

Least-Cost Options for the Collection, Treatment, and Disposal of Biomedical Waste in Maine

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EXECUTIVE SUMMARY

It is estimated that Maine's 39 hospitals produce approximately 111 tons of non-pathological, non-chemical, biomedical waste each month. Most hospitals in the state have managed their biomedical waste by contracting with private firms for disposal service, including transportation of the waste to out-of-state facilities for treatment at an estimated statewide average cost of \$685 per ton. Recently, consolidation in the waste management industry and the closure of some out-of-state incinerators have prompted the hospital industry and environmental regulators to explore alternative waste-disposal options. The cost effectiveness of utilizing current treatment technologies to sanitize, disinfect, shred, and dispose of biomedical waste within the state is examined in relation to the costs of current disposal practices in Maine.

The study employs a linear programming model to determine the combination of treatment facilities, transportation options, and disposal sites to treat all waste produced in Maine at the lowest statewide cost. A least-cost solution is developed for three different scenarios. The first two scenarios assume that all treated waste must be shredded in accordance with current regulatory requirements. The third scenario assumes that regulations are changed to require only that the sharps portion of the biomedical waste stream be shredded. All scenarios assume that the treatment facilities would be located on-site at one or more hospital locations, that there are no barriers to inter-hospital shipment of waste for treatment, and that any hospital has the option to continue shipping its waste out of state.

In the first scenario, all hospitals are included as potential locations for a waste-treatment facility in determining a shared, least-cost solution. The lowest cost arrangement under these conditions includes two facilities, located in Bangor and Portland, to treat 95% of the total waste stream at a statewide average cost of \$445 per ton. The remaining 5% of the waste would continue to be shipped out of state.

The second scenario assumes that four of the larger hospitals in the state would seek to minimize their own costs separately. Therefore these hospitals are not evaluated jointly with the other hospitals in the state. The least-cost option for the remaining 35 hospitals is a treatment facility in Lewiston. (An additional machine would be located in Bangor to minimize that hospital's own-waste treatment costs.) The total statewide cost of this scenario, including the disposal costs incurred by the four larger hospitals, is \$518 per ton.

The third scenario includes all hospitals as potential treatment sites but excludes the shredding requirement for the non-sharps portion of the waste stream. The reduced capital cost without shredding leads to a solution with ten different treatment locations at a total statewide average cost of \$412 per ton.

Recommendations for additional research include an evaluation of alternative waste-handling technologies, an examination of specific treatment technologies, and an analysis of off-site versus on-site locations of treatment facilities.

INTRODUCTION

Biomedical waste is defined as “wastes that may contain human pathogens of sufficient virulence and in sufficient concentrations that exposure to them by a susceptible host could result in disease” (Maine DEP 1991:2). Historically, disposal of these wastes has been by means of incineration. With tightening environmental regulations, this approach is no longer practical in Maine. The small remaining volume of biomedical waste that is incinerated in Maine is likely to be phased out soon. Currently, most Maine hospitals contract with out-of-state waste-disposal firms for shipment to out-of-state treatment facilities. With research indicating that by-products of incineration include dioxin, lead, and mercury, with growing concern about the cost and availability of out-of-state disposal, and with the prospect of potential cost savings, there is a growing interest in investigating alternative waste-disposal options in Maine. This paper presents the results of a study to determine the least-cost options for the collection, treatment, and disposal of biomedical waste for Maine hospitals.

The analysis employs a mixed-integer linear programming model that includes 39 hospitals as the sources of waste and as potential sites for processing the waste (sterilizing and shredding), six landfills potentially used for disposal of treated wastes, and up to four different sizes of treatment equipment (see Figure 1).

The model accounts for shipments of biomedical waste between hospitals while allowing hospitals to treat their own waste on-site if it is cost-effective to do so. This allows the model to designate any hospital as a generator of wastes, as a treatment site for wastes generated at other hospitals, or as both. As depicted in Figure 2, hospitals have the option to continue their current practice of shipping raw (untreated) waste out of state, or shipping their raw waste to a hospital that has the equipment and capacity to treat the waste. Alternatively, hospitals may opt to purchase and install equipment on-site for treatment of their own waste and/or waste from other hospitals. All waste treated in-state is designated for disposal at any of six different landfills included in the study as potential disposal sites. Three different scenarios are examined wherein the model identifies the optimal number, size, and location of treatment facilities to minimize total waste-disposal costs given the sources and volumes of waste and the distance to available landfills.

