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DISPOSABLE VS. REUSABLE SYSTEMS: TWO SOURCE REDUCTION CASE STUDIES*

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ABSTRACT

This is the first of two articles presenting case studies of successful solid waste source reduction programs at five businesses. Both process and economic analyses were performed for each case study. The first article examines the substitution of reusable products for single-use equivalents at a hospital and day care center. Replacing polystyrene foam dishware with washable ceramic dishes at a hospital reduced dishware solid waste generation by 42.8 pounds/1000 meals, or 99 percent. Total costs in the washable dishware case increased 6 percent, but this cost differential is very sensitive to wage rates and disposable dishware costs. When disposable diapers at a day care center were replaced with cloth diapers laundered by an outside service, solid waste generation was reduced by 0.34 pound per diaper, or 99 percent. The unit cost per disposable diaper is $0.25 compared to $0.22 for cloth diapers. Disposable items constituted the major cost of both single-use systems, while labor and services were the major cost of both reusable systems. At present, solid waste avoidance provides relatively minor cost credits for the reusable systems.

Both per capita and total solid waste generation increased significantly between 1960 and 1988 in the United States, and recent projections through 2000 do not indicate a reversal of this trend [1, 2]. Data presented in Table 1 show gross

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Table 1. Trends in Gross MSW Discards

	Total MSW (Million Tons)		Per Capita MSW (Lbs/Day)	
Year	1988[a]	1990[b]	1988[a]	1990[b]
1960	87.5	–	2.65	–
1986	157.7	167.0	3.58	3.80
1988		180.0		4.00
2000		216.0		4.40

[a] Estimates from [1].
[b] Estimates from [2], updated to include additional items.

discards of municipal solid waste (MSW) without accounting for either material recovery or combustion.

Faced with increasing rates of waste production and decreasing landfill capacity, the EPA recommends an integrated waste management hierarchy emphasizing: source reduction (including reuse), recycling (including composting), and finally combustion or disposal in landfills [3].

Reuse is an important source reduction strategy that can be expected to yield significant waste reduction compared to single-use systems. Diaper use at a day care center [4] and dishware use at a hospital [5] provide two case studies of solid waste reduction achieved by converting from disposable to reusable products. These case studies were conducted to facilitate the transfer of similar solid waste reduction programs to other businesses. Both process and cost analyses were used to contrast the single-use and reusable systems.

A comprehensive approach to resource management also requires a life cycle analysis of each waste reduction strategy. The life cycle system for a product or service includes raw materials procurement, manufacturing, distribution, use, resource recovery and disposal. Life cycle analysis provides information that can be used to avoid shifting waste and risks from one medium to another or between stages of the life cycle. The case studies presented here are limited to processes and related support services at the business under investigation. Life cycle analysis, including environmental impact and health risk assessments, is beyond the scope of this article.

METHODOLOGY

Process Analysis

Process analyses were conducted for the before and after case of each waste reduction activity. System boundaries were defined to develop a basis for comparative analysis. The three main components of the process investigation were:

- inputs to the process;
- description of process steps; and
- outputs, both useful products and waste products.

Material flows and transformations which were not affected by the waste reduction change were not analyzed in depth.

Inputs include all the raw materials, energy, labor and other factors that are combined to produce a good or provide a service. Input data were obtained from purchasing records, interviews with managers and on-site measurements. Labor requirements for each waste reduction activity were obtained from single measurements with an estimated uncertainty of 15 percent.

Flow diagrams were used to systematically trace materials streams and process steps related to each waste reduction activity. General operating conditions, equipment needs and other specifications were documented from on-site observations. Equipment specifications and utility requirements were obtained from the manufacturer.

Characterization of material output streams required quantification of weights and flow rates. Data from company records or waste disposal companies servicing the case study firm were used when available. If the waste reduction program was implemented without measurement of the waste stream, materials were weighed to determine the amount of waste reduction achieved. For small packaging materials, analytical balances were used to obtain greater precision.

