifically)<sup>43</sup>.

<sup>41</sup>-----  
<sup>41</sup> House Bill #645, State of Washington, 45th Legislature, 2/7/77, An Act Relating to public health.

<sup>42</sup> Oregon House Bill #2838, Relating To Solid Waste Disposal, 1979.

<sup>43</sup> "Results of the Solid Waste Questionnaire", Committee on Environment and Agriculture, House of Representatives, State of New Hampshire, 1/7/88.

In the area of public health, those states and localities that are exclusively dependent upon landfill disposal are more likely to pursue action to eliminate single-use diapers from the solid waste stream or to mitigate their impacts. Greater scrutiny should be, and probably will be given to determining if and under what conditions single-use diapers, as a growing percentage of the waste stream, constitute an infectious waste.

Changes in public policy as they affect diapers will likely focus on:

- o providing economic incentives for the beneficial reuse of materials, including use of cotton diapers and diaper services;
- o implementing economic disincentives, such as a tax, on single-use disposable products;
- o promoting waste disposal alternatives to landfilling, including composting and resource recovery;
- o regulating the disposal of single-use diapers, from the perspective of waste minimization and/or public health;
- o promoting changes in diaper products and material configuration;
- o assessing the health impacts of current disposal techniques for single-use diapers;
- o assessing the economics of single-use compared with reusable products; and,
- o educating parents and institutional diaper users.

These changes may be implemented on a federal, state and/or local level.

The approaches and recommendations made in this report are based upon the author's own hierarchy of desirable waste management policies as they affect diapers. These are: 1. waste minimization; 2. product reuse; 3. recycling and composting; 4. waste-to-energy; and 5. Landfill disposal.

This hierarchy must be perceived within the context of an integrated waste management approach. This is to say that no single policy or approach will be used, and probably all will have to be utilized to some degree. The issue becomes one of emphasis. In the case of diapers, today's disposal emphasis is clearly on landfilling, which is the least desirable option for this throwaway and potentially harmful product. The public policy issue is whether to change this, and how.

In the final analysis, society is subsidizing the industries that manufacture products such as single-use diapers and household batteries. The cost of collection, disposal, any environmental clean-up or potential short-term and long-term medical costs accruing from exposure to these products is not borne by the producer (private sector), but by the consumer and the public sector. That is, the social and environmental "externalities" are not accounted for in the price of the product.

Single-use diapers in the solid waste stream are but one significant aspect of this greater situation facing our consumer-oriented society. As a society, we have been sold on the idea of "disposability", without a full recognition of the costs associated with convenience. While single-use diaper manufacturers promote convenience as a higher social value than reusability or recyclability, few stop to question or to draw the line between ease of disposal and the environmental impacts associated with that convenience. These limits are not fixed, but will change with the recognition of the social and environmental impacts of convenience.

## B. Single-Use Diapers As Infectious Waste

The author's study of single-use diapers as infectious waste indicates that the potential hazard of the spread of communicable disease from this product merits consideration. More needs to be known about the risks of single-use diapers as potential reservoirs for infectious diseases. Single-use diapers frequently contain feces upon disposal, perhaps as much as 30% of the total number of diapers disposed, and nearly always contain urine. Fecal material and urine may occasionally contain infectious organisms<sup>44</sup>.

Viruses are a particular source of concern, since babies are the most effective carriers of enteroviruses and have generally been immunized with live poliovirus vaccine. In a study where single-use diapers were studied as a potential source of viruses, over 10% of diapers analyzed contained viruses. The author of this study, Dr. Mizdra Peterson, concluded that "Until such diapers are excluded from solid waste or until an effective method can be developed to disinfect such diapers before they are mixed with solid waste, these virus-laden materials will continue to present a potential threat to the health of those who handle the solid waste during collection and constitute a feed ground for disease vectors and a source of contamination of groundwater when the waste is disposed in improperly constructed landfills"<sup>45</sup>.

Many hospitals treat as infectious waste those wastes (including single-use diapers) that have come into contact with newborns<sup>46</sup>. Ninety-five percent of the hospitals in the U.S. rely on single-use diapers for infant care. However, there is no regulation or code in place that requires single-use diapers be separated out from the regular trash except when the patient has an infectious disease, although some hospitals do so routinely.

The preceding considerations present the case for classifying the wastes of single-use diapers as infectious waste. The potentially most significant hazard single-use diapers pose is along transmission routes. The first transmission route, contact transmission, involves the physical transfer of an infectious agent between a susceptible host and an infected person or contaminated object (e.g. a single-use diaper). Among the pathogens this transfer may include are: poliovirus 3, echovirus 3, coxsackievirus B3, and hepatitis A. Improper storage of single-use diapers in refuse cans or dumpsters, transfer of the contents of such

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<sup>44</sup> Lynch, Patricia and Jackson, M.M. "Isolation Practices: How Much Is Too Much or Not Enough?" *ASEPSIS The Infectious Control Forum*, vol 8 no. 4, pp 2-5, Fourth Quarter, 1986.

<sup>45</sup> Peterson, Mirdza L., "Soiled Disposable Diapers: A Potential Source of Viruses", *American Journal of Public Health*, September, 1974, vol 64 no. 2, pg. 913.

<sup>46</sup> Turnberg, Wayne L. "An Examination and Risk Evaluation of Infectious Waste In King County, Washington", *Seattle-King County Department of Public Health*, March 18, 1988. See page 17.



containers into trucks, and transport of the refuse to waste-management facilities or landfills all provide opportunities for waste-management personnel and the public at large to become exposed.

Vehicle transmission (disease transmission through food, water, or blood) could occur from littered single-use diapers near streams or stationary water supplies. Finally, vectorborne transmissions, or transmissions by insects, rodents and birds, are possible whenever diaper waste is exposed at landfills.