Under the base scenario, all Maine hospitals are considered as waste generators and potential waste-treatment sites. The model determines the least-cost solution for all of the hospitals as a group.

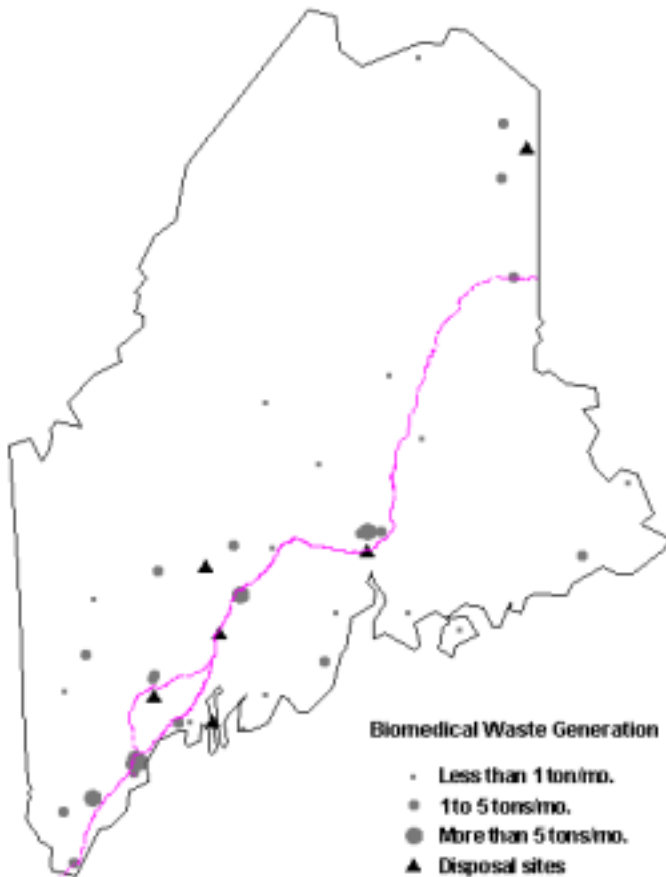


Figure 1. Locations of the 39 hospitals and six landfills included in the study.

The second scenario, (referred to as the “big four scenario”) assumes that the four hospitals that generate the most waste would (or will) develop their own individual waste-management solutions separately from the other hospitals in the state. The model then determines the least-cost solution for the remaining 35 hospitals as a group. The third scenario is the “no-shred scenario” in which all hospitals are considered waste generators and potential treatment sites, but the shredding of the non-sharps portion of the waste stream is not required. The biomedical sharps (for example, needles and scalpels) are collected, treated, shredded, and disposed of separately from the rest of the biomedical waste stream. In all scenarios, shipping waste out of state, as is currently done, is considered an option for each of the 39 hospitals.

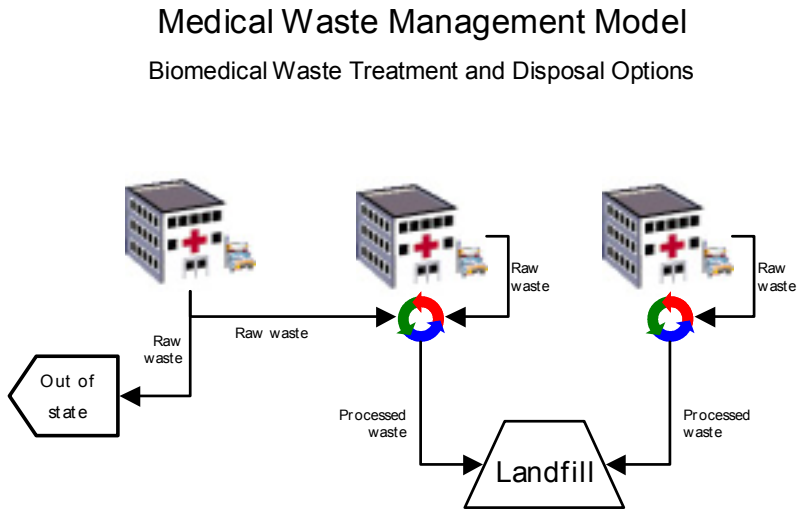


Figure 2. Alternative waste-management options included in the study.