Cost Analysis

The cost analysis accounts for fixed and operating costs before and after implementation of each documented waste reduction activity. To simplify the analysis, costs or revenues that were unaffected by the waste reduction processes were not evaluated. The analysis consisted of an evaluation of baseline costs and revenues contrasted with after-intervention costs, revenues and savings. The inputs, outputs and operational steps of the process analysis were used as a guide to identify items for the cost analysis. Data on equipment costs were obtained from the case study firms, vendors and manufacturers. Labor costs, including full benefits, were obtained from the case study firms, and utility costs were obtained from the various providers.

The analysis for each case is limited to process and cost factors pertaining to on-site activities and does not specifically address broader life cycle issues. Ideally, externalities such as environmental and social costs, which are frequently borne by society and not reflected in process or market prices, should be quantified so competing systems can be fully evaluated and compared.

DIAPER CASE STUDY: CHILD DAY CARE CENTER

The market for disposable diapers has expanded rapidly since the 1960s due primarily to their convenience. By converting from disposable to cloth diaper use, the case study day care center demonstrates a reversal of this trend. On average, the center provides care to twelve infants/toddlers who require diapering (infants are less than twelve months old; toddlers are one to three years old), twenty-three preschool children, and seventeen kindergarten children.

Single-use diapers are a major constituent of solid waste produced at day care centers. Disposable diapers constitute from 85 to 90 percent of all diapers used in the United States, with children under three years of age accounting for 90 percent of total diaper usage [6]. Diapers are also used by adult incontinents at home, in nursing homes and hospitals. Adult incontinence occurs in 10 to 20 percent of the population over sixty-five years and 40 to 50 percent of the elderly population of nursing homes [7].

An estimated eighteen billion disposable diapers are discarded each year. Waste from single-use diapers comprises approximately 2 percent of the total MSW stream; no other single consumer product, with the exception of newspapers and food containers (including beverage containers) contributes more to MSW [6].

Data from this study were compared with Little [8] and Lehrburger [6]. Substantial controversy surrounds the validity of their methodologies; therefore, data reported by each should be viewed with caution.

Results of Process Analysis

The cloth diapers used at the day care center are washed by a diaper service. After the conversion to cloth diapers, disposable diapers were still used for most children's final change of the day. If parents used cloth diapers at home, infants/toddlers were sent home in cloth diapers and returned in cloth diapers the next day; however, only a few of the children are diapered in cloth at home.

Moisture proof outer wraps that prevent leakage are an integral part of a successful cloth diapering system. Three dozen double-layer, nylon wraps were purchased with an expected life of one year or more for use with cloth diapers. Approximately two dozen wraps are used and washed each day. This activity constitutes the major difference in day care center labor inputs between the two systems.

Both cloth and disposable diapers are used at the same rate: one diaper per change. Interviews with parents using cloth diapers indicate that some double diapering is done at night because diapers are changed less frequently. A. D. Little indicates that 1.9 cloth diapers are used per diaper change, citing interviews that document consistent double diapering among those using cloth diapers at home. This report also suggests that care givers may tend to change cotton diapers more frequently because they readily show that a baby has wetted [8]. Care givers at the

Table 2. Weekly Diaper Use Process

	Before Case		After Case	
Unit Per Week	Disposable Diapers	Cloth Diapers	Disposable Diapers	Total
Children diapered/day	12	12	12	12
Diapers used/child/week	17.5	12.5	5.0	17.5
Total Diapers	210	150	60	210
Solid Waste:				
Excrement weight[a]	46.26 lb		11.56 lb	11.56 lb
Diaper weight	25.77 lb	0.21 lb	7.36 lb	7.57 lb
Diaper packaging weight	0.30 lb	0.06 lb	0.09 lb	0.15 lb
Refuse bag weight	0.23 lb	0.32 lb	0.07 lb	0.39 lb
Total material reuse[b]	0.30 lb	0.06 lb	0.09 lb	0.15 lb
Total Material Discards[b]	72.26 lb	0.32 lb	18.99 lb	19.32 lb
Utilities:				
Clothes washing water		144 gal		144 gal
Gas to heat wash water		0.1404 Ccf		0.1404 Ccf
Electricity for washer		0.75 kwh		0.75 kwh
Labor:				
Purchase and stocking	15.0 min		4.3 min	4.3 min
Washing		11.7 min		11.7 min
Drying and folding		53.0 min		53.0 min
Total	15.0 min	64.7 min	4.3 min	69.0 min

[a] Includes feces and urine, estimated from [8].
[b] At the day care center.

center did not double diaper and did not change diapers more frequently. An effective outer wrap obviates the need for multiple diaper use or an increased changing rate.