Under the EPA definition, single-use diaper waste is infectious waste if it is<sup>47</sup> generated by patients with suspected or diagnosed communicable disease. Environments for generating single-use diaper waste with an "infectious" classification include neonatal, pediatric, and gastrointestinal wards of hospitals, infirmaries of nursing homes and mental health institutions, and private residences (in the case that a diaper-wearing occupant has a communicable disease but is not hospitalized).

Solid waste management practices at hospitals and other institutions that are regulated by public agencies are likely to control the disposal of infectious single-use diaper waste or, at least, are accessible for governmental inspection and intervention to assure such control. Private residences generating infectious waste, as defined above, or disposing of single-use diapers present a different public health issue. The dangers posed to waste-management personnel and the general public from exposure to viral and bacteriological infection from single-use diapers are probably underestimated. Efforts should be made on national, state and local levels to understand the health and environmental impacts of single-use diapers in the solid waste stream, and to determine if solid waste and local health codes should be amended to ensure safe and proper disposal of these wastes.

In considering this subject, it should not be assumed that home washing of cotton diapers is without potential health problems. Handling of soiled diapers, washing diaper covers in the sink, and failure to achieve hot enough washing conditions all contribute to an environment in which infections may spread.

<sup>47</sup>-----  
from: 40 Code of Federal Regulations, Chapter I, Section 240.101 (p). 7-1-87 Edition.

### C. National Approaches and Recommendations

#### Federal Reuse Policy: Reducing Single-Use Diaper Waste

In the immediate and near-term future, regulating or managing the solid waste impact of single-use diapers involves encouraging the use of cotton diapers and/or diaper services rather than single-use diapers.

Federally-funded institutions can act by undertaking or requiring an economic evaluation of switching from disposable products to reusable products, including diapers and linens. As an example, a recent study revealed that by switching to a diaper service, New Jersey institutions could save 60% over the cost of purchasing single-use diapers<sup>48</sup>.

Direct support for federal hospitals, institutions, military personnel, and lower-income families to use diaper services would promote reusable cotton diapers rather than single-use diapers. Congress could also promote materials reuse and discourage waste by creating a special deduction for the cost of using diaper services from income taxes.

Additional tax benefits could be extended to diaper services themselves. In addition to promoting reuse and waste minimization, this would assist this industry to grow rapidly to meet the challenge of eliminating single-use diapers from landfills, while also creating jobs and stimulating economic development.

The Federal government could take action swiftly and thoroughly by authorizing that all federally funded or operated institutions, reserves, and compounds use or dispense cotton diapers. This requirement could extend to Veterans Administration and military hospitals, government-operated stores on Native American reservations and military bases, and other institutions receiving federal funds.

One institutional disincentive to using cotton diapers is the potential effect of recent trade sanctions against imported cotton. Import quotas imposed by the Federal government in 1988 threaten to increase the cost of cotton diapers to diaper services by as much as 25%. Federal officials must analyze the effects of this trade protection policy on consumer use of cotton diapers, and recognize that the effect on consumers is to reduce the positive economic margin of reusable over single-use diapers.

Through its wide-ranging channels for public communication, the Federal government could either promote or sponsor educational campaigns on the environmental impacts of various diapering products. The Department of Health and the EPA could both participate in such an effort, targeting different audiences. Also, Federal funding could assist state government, local government and private (not-for-profit) public information efforts.

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<sup>48</sup> "Institutional Recycling and Solid Waste Management Program Development and Client Participation", Bellan, Robert, Department of Human Services, State of New Jersey, 12/88.

A tax on each single-use diaper, with the proceeds going to encouraging or developing other alternatives, would be a significant change in current public policy. Although this approach seems unrealistic on the national level, a state imposed "disposal fee" on manufacturers of disposable products could raise revenues to finance public education. However, any tax policy must be put into the larger context of an integrated solid waste plan that includes other single-use products as well as diapers.

In the medium-term future, the most effective reduction of single-use diaper waste after switching to reusable cotton diapers may occur at the point of product manufacture. If the industries that produce single-use diapers modify the product to generate less waste than the current single-use diaper, waste reduction can be achieved by eliminating diapers from the solid waste stream. The role of Federal agencies in single-use diaper product modification may include:

1. A strong public policy that encourages the manufacture of less bulky single-use diapers destined to become solid waste, accompanied by a timeline to eliminate single-use diapers from the solid waste stream;
2. Research and development at national laboratories (Departments of Agriculture, Energy and Health, as well as EPA);
3. Positive financial incentives such as grants to universities, industry and private foundations;
4. Tax incentives to industries that engage in research on waste-reducing, flushable biodegradable single-use diapers.

#### Composting

The most viable means of recycling the waste generated by single-use diapers today is composting. This can be accomplished composting leaf and yard waste, or by adding sewage sludge to msw (co-composting). The federal government could and should be encouraging the rapid commercialization of co-composting facilities. This can be done by:

- o Assuring that Federal purchasing programs encourage the marketing of by-products from commercial composting facilities;
- o Helping to eliminate the disposal of hazardous waste in the sewage and solid waste stream, which among other things is likely to contaminate compost and minimize its marketability;
- o Sponsoring research to develop fully biodegradable products, efficient composting techniques for the current single-use diaper, and co-composting techniques.

As noted in section 4C, unless or until there is a drastic change in public policy or the direction of waste management technology, most single-use diapers will be landfilled or burned in the near future.

## Incineration

Incineration is preferable to direct landfilling because of its ability to reduce the overall volume and weight of waste, destroy harmful pathogens, and generate useful energy. This disposal process retains undesirable characteristics, including the failure to eliminate potential health problems for sanitation workers prior to incineration, air pollutants and the disposal of hazardous ash residues. In regard to incineration, the Federal government can:

- o Set standards for emissions that protect the public health;
- o Encourage the beneficial reuse of ash and other byproducts; and
- o In addition to regulations promoting the use of cotton diapers, require that where feasible, single-use diapers be incinerated rather than landfilled.

## Landfilling

The Federal government can impact the current reliance on this least desirable mode of disposing of single-use diaper waste by:

- o Undertaking or sponsoring research on the "life cycle" of single-use diapers in landfills and the effect of diaper wastes on landfill leachate;
- o Undertake a review of diaper wastes, particularly in institutional settings, as potentially being a regulated "infectious waste";
- o Conduct a thorough review of the health implications of throwing single-use diapers into landfills.

#### D. State Approaches and Recommendations

Many state initiatives will duplicate or supplement Federal-level and local actions and, hence, will receive less attention here than in the previous sections. There are, nevertheless, significant steps that rely primarily on state government development and implementation, that can play very important roles in the regulation or management of single-use diaper waste.

Obviously, the fact that each state will be confronted with a different set of solid waste conditions and priorities, argues against a uniform policy for state governments regarding single-use diapers. However, with the underestimation of the quantities and impacts of single-use diaper waste now being realized, a review of the solid waste management, public health, and policy implications is in order.

##### State Reuse Policy: Reducing Single-use Diaper Waste

State government policy for reuse should essentially mirror that of the recommended Federal policy: that is, reuse would involve promoting the use and availability of cotton diapers. State governments should first act by requiring an economic evaluation of switching to reusable diapers in all state operated and funded medical, child care, geriatric, mental health, and other related institutions.

Any existing disincentives which may exist in state government programs for the procurement of cotton diapers in deference to single-use diapers should also be eliminated. The program revisions listed in the National Approaches and Recommendations section should be implemented.

Direct economic support of low-income parents for the use of cotton diapers or diaper services should be examined. State legislatures may promote reusable cotton diapers by creating a special deduction of the cost of diaper services from income taxes. The primary rationale for this would be confronting the disposal of single-use diaper waste in landfills, although a secondary benefit would be economic savings by low-income families, due to use of a less expensive diapering method.

Another waste-reduction strategy that states could adopt for single-use diapers is a public information campaign similar to the proposed federal-level initiative. State health and environmental agencies could participate in this type of program, conducting a state-directed, statewide effort and/or funding local governments to organize and implement their own waste reduction programs.

One waste reduction technique that state governments may exercise is sales taxation of single-use disposable products. The Consumer Products Ad Hoc Committee of King County, State of Washington's County Council, has supported establishing a tax on the sale of disposable diapers to support an ongoing education program. Such a tax would serve as an "impact fee" -- a charge imposed for the privilege of using a particular product and would subsequently encourage consumers to investigate waste-reducing strategies such as cotton diapers and diaper services. Such a policy would require, however, that a percentage of funds generated be applied to:

- o Supplement low-income purchase of cotton diapers or the use of diaper services;
- o Public education about waste reduction; and/or,
- o Tax incentives to help diaper services expand and institutions to invest in equipment to convert to resusable products.

The issue of banning the sale of single-use "disposable" diapers has been raised, and was proposed by Oregon in 1979. The author believes that although this drastic policy may have merit in locales faced with solid waste crises, that a ban would potentially cause more political damage than gains. A comprehensive public policy, inclusive of all disposable products and infectious and hazardous wastes, that sought to discourage single-use diapers going to landfills within a set timeframe is a more reasonable approach. This approach would also offer a better opportunity to provide for a start-up public education program on diapering.

More important than considering a ban or a tax on just this one product, state legislatures should include single-use diapers as a component in drafting and considering waste reduction, packaging, litter control, and infectious waste legislation. Few states had done so in 1988, although over 70 specific legislative proposals to reduce packaging waste were considered around the country.<sup>49</sup>

#### Composting

After addressing the first priority of encouraging reusable cotton diapers over single-use diapers, state government may act to discourage single-use diaper waste from landfills. State government agencies should focus on co-composting of municipal wastes in order to promote the recovery of single-use diaper waste in the near future. As with Federal-level initiatives, state agencies should:

- o Provide incentives to counties and municipalities to develop municipal composting and co-composting facilities. These incentives can include technical assistance, and state financing through grants, low-interest loans or bonds;

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<sup>49</sup>-----  
*"Legislative Proposals Around The Country Concerning Packaging", Legislative Commission on Solid Waste Management, Albany, New York.*

- o Provide market assistance through state purchasing programs for developing markets for compost end-products;
- o Emphasize efforts to develop co-composting as part of state planning and development of solid waste facilities;
- o Promote research in government labs, at state colleges and universities on efficient composting techniques for disposable products, including diapers;
- o Subsidize, or make grants available for developing fully biodegrading products; and
- o Eliminate hazardous materials from entering the solid and sewage waste stream by stricter regulation and enforcement.

#### Incineration

Similar to federal initiatives on incinerating single-use diaper waste, state actions should:

- o Insure strict and safe emission standards;
- o Develop a policy of beneficial reuse of incinerator by-products where possible;
- o Consider requiring incineration, where available, of all single-use diapers as an alternative to landfilling.

State regulation of single-use diaper incineration could feasibly extend to requiring that all large generators of single-use diaper waste enclose the waste in separate, demarcated containers so that incineration would absolutely take place. Such generators would include hospitals, nursing homes, and larger child-care facilities.

#### Landfilling

State governments have a significant influence on the regulation and management of landfill disposal of single-use diapers. As discussed above, this could and should include discouraging the disposal of single-use diaper waste from entering landfills that do not meet environmental standards or are running out of precious landfill space. Such a step cannot take place in a policy vacuum, however, and should be considered along with other hazardous, infectious and disposable items.

To this end, State government can offer assistance to communities to:

- o Ensure that inoperative municipal landfills are properly closed so as not to cause environmental damage to groundwater;
- o Ensure operating landfills meet basic environmental requirements;
- o Investigate the health impacts of diaper waste in landfills.