A summary of results from the process analysis is presented in Table 2. The conversion from disposable to reusable diapers reduced municipal solid waste generation by fifty-three pounds per week. If cotton diapers were used exclusively, diaper-related solid waste generation would decrease an additional nineteen pounds per week.

Solid waste produced by the disposable system includes disposable diapers, fecal matter and urine, and garbage bags used for disposal of the diapers. Although manufacturers recommend rinsing or shaking excrement into a toilet, this practice is not generally followed. The excrement generation rate was estimated from A. D. Little [8]. The disposable diapers used by the day care center weigh an

average of 0.123 lb each. Plastic (LDPE) packaging for a case of sixty-four diapers, which weighs 0.09 lb, is reused for holding wet cloths to be sent home with parents and is thus not considered a component of the day care center's waste stream.

Solid waste generated by cloth diapers is comprised of plastic bags (0.06 lb) provided by the diaper service to collect both soiled diapers and wraps. A single bag is used each day to collect the wraps, and one bag is used each week to return soiled diapers to the diaper service.

The average diaper washed by the diaper service weighs .275 lb and can be reused 125 times.[1] A. D. Little reported an average usage of ninety cycles [8]. Lehrburger states that cloth diapers laundered at home have a life expectancy of 50-100 uses, while diaper services may use cloth diapers 200 times [6]. Old cloth diapers are sold to paint shops, car wash stations, auto body shops, janitorial companies and furniture manufacturers for use as rags. Cloth diapers enter the waste stream only after they are further degraded by these secondary uses.

The day care center's use of 150 cloth diapers generates 0.21 pound of retired diapers per week, compared to 25.77 pounds of disposable diaper material waste, not including the excrement, produced by using 210 disposable diapers. For every 100 diapers, cloth generates 0.14 lb of diaper waste and disposables generate 12.27 lbs of diaper waste.

Hampers and diaper pails used for cloth diapers, and refuse containers used for disposable diapers were assumed to generate an equivalent amount of waste at the end of their useful life and were therefore not included in the analysis.

Diaper wraps are laundered at the day care center in a washing machine. Utility requirements include hot and cold water and electricity for operating the washing machine once a day. Wraps are dried on a clothes line in the diaper changing room, which saves energy and extends the useful life of the wraps.

The cloth system requires more total labor inputs than the disposable system, primarily as a result of laundering the wraps and folding cloth diapers into the wraps. This additional labor is somewhat offset by the decreased time spent shopping for disposable diapers. The care givers indicated no significant difference in changing times between disposable and cloth diapers.

Results of Cost Analysis

Itemized cost data are presented in Table 3. The first column lists costs associated with the disposable diaper system before the conversion to cloth. The second and third columns itemize costs for cloth and disposable diapers (last change of the day) respectively after the conversion was implemented.

Cloth and disposable diapers currently represent comparable costs to the day care center; the unit cost per diaper is $0.25 for the disposable diapers and $0.22

[1] Tests conducted by Diapers Unlimited in Kalamazoo, Michigan.