## E. Local Approaches and Recommendations

### Reuse and Waste Minimization

Since the fiscal resources and revenue-producing means of most localities are limited, counties and municipalities should concentrate on waste reduction and minimization strategies, including promoting the use of cotton diapers. City and county governments can assist institutions to perform economic evaluations of switching to reusable diapers and other products in city-funded and -operated facilities. Also, a review of solid waste handling practices from the perspective of waste reduction as well as public health concerns can be undertaken and should include an analysis of the impacts of diaper waste on residential and institutional waste collection.

### Composting

Resource conservation, waste reduction and product reuse should be promoted on the local level as viable waste management strategies. This includes developing leaf and yard-waste composting and municipal co-composting programs for both sewage and solid waste. When new local or regional waste management facilities are proposed, these options should receive equal attention with new landfills or resource recovery options.

### Incineration

Local regulation of single-use diaper incineration could feasibly extend to requiring that all large generators of single-use diaper waste enclose the waste in separate, demarcated containers so that incineration would absolutely take place. Such generators would include hospitals, nursing homes, and larger child-care facilities.

### Landfilling

The public health impacts of disposing of single-use diaper waste in landfills should be evaluated. Within the context of any given localities landfill capacity conditions, discouraging single-use diaper waste going to landfills should be considered upon development and implementation of necessary alternatives and technological and policy preconditions.



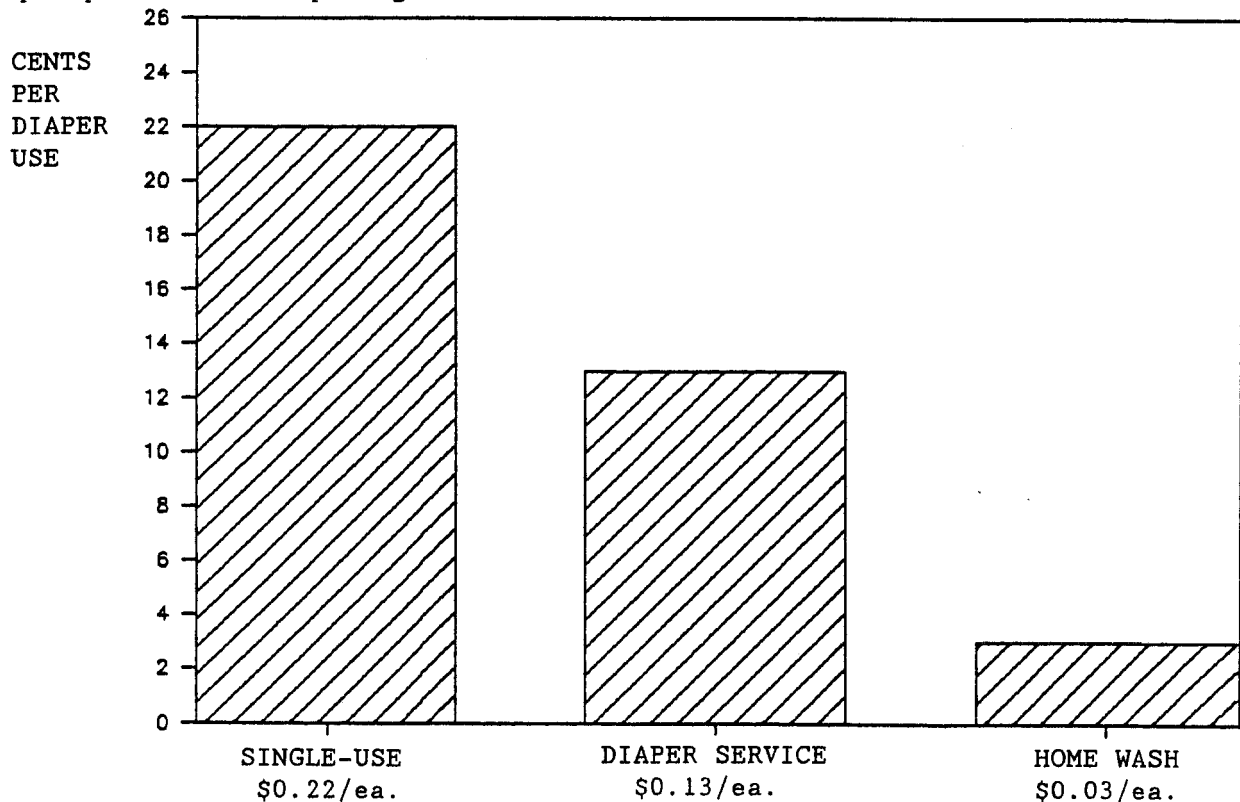
## Section 6. DIAPER ECONOMICS

This analysis concentrates on the direct and out-of-pocket expenses of diaper products over their life cycle of use. The primary calculation is presented in figure 21 - "Life Cycle Diaper Costs". There, single-use diapers, cotton diapers washed at home, cotton diapers washed by a diaper service, and a prospective new flushable product not now available are compared with respect to out-of-pocket expenses to consumers and imputed costs for home labor, air pollution control and water resulting from disposal. In early 1988 prices, per-unit diaper costs were as follows:

single-use diapers:	\$0.22/use
cotton diapers washed at home (with home labor imputed)	\$0.15/use
cotton diapers washed by diaper service:	\$0.13/use
theoretical flushable diaper:	\$0.16/use

These costs are illustrated in figures 19 and 20, which present bar charts showing per-unit diaper costs for single-use and cotton diapers.