Table 3. Weekly Cost of Diapering

	Before Case	After Case		
Unit Per Week	Disposable Diapers	Cloth Diapers	Disposable Diapers	Total
Diapers:				
Diapers	$48.15	$18.75	$13.76	$32.51
Diaper wraps		$ 2.12		$ 2.12
Total	$48.15	$20.87	$13.76	$34.63
Supplies:				
Washing supplies		$ 0.68		$ 0.68
Refuse bags	$ 0.40		$ 0.11	$ 0.11
Total	$ 0.40	$ 0.68	$ 0.11	$ 0.79
Equipment:				
Washer depreciation		$ 0.49		$ 0.49
Washer maintenance		$ 0.29		$ 0.29
Total[a]		$ 0.26		$ 0.26
Utilities:				
Water/sewage		$ 0.54		$ 0.54
Gas		$ 0.11		$ 0.11
Electricity		$ 0.08		$ 0.08
Total		$ 0.73		$ 0.73
Transportation:				
Total Transportation	$ 0.26		$ 0.07	$ 0.07
Labor:				
Total Labor[b]	$ 3.59	$10.45	$ 1.03	$11.48
Total Costs:				
Per diaper	$ 0.25	$ 0.22	$ 0.25	
Total Costs Per Week	$52.40	$32.99	$14.97	$47.96
Total Costs Including Refuse Disposal:				
Disposal cost/week[c]	$ 2.39	$ 0.01	$ 0.63	$ 0.64
Weekly Total with Disposal	$54.79	$33.00	$15.60	$48.60

[a] The total cost of the washer is taken as one-third total depreciation and maintenance costs because the washer is used only one-third of the time for washing diaper wraps.
[b] Care giver wage with benefits is $9.70 per hour, management wage is $14.36/hour.
[c] This is the actual collection and disposal cost ($66 per ton); this cost is not included in the total cost incurred by the day care center.

for the cloth diapers. A. D. Little estimated that total life cycle costs of disposable diapers are $0.23 per diaper [8]. Total costs for cloth diapers were estimated at $0.38 per diaper based on home laundering. Costs for home laundering include operating a clothes washer and dryer, purchasing outer wraps, a wage for domestic labor and the use of 1.9 cloth diapers for every diaper change. Total costs fall to $0.17 if domestic labor is excluded. The discrepancy in cloth diaper costs between Little [8] and this study is largely attributable to differences in diaper use rates. Using assumptions substantially more representative of actual cloth diaper use as demonstrated at the case study day care center, Lehrburger estimates total single-use diaper costs to be $0.22 per diaper, while cloth diapers provided by a diaper service cost $0.13 per diaper [6]. Outer wrap costs are not included in this figure. Home washed diapers (no outer wraps) were estimated to cost $0.15 per diaper change, using the same wage rate as A. D. Little [8], and $0.03 per use with no labor inputs.

The major cost of the single-use system is the disposable diapers. This cost accounts for 92 percent of the total cost per child. Other costs include refuse bags for diaper disposal, transportation costs for purchasing the diapers each month and labor costs for purchasing and stocking diapers. Transportation costs were calculated using a rate of $0.26/mile.

The costs of diapering a child in cloth, presented in column two of Table 3, include diaper service fees and costs for purchasing outer wraps. Most other costs associated with the cloth diaper system are related to washing the wraps. Wrap laundering requires use of a clothes washer, utilities, detergent and labor. Labor for laundering wraps, which includes washing, drying on a clothes line and folding cloth diapers into the wraps, costs $10.45 per week.

Discussion

Solid waste generated from cotton diaper use is minimal. Repeated reuse and subsequent diversion to secondary applications substantially reduces cotton diaper material discards. Single-use diapers contribute far more to MSW than cotton diapers. Few opportunities currently exist to divert single-use diapers from landfills, but several options are at least theoretically possible.

Recycling disposable diapers has been suggested as a waste management alternative [8]. Although recycling unsoiled, single-use diapers may be technically feasible, the separation of plastic, paper and gelling agents from disposables is not likely to be an economical resource management strategy. Actual discarded diapers will be heavily soiled with human waste, presenting substantial sanitation problems and additional material separation difficulties.

Composting, particularly with sewage sludge, is one alternative that could be practical if plastic liner material in disposables was degradable. However, MSW composting capacity is currently very limited in the United States [6], and pathogens may not be fully eliminated unless composting is well controlled.

Good hygiene is essential for preventing fecal-borne disease transmission. Similar exposure opportunities are common to both disposable and reusable diapers during changing and subsequent handling related to disposal or laundering [6, 8]. In a cotton diaper system, human waste is diverted to a sanitary sewage system, which may be preferable to disposal in landfills [6]. However, little information apparently exists on pathogens attributable to the disposable diapers in municipal solid waste, and the possibility of disease transmission from human excrement in the solid waste stream has yet to be proven [9].