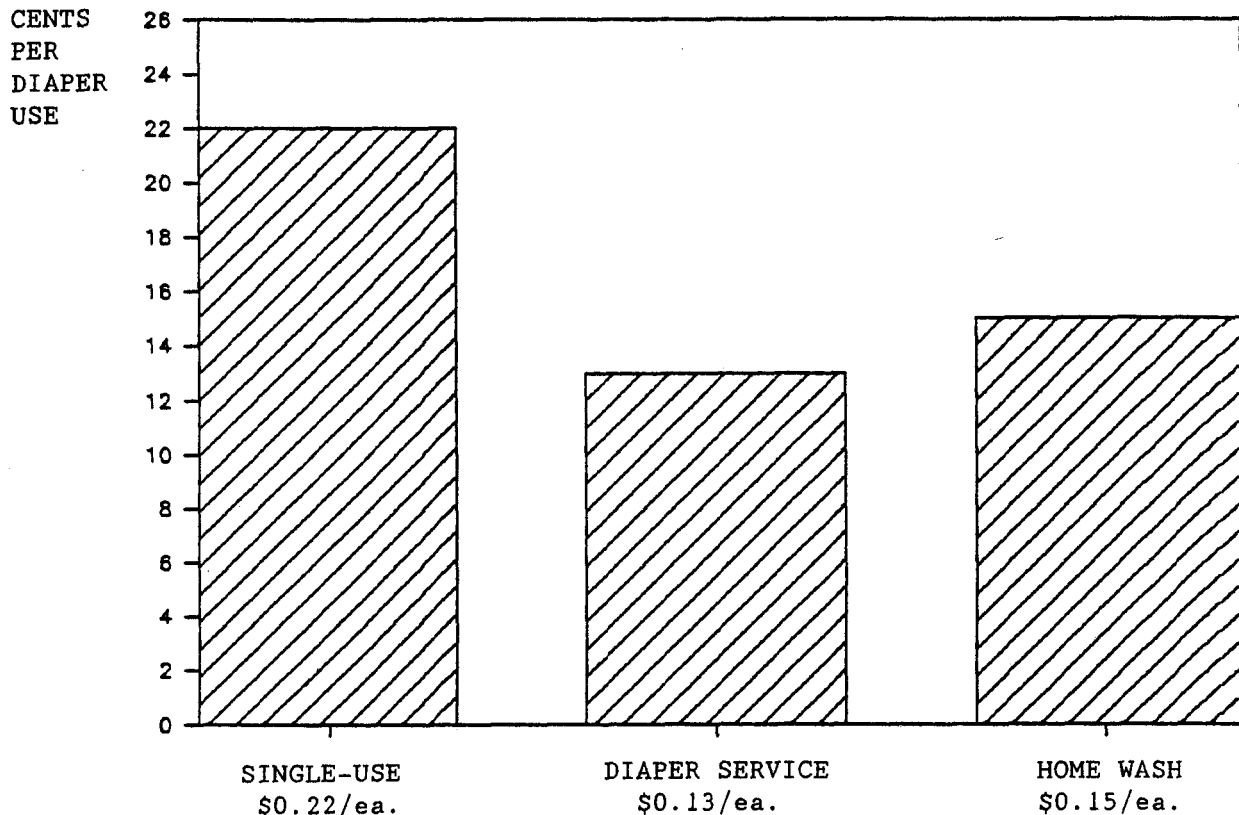
Interestingly, economics do not appear to play a determining role in the type of diaper parents will select. Even though single-use diapers are clearly more expensive than both home-washed and diaper service cotton diapers, they dominate the market. The following chart gives a relative perspective of diapering economics.



Units expressed in cents per diaper use

Figure 19. Diaper Economics (without domestic labor input)

The major economic factors computed in the home washing of diapers are the cost of energy, water and detergent. Not included in the home-washed computation is the cost of labor, which is considerable. As indicated by the following analysis, home labor computed at the rate of \$6.00 per hour makes home washing more expensive than a diaper service, although still less expensive than single-use diapers. This clearly detracts from the practical and economic appeal of home-washed diapers, and partially explains the success of single-use diapers over cotton diapers.



Units expressed in cents per diaper use

Figure 20. Diaper Economics (with domestic labor input)

Inclusive in the life-cycle costs of single-use diapers are the production costs plus the additional expense to consumers for solid waste disposal. In addition, social costs for air pollution control, as well as social benefits from recovery of electricity generated from resource recovery facilities are included<sup>50</sup>.

<sup>50</sup>-----  
The monetization of nonmarket elements, such as air and water pollution, was carried out on an extraction, rather than a willingness to pay basis. Air pollution produced in waste-to-energy plants, for example, is assigned a value equal to its costs of extraction with dry scrubbers. This underestimates long term costs associated with landfills, as well as other environmental and resource impacts.

The life-cycle costs for one year's production of cotton diapers vary slightly depending on whether diapers are washed at home or washed by a diaper service. Calculations for cotton diapers reuse are estimated to be 90 times for home washing and 150 times for diaper services. Calculation of home operating and capital costs are based on an analysis of typical laundering and drying appliances, and include an imputed cost for domestic labor or the parent's time of \$6.00 per hour. Without the imput of domestic labor, the life-cycle unit cost for home-washed diapers is \$0.03 per diaper.

Calculation of total costs for cotton diapers handled by a diaper service are based on market costs -- approximately \$10 per 80 diapers, or \$0.125 per soiled diaper. No other costs are included, since it is assumed that all other costs (e.g., water, waste water processing, detergent, electricity, labor and profit) are included in the cost of the diaper service.

Double-diapering is common with home-washed cotton diapers. This may indicate that the per unit life-cycle cost for cotton home-washed diapers is somewhat higher than shown. Since cotton diapers used by a diaper service are generally thicker than store purchased diapers, this may not hold true for cotton diapers washed by diaper services.

Diaper covers are an additional economic input to using cotton diapers that may cost between several ten's to several hundred dollars during the time an infant needs diapers. This could add between \$0.005 to \$ 0.04 per diaper use on top of home washing or a diaper service.

The projected new flushable product envisioned by the author is a biodegradable single-use diaper. It is anticipated that the single-use pad, which will be purchased in the store, will be wrapped in a reusable diaper cover, similar to plastic, wool and cotton products presently on the market for use with cotton diapers. A lower per unit cost is projected over conventional single-use diapers because less materials will be required. The absorbent padding is assumed to be about 35% of the current dry weight of a single-use diaper. Given average national water costs, the subtotal of out-of-pocket expenses to the consumer and general costs to society are substantially lower for this theoretical product than for conventional single-use diapers.

Three cost catagories are relevant to the economic analysis of diapering modes demonstrated in figure 21. First, there is the prime cost of the diapers themselves -- the price paid at the store. Secondly, there are other out-of-pocket expenses associated with the use and possible reuse of diaper products. The cost of laundry detergent for home washing cotton diapers is an example. Less obvious, perhaps, are solid waste disposal costs borne by households relying on single-use diapers.

	Single-use (Disposable) Diapers	Cotton Diapers (Home Washed)	Cotton Diapers (Diaper Service)	Theoretical Flushable Diaper <sup>a</sup>
Diaper Cost/use	\$0.22	\$0.15	\$ 0.13	\$0.16
Unit Cost/diaper	\$0.20	\$0.83 <sup>b</sup>	\$18.98 <sup>c</sup>	\$0.15
(all numbers below in millions)				
Operating Costs				
Detergent		\$60.7		
Water		\$40.8		
Energy use		\$ 9.8		
Labor (imputed)		\$1,166.4		
Capital Costs				
(washing/drying)		\$77.8		
Air Pollution <sup>d</sup> Prevention	\$0.04			
Water				\$121.5
Landfill	\$339.4 <sup>e</sup>			\$2.4
Net Energy	(\$3.6)			(0.2)
Incineration Tip Fee	\$25.7			\$0.02
Subtotal	\$ 361.5	\$1,355.5		\$ 124.0
Life Cycle Costs	\$3,961.5	\$1,445.3	\$ 227.8	\$2,824.0

Figure 21. Life-Cycle Diaper Costs (1988)

<sup>a</sup>Theoretical flushable diaper product with reusable diaper cover: assumes total replacement of single-use diapers. Unit costs of this new product prorates the costs of the reusable shell to a per diapering basis.

<sup>b</sup>Unit cost of cotton diaper (home wash): assumes 90 uses in life cycle.

<sup>c</sup>Unit cost of cotton diaper (diaper service) includes all diaper service costs: assumes 150 uses in life cycle.

<sup>d</sup>Air pollution prevention: additional cost of pollution control equipment for incineration.

<sup>e</sup>Landfill costs includes disposal of all diaper wastes and not just the diaper and its contents.

The third cost category is more diffuse and difficult to value. These are effects of diaper use which are not necessarily paid by producers or users of diaper products, but which impact on general productivity and social welfare. Public health hazards of single-use diapers might be an example. If the direct consumer of the diaper transmits, but does not contract an ailment related to fecal material in diapers, productivity and general welfare can be affected in ways difficult to precisely quantify.

These are called economic externalities, and are costs which exist outside of the usual market processes, but which impact on production and consumption.

The analysis suggests the major hidden costs associated with single-use diapering are disposal costs. An interesting implication is that increased reliance on incineration of single-use diapers would be associated with higher disposal costs, due to higher average tipping fees over landfilling.

Just as cost savings can be realized in the residential sector by using cotton over single-use diapers, a recent study of five institutions in the state of New Jersey who utilize adult single-use diapers revealed that the 765,000 diapers used annually cost \$367,285 per year. The analysis concluded that by switching to reusable cloth diapers through a diaper service, a combined savings of \$234,450 per year can be realized, or over<sup>51</sup>60% of the costs for single-use diapers (includes disposal costs).

Based on the foregoing, it would be difficult to argue against the cost benefits to consumers of using reusable versus single-use diapers.

<sup>51</sup>-----  
*Institutional Recycling and Solid Waste Management Program Development and Client Participation*", Bellan, Robert J., Department of Human Services, State of New Jersey, presentation to the International Conference of Urban Waste, Philadelphia, PN, 12/6/88.

## Appendix I.

### A Word About Diaper Terminology

#### "Disposable" versus "Single-Use"

The common terminology for modern diapers is "disposable diapers," which has generally come to connote the store-bought variety that are thrown away after a single use. Throughout this report, the term "single-use" is substituted for "disposable" in referring to this type of diaper. In defining the diaper as single-use, the author seeks to avoid succumbing to imagery projected by product marketers, and instead to define the product by actual function and use patterns.

Webster's Ninth Dictionary cites several definitions of the word "disposable" that imply that the word is used correctly in referring to diapers. Specifically relevant are the "systematic destruction; esp., destruction or transformation of garbage" and "the act or process of disposing: as (a): orderly placement or distribution".

Unfortunately, the term has become synonymous with the concept "to deal with conclusively", also cited by Webster. The myth that single-use diapers disappear, are dealt with conclusively, or are eliminated as an economic, social or health variable after being thrown into a trash can, is at the root of the discrepancy regarding the word "disposable."

Although placing a used product in the waste stream eliminates it from the home (and from the consumer's consciousness), the product lives on indefinitely, even after landfilling. The diaper is merely physically transported to another location and buried, where it remains for many decades.

The author seeks to eliminate the definitional controversy by referring to the product simply as the "single-use diaper".

To be functionally consistent, then, cotton or cloth diapers should be referred to as "reusable" or "multi-use" diapers, since they are washed and reused many times. However, since "cotton diaper" describes this product without controversy, the author relies on the traditional description rather than the phrase "reusable diaper."

## Appendix II.

References for solid waste composition studies cited in section 4b, figure 11, 12, and 13.