Resource consumption should also be considered in tandem with waste generation. A life cycle analysis of cloth and disposable diapering systems would provide a more comprehensive assessment of material and energy flows through each systems and thus allow a full comparative evaluation.

The conversion from disposable to cloth diapers resulted in a cost savings to the day care center of $4.44 per week, or 8.5 percent. Solid waste disposal is a significant environmental cost not included in the total costs incurred by the day care center. The conversion to cloth reduced solid waste discards by half, but the collection and disposal cost to the day care center remained unchanged. Collection and disposal fees are included in the center's property tax assessment; these fees are not calculated on a weight or volume basis. Actual costs for collection and disposal of the diaper waste are shown at the bottom of Table 3. Total costs per week would increase $2.39 before the conversion and $0.64 after the conversion if disposal costs were included in the overall analysis.

DISHWARE USE CASE STUDY: HOSPITAL FOOD SERVICE

The case study hospital is a 136 bed facility with 420 full-time equivalent employees. Food for patients, hospital employees and visitors is provided by an outside contractor.

Many hospital food services converted from ceramic to disposable dishware during the last several decades in an effort to lower costs. Now, as the cost of disposable dishware and solid waste disposal rises, disposable systems may appear less cost effective. The recent conversion to washable dishes at the case study hospital offers an opportunity to contrast the use of disposable dishware with washable dishware in a food service system where other variables remain constant.

Life cycle analyses of disposable and reusable dishware systems have not yet been conducted. Beverage containers are the most comparable system that has been studied with life cycle techniques. Sellers and Sellers estimate that total life cycle energy use is lower for refillable glass beverage bottles used just eight times than for single-use PET (polyethylene terephthalate) plastic bottles [10]. Refillable glass bottles also generate fewer air and waterborne emissions over their life cycle, while producing more pounds but less volume of solid waste than PET

bottles [10]. A substantially higher trippage rate for refillable glass bottles would change estimates of life cycle solid waste generation. Gaines states that two-liter glass beverage containers refilled three times use less energy over their life cycle than two-liter, single-use PET (with HDPE base cups) containers [11]. Hocking compared life cycle impacts of paper and polystyrene single-use cups but did not analyze reusable dishware [12]. Although some aspects of these studies may be applicable to dishware use, solid waste generation and other life cycle material flows and impacts of reusable and disposable dishware systems are largely unexplored.

Results of Process Analysis

The case study hospital serves approximately 3100 cafeteria meals and 900 patient meals per week. Before the widespread introduction of ceramic dishes, all flatware and trays used in the hospital were washable. Meals in the cafeteria were served on disposable dishes, primarily expanded polystyrene (EPS). With the exception of ceramic plates, dishes used for patient meals were also disposable. Single-use cup lids and straws were provided in conjunction with disposable cups for cold drinks.

When the hospital food service began using washable dishes, ceramic items replaced most comparable disposable dishware with one significant exception. Cold drinks are still dispensed in single-use cups with disposable lids and straws, but the cups are now paper rather than EPS. Although washable glasses are not used for cold drinks, hot drinks are now offered in ceramic cups.

Substituting reusable for disposable dishware produced two major changes in the dishware use process at the hospital: total waste disposal from dishware use was essentially eliminated, and labor inputs increased substantially. Process changes are quantified in Table 4.

Disposable expanded polystyrene dishware added 33.5 pounds to the hospital's solid waste stream for every 1000 meals served. The hospital has no access to a corrugated cardboard recycling program. Old corrugated containers (OCC) comprised 22 percent of the solid waste generated by disposable dishware use.

Ceramic dishes are much heavier than polystyrene equivalents, but only 5 percent of total inventory breaks each year, producing 0.25 pound of solid waste for every 1000 meals served. The hospital generated 42.8 pounds less waste per 1000 meals after converting to washable dishes in its food service operation, a reduction of 99.5 percent.

Water, steam and electricity use increased after conversion to washable dishes. Electricity for heated, self-leveling dispensing racks which were purchased for the washable system added to electricity demand as did increased use of the dishwasher.