- 1 Oyster Bay, Long Island: Waste Age Magazine, 5/88, "Ultimate Unrecyclable: Diapers", page 18. Camp, Dresser and McKee were the Town's consultants.
- 2 Tuscan, Arizona, Bay Area, California and Chicago, Illinois: "The Mullins Dig: An Archaeological Excavation of Three Modern Landfills", The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona, Tuscan, Arizona.
- 3 Dearborn Hights, Michigan: "A Comprehensive Municipal Refuse Characterization Program", Herbert I. Hollander, Junius Stephenson, Virgil Eller, and John Kieffer page 14, Table 2. Presentation to the 9th ASM National Waste Processing Conference, Washington D.C., May 11-14, 1980.
- 4 Cincinnati, Ohio and Kentucky: "Soiled Disposable Diapers: A potential Source Of Viruses", Mirdza L. Peterson, American Journal Of Public Health, Vol. 64, no. 9, September, 1974. In this study municipal solid waste collected from an area in Cincinnati, Ohio and from an area in northern Kentucky were delivered to a pilot laboratory where the waste was separated. Each location had two samples. For the above analysis, the author weighted the percentage of diapers from the two samples in each location to derive a single percentage.
- 5 Solid Waste Management Program, County of Onondaga, New York, "Solid Waste Quantification and Characterization:", William F. Cosulich Associates, PC, October, 1987. For purposes of determining the percentage of the municipal waste stream occupied by single-use diapers, the author did not use the average of all landfills surveyed by William F. Cosulich Associates, and subtracted "hardfill sites". The result of using only some of the landfills surveyed was to raise the diaper percentage from 1.2% as reported in this study, to 1.33%, as recalculated by the author.
- 6 East Hampton and Buffalo, New York: "Intensive Recycling: Preliminary Results From East Hampton and Buffalo", B. Commoner et.al. Presented at the 4th Annual Conference on Solid Waste Management and Materials Policy, January 27-30, 1988.
- 7 Tuscon, Arizona: Unpublished data obtained from The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona, Tuscan, Arizona.
- 8 Cincinnati, Ohio: "Biological Properties Of Sanitary Landfill Leachate", R.S. Erglebrach, M. J. Weber, P. Amirhor, D. H. Foster, and D. LaRossa. University of Illinois at Urbana-Champaign, Urbana, IL.

### Appendix III.

#### Calculations for quantifying single-use diapers in the solid waste stream

Another way to estimate the quantity of single-use diapers in the solid waste stream is to calculate the percentage based upon data derived from material flow analysis. The following format is utilized:

$$\frac{(\text{average diaper weight}) \times (\text{total number of diapers sold})}{\text{total solid waste discarded (weight)}} = \begin{matrix} \text{\% of waste stream} \\ \text{(by weight)} \end{matrix}$$

For calculating the percentage of single-use diapers in the municipal solid waste stream, the following inputs are utilized:

Total number of single-use diapers purchased: in 1988, estimated to be 18 billion units.<sup>52</sup>

Average weight of a single-use diaper when discarded: computed at 7 ounces. The author's own estimates based on frequent sampling is 8 ounces/diaper.<sup>53</sup> Results of an unpublished survey by The Garbage Project in the Spring of 1987 indicated an average diaper weight of 6.79 ounces (823 diapers), and results of a study undertaken in 1982 indicated an average diaper weight of 6.5 ounces (3,172 diapers).<sup>54</sup> Market researchers have noted a decline in the average daily consumption of single-use diapers per baby. It is assumed that the percentage of decline in the number of diapers used per day is nearly proportional to the increase in average weight of a single-use diaper. Goldman Sachs Research reported in their Research Brief on the Kimberly Clark Corporation in 1986, "Daily (disposable diaper) unit usage before 1984 is unchanged at 7.0 units; 1985's is lowered to 6.9 units, 1986's to 6.7 units, 1987's units to 6.5 units, and 1988-1990's to 6.3 units".<sup>55</sup>

<sup>52</sup>-----  
*CMR Chem. Bus.*, 8/87, page 27 cites 17 billion units sold in 1987. A conservative 6% growth rate for 1988 is assumed to arrive at 18 billion units. Also "Procter's Gamble -- Is Smaller Better?" by Francis Bouda, Nonwovens Industry, 1/86 which cites 18 billion diapers sold in the U.S. Also "Kimberly-Clark Corporation" by Goldman Sachs Research, Research Brief, April 17, 1986 which estimates 1988 units sold to be 17.79 billion.

<sup>53</sup>Unpublished research by The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona, Tuscan, Arizona, provided to the author by the Director, Dr. William Rathje.

<sup>54</sup>See previous footnote.

<sup>55</sup>Research Brief, "Kimberly-Clark Corporation", April 17, 1986, Goldman Sachs Research. Table 5.



Calibrating The Garbage Projects's average diaper weight in 1982 is accomplished by multiplying the weight by the percentage change from 7 units to an estimated 6.5 units used daily cited by Goldman Sachs for 1987. This yields an average single-use diaper of 6.94 ounces in 1987. The author computed the average weight of a single use diaper at 7 ounces in his calculations based upon his own estimate of 8 ounces, The Garbage Projects 1987 study of 6.79 ounces, and The Garbage Projects 1982 study calibrated to 6.94 ounces as cited above.

Total Solid Waste Discarded: Municipal Solid Waste: Franklin Associates  
table "Products Discarded Into the Municipal Waste Stream" was used to  
 derive 144.9 million tons discarded in 1988.<sup>56</sup> This number was  
 estimated based on last baseline year in 1986 of 140.8 million tons, and  
 an estimated 149 million tons in 1990.

18,000,000,000 diapers	X 7 ozs.	= 7,875,000,000 lbs/yr.;
7,875,000,000 lbs/year	/ 2000	= 3,937,500 tons/yr.;
3,937,500 tons/year (diapers)	/ 144,900,000 tons (msw)	= 2.71% of msw (by weight).

The above estimate of 2.71% of total solid waste being composed of single-use diaper waste is slightly above the upper range of the five previously calibrated waste composition studies of 1.23% to 2%.