A life cycle analysis of energy inputs for each system includes energy required to manufacture and distribute washable and disposable dishware. Accounting for

Table 4. Dishware Process per 1000 Meals

Item	Disposable Dishware	Washable Dishware	Difference
Waste Production:			
Dishware disposal weight	33.5 lb	0.25 lb	33.3 lb
Packaging weight	9.5 lb	0.00 lb	9.5 lb
Total Disposal Weight	43.0 lb	0.25 lb	42.8 lb
Utility Use:			
Rinsing water use	7 gal	125 gal	-118 gal
Washing water use	305 gal	1390 gal	-1085 gal
Booster steam use	116.7 lb	700.0 lb	-583.3 lb
Dishwasher use	2.3 kwh	14.0 kwh	-11.7 kwh
Dishware rack electricity		25.9 kwh	-25.9 kwh
Labor:			
Purchase labor	0.13 hour	0.04 hour	0.08 hour
Stocking labor	0.13 hour	3.50 hour	-3.38 hour
Rinsing labor	0.00 hour	4.38 hour	-4.38 hour
Dishwashing/drying/labor	1.17 hour	7.00 hour	-5.83 hour
Refuse disposal labor	7.00 hour	0.29 hour	6.71 hour
Total Labor	8.40 hour	15.20 hour	-6.80 hour

total embodied and transportation energy could either increase or reduce the disparity in energy use between the two systems.

Labor requirements increased 81 percent after the hospital converted to washable dishes. Stocking labor in the reusable case is defined as the labor required to unload dishware and place it in racks after washing. Stocking labor in the disposable case refers to the labor needed to place weekly shipments of disposable dishware in inventory.

Labor required to distribute meals and collect used dishes is the same for both cases and was omitted from the process analysis. Labor needed to unload collection carts in the kitchen is included in the disposal category for disposable dishes and in the rinsing category for reusable dishware. Waste gathering and disposal labor are significant components of the disposable dishware use process.

The hospital enjoyed several dishwashing process advantages that facilitated the conversion from disposable to washable dishware. A dishwasher to clean trays, flatware and ceramic plates for patient meals was already in place but used only twenty minutes per day in the disposable case. The hospital kitchen was also equipped with underused rinsing equipment and sinks. Thus, no additional capacity was required for the reusable dishware system.

Results of Cost Analysis

The conversion from disposable to reusable dishware did not substantially change food service costs. Table 5 provides a detailed breakdown of costs associated with each case.

Two categories account for over 60 percent of total costs in each case: labor costs nearly double when ceramic dishes are used, and dishware and supplies cost half as much when ceramic dishes are used.

Differences in these two categories essentially counterbalance, resulting in a slight cost advantage for disposable dishware use. Water, steam and electricity costs increase when washable dishes are substituted for disposable dishware. An increased burden on existing equipment is addressed in the cost analysis by a proportional increase in maintenance costs. New equipment requirements include racks for collecting the ceramic dishware and heated, self-leveling dispensing racks.

Table 5. Costs of Dishware Use per 1000 Meals

Item	Disposable Case	Reusable Case	Difference
Dishware:			
Dishware and supplies	$160.00	$ 60.00	$100.00
Cost of dishware alone	$133.75	$ 1.20	$132.55
Cleaning chemical cost	$ 1.01	$ 18.00	-$ 16.99
Total Dishware Cost	$161.01	$ 78.00	$ 83.01
Equipment:			
Equipment maintenance and repair	$ 0.35	$ 2.31	-$ 1.97
Dishware racks	$ 0.00	$ 7.50	-$ 7.50
Total Equipment Cost	$ 0.35	$ 9.81	-$ 9.47
Utilities:			
Water/sewer costs	$ 1.02	$ 4.30	-$ 3.28
Steam cost	$ 1.15	$ 6.87	-$ 5.73
Electricity cost	$ 0.18	$ 3.01	-$ 2.83
Refuse disposal	$ 3.89	$ 0.00	$ 3.89
Total Utilities Cost	$ 6.24	$ 14.18	-$ 7.95
Labor:			
Total Labor Cost[a]	$ 83.13	$163.74	-$ 80.60
Total Costs per 1000 Meals	$250.73	$265.73	-$ 15.00

[a] Housekeeping labor (trash disposal) costs $9.50/hour, including all benefits; dietary labor (dishwashing/rinsing) costs $10.76/hour; and purchasing labor costs $21.88/hour.