The sampling techniques employed by the five msw waste composition studies did not measure or include other types of single-use diaper waste, such as packaging and manufacturing wastes and baby wipes, which could account for 659,200 tons of solid waste in 1988.<sup>57</sup> This would imply that the actual composition of single-use diaper waste is higher than the 1.57% average of the five studies, and is at or above the high end of the studies or 2% of the municipal solid waste stream, with a statistical diviation of 0.5%.

<sup>56</sup>-----  
Characterization of Municipal Solid Waste in the United  
States, 1960-2000, Franklin Associates, LTD., Prairie Village,  
Kansas, upgraded March 30, 1988, EPA Contract No. 68-01-7310.  
<sup>57</sup> Refer to figure 16.

## Appendix IV.

### Calculations for quantifying single-use diapers in the household solid waste stream

Total Solid Waste Discarded: Household Solid Waste: Franklin Associates table "Products Discarded Into the Municipal Waste Stream" (1986) was used to derive 107.29 million tons discarded for 1990. This was done by subtracting the following fractions of commercial discards and yard waste out of the municipal waste stream figures:

<u>Materials</u>	<u>% Excluded</u>	<u>Million Tons</u>	<u>Total</u>
rubber tires	100%	1.6	
other durable goods	25	4.6	
office paper	100	4.6	
commercial printing	100	4.3	
glass	25	2.8	
steel	25	.67	
aluminum	25	.15	
corrugated boxes	80	3.45	
other paper, packaging, books, magazines, plastics and wood packaging	20	4.4	
Food, yard and miscellaneous organic wastes	20	7.54	(34.11 million tons)

141.4 million tons msw - 34.11 million tons commercial =  
107.29 million tons projected in 1990 household waste stream

107.29 X .98 = 105.144 million tons household solid waste in 1988  
(1% growth per year deducted from 1990 estimate to arrive at 1988)

3,937,500 tons/year (diapers) - 5% for hospital and institutions =  
3,740,625 tons/year in household waste stream

3,740,625 tons/year (diapers) / 105,144,000 tons (household) =  
3.557% of household solid waste stream.

This is within 0.043% of The Garbage Project's conclusion as reported  
in Time Magazine, September 5, 1988, page 82.

If all yard wastes are taken out of the definition of household waste:

(105,144,000 tons (household) - an additional 19,280,000 tons yard wastes  
= 84,864,000 of household waste without yard waste)

3,740,625 tons/year (diapers) / 85,864,000 tons (household waste) =  
4.35% of household solid waste stream.

## Appendix V.

### Summary of Proposed Research by the Author

In the course of developing this report, the author has identified several important topic areas that demand further investigation related to solid waste management and to single-use diapers, problems encountered by their use, and methods for surmounting these problems. The author, in conjunction with professional researchers, is interested in pursuing these projects. For additional information, contact Carl Lehrburger, P.O. Box 580, Sheffield, Massachusetts 01257.

1. CLASSIFICATION OF SINGLE-USE DIAPERS AS INFECTIOUS WASTE AND PUBLIC HEALTH IMPACTS:

The potential for single-use diapers to act as a source or vector for the spread of infectious disease is significant. Additional research to determine the conditions and probability of single-use diapers spreading infectious disease is proposed. With this information, public health officials can confidently establish codes and guidelines for the safe disposal and handling of this product, in both institutional and residential environments. Additionally, this information can offer evidence as to whether and under what circumstances single-use diapers should be categorized as an infectious waste. Proposed project director: Dr. Daniel Perlman, Infectious Disease Division, University of Colorado School of Medicine, Denver, Colorado.

2. DEVELOPMENT OF A FLUSHABLE AND RAPIDLY BIODEGRADING SINGLE-USE DIAPER:

Research on a technical level aimed at developing a flushable and rapidly biodegrading single-use diaper is proposed. Materials research, including the use of super-absorbing materials in a variety of different configurations, including a two-piece and a single-piece diaper, will be assembled and evaluated in a laboratory environment. Preliminary market research will be undertaken to ascertain the prospect of introducing a flushable diaper alternative and the type of public education efforts that will be required. Proposed principal investigator: Dr. Bruce Nauman, Department of Chemical Engineering, Rensselaer Polytechnic Institute, Troy, New York.

3. ACCURATE MEASUREMENT OF THE QUANTITY OF SINGLE-USE DIAPER WASTE:

A study to quantify the amount of diaper waste in the household and solid waste stream is proposed. This would include fecal/urine, packaging and diaper contribution and the disposal habits of consumers and institutions. Field work will include sampling on a broad spectrum of socio-economic and institutional diaper use. In addition to refining quantitative information on diaper waste, information may help develop guidelines for controlling waste generated by this product. Proposed project director: Dr. William Rathje, The Garbage Project, Bureau of Applied Research in Anthropology, University of Arizona.

Determining the actual composition of single-use diapers in the household waste stream is more difficult than municipal solid waste because it is more subject to varying definitions. The range of the three previously calibrated household studies was 2% to 6.4% of the household solid waste stream, with an average of 4.3%. Considering the above calculations, partially supported by the calibrated studies, a range of 3.5% to 4.5% is estimated for the single-use diaper contribution to the household solid waste stream, subject to definition and interpretation.

4. APPLICATION AND GENERALIZATION OF COMPUTER PROGRAMS TO ANALYZE LIFE CYCLE COST OF PRODUCTS: Refinement and extension of software developed in this research to segment, classify, and link life cycle cost in user-defined tables is proposed. The computer program would apply updated input-output coefficients associated with production. Costs associated with use and disposal of a product would be identified, quantified, and tabulated. The software would be capable of addressing current economic and policy issues, and the comparative merits of single-use and reusable versions of a products. The input output coefficients will be able to track waste and other impacts of major products and materials in the waste stream. Detailed comparison of environmental and economic impact of diapers on the sewage waste stream compared to the solid waste stream is an example of the application of this program. Proposed project director: C. V. Jones, Principal, Economic Data Resources, P.O. Box 1009, Boulder, Colorado 80306.