Changing costs in relatively minor categories could easily make ceramic dishware less expensive to use than disposable equivalents. Heated dispensing racks are not essential, especially for cafeteria meals that will be eaten promptly. Eliminating heated racks would save the hospital approximately $7.70 per 1000 meals.

Disposable paper cups cost $31.00 per 1000 meals, compared to the $15.00 per 1000 meals cost of single-use EPS cups used previously. If cold drinks were still served in EPS cups, total costs in both systems would be approximately $250.00 per 1000 meals. Offering drinks in washable glasses may produce a further cost advantage over EPS cups.

No major equipment purchases were necessary when reusable dishes were substituted for disposable items. Purchasing a new dishwasher of the same brand and size as that currently in use would cost an additional $7 per 1000 meals, depreciated according to accepted accounting practices (i.e., yearly costs are purchase price divided by life expectancy of the product). Reorganizing a kitchen to accommodate a rinsing and washing area would require an additional capital investment.

Discussion

A sensitivity analysis reveals how both systems react to changes in the cost of various components. A 10 percent rise in the price of disposable dishware and cups increases costs in the reusable case 1 percent while adding 5 percent to the costs of the disposable system. Under these conditions, total costs for the reusable system would be $4.72 more than the disposable system per 1000 meals. An increase of 15 percent in the cost of single-use dishware essentially balances costs in both systems.

Costs in the disposable case are much less sensitive to changes in disposal fees. Sixty four percent of total costs are allocated for dishware and related supplies while disposal fees account for only 1.6 percent of total costs. If disposal charges tripled, the current cost differential in favor of the disposable system would only decrease from $15.00 to $7.22. In the short run, increases in the cost of disposable dishware can thus be expected to have a much greater impact on the economics of disposable dishware use than increases in disposal fees.

Changes in labor costs would have the greatest impact on the cost of using washable dishes. An increase in labor costs of 10 percent, without an accompanying increase in the productivity of the workforce, would increase costs of the washable dishware system to $23.06 more than the disposable system. This figure is based on labor costs retaining the current differential for kitchen workers and waste disposal personnel. Comparative costs of the two systems are sensitive to these differential wage rates. Equalizing wages at the housekeeping rate of $9.50 per hour essentially balances total costs in both systems.

CONCLUSIONS

Municipal solid waste generation was substantially reduced at both the hospital and day care center by substituting reusable items for disposable items. Other opportunities for source reduction exist at hospitals and day care centers. A partial list of single-use items that could be replaced by reusable items at hospitals includes: linens, gowns, bedding, diapers, medical equipment (i.e., syringes, scalpels) and bedpans and similar supplies. Until recently most of these items were reusable. Day care centers can practice source reduction by using washable dishware and teaching children to select only what they will eat at mealtimes thus avoiding unnecessary food waste.

Replacement of single-use items with reusable equivalents resulted in minor overall cost changes. At the day care center, implementation of a cloth diapering program saved 8.5 percent of diapering costs. Reusable dishware costs the hospital 6 percent more to use than disposable dishware, but this cost differential is very sensitive to changes in operations, material selection and wage rates. Both reusable systems were initiated with minor capital costs. Disposable items were the major cost for both disposable systems. At the hospital, labor required for handling and discarding waste also contributed significantly to total system costs.

Based on these examples, reusable systems appear to offer MSW management advantages compared to disposable systems. Externalities, such as environmental impacts, are not accurately reflected in operating costs incurred by the case study firms. Life cycle analyses of both the dishware and diaper systems would provide the necessary data for making a full comparative evaluation. Material and energy flows during the manufacture, distribution and final disposal of dishware and diapers, as well as an assessment of the health risks and environmental impacts associated with each system, are necessary before broader conclusions can be made.

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