While it is important to note what this analysis can do, it is also important to note its limitations. First, this analysis does not attempt to determine least-cost options for individual hospitals in Maine. Rather, this project evaluates least-cost options for all Maine hospitals as a group. In addition, the costs of purchasing and operating the equipment used in this analysis were derived from averaging data obtained from commercial vendors. Last, by aggregating the cost estimates from equipment vendors, this project does not attempt to promote any specific waste-processing technology; the actual technology used by any group of hospitals is left for the specific hospitals to determine. Thus, while this project attempts to promote relative options, it does not make any claims to specific data or technology.

BACKGROUND

Maine hospitals have made advances in recent years in reducing the amount of waste they generate and the means by which that waste is disposed. Through comprehensive education and awareness programs, Maine hospitals are now segregating their waste. Solid wastes are disposed of directly, recyclables are shipped to a recycling facility, and the remaining 15%, which is biomedical waste, is

disposed of separately (Health Care Without Harm 2000:3). Of the 15% that is biomedical waste, approximately one-seventh is pathological waste consisting of human tissues, organs and body parts. Another small portion of the biomedical waste stream is comprised of trace chemotherapy wastes that are chemical in nature and not biological. Incineration remains the most appropriate means of disposal for these latter two segments of the biomedical waste stream.

Until recently, Maine hospitals had the option of selecting from among several competing firms that offered biomedical waste-disposal services. Today, however, there is only one. Historically, that waste-disposal firm collected biomedical waste from Maine hospitals for shipment to an incinerator in Massachusetts. For various reasons, the Massachusetts incinerator recently was shut down permanently and the waste must now be shipped further south for processing. While this is acceptable in the short term, higher costs and uncertain availability make this option undesirable as a long-term solution.

Under the current situation, biomedical waste disposal is contracted for a period of years with the existing waste disposal firm. Because there is only one firm in operation, there is concern regarding long-term competitive prices. Also, with the firm's need to ship the waste further south for treatment, disposal costs likely will increase. In addition, there is no guarantee how long these southern treatment sites will be in operation. As a result, Maine hospitals may have to develop their own treatment and disposal solution.

The solution for Maine's hospitals will be influenced by the treatment equipment that is available. At present, there are two fundamental technologies for the treatment of biomedical waste. One technology uses steam/autoclave technology to kill all biological life exposing the waste for 30-minutes to high-temperature steam and pressure. The other uses microwave technology to disinfect the waste, by bombarding the waste with microwaves for 25 minutes. Both technologies are able to include a shredding component to their operation. Six different models are evaluated with capacities ranging from 6 to 130 tons per month.

THE MODEL

In an attempt to address the issue of biomedical waste-disposal in Maine, the Maine Department of Environmental Protection (DEP) contracted with The University of Maine's Department of Resource Economics and Policy (REP) to develop least-cost solutions

for each of the three scenarios outlined in the Introduction. The mixed-integer linear programming model used for this analysis accomplishes its goal by employing cost estimates for the different aspects of the collection, treatment, and disposal of biomedical waste and arrives at the solution that generates the least cost for Maine hospitals as a group. The individual costs included in this analysis are associated with each aspect of the collection, treatment, and disposal of the biomedical waste (see Table 1).

Collection Costs

The costs associated with the collection of biomedical waste include bags into which the waste is placed, boxes into which the bags are placed, the labor cost of boxing the bagged waste, and the cost of shipping the boxed waste to the treatment site. These costs are implicit in the current out-of-state disposal contracts. For those hospitals that are treatment sites, on-site boxing of waste is unnecessary, so the cost of boxes and the cost of boxing the waste are omitted. The cost of bags is still included because all waste must be bagged. As for shipping the untreated waste, mileage and travel times between hospitals are estimated, as are truck costs. From these estimates a cost per ton-mile is determined from which a total cost of shipping untreated waste from a generating hospital to a treatment site is calculated for all possible shipping and receiving combinations.

Treatment Costs

The costs associated with each treatment option consist of the capital cost of acquiring the treatment equipment and the operating and maintenance cost associated with the equipment¹. Cost estimates for the different equipment sizes of each treatment option were obtained from the equipment vendors. Four treatment machine sizes were used for this analysis—a small (6 tons/month), a medium (35 tons/month), a large (100 tons/month), and a very large (130 tons/month). For graphical purposes, costs from these four treatment machine sizes, along with interpolated values, are included in Figure 3.

This cost curve reflects the treatment cost reduction possible as larger quantities of waste are processed. If a hospital generates five tons of biomedical waste per month and treats it with its own small machine (i.e., 6-ton-per-month capacity), the average total cost for

¹The costs include a permitting fee established and collected by the Maine DEP. The initial permitting fee is \$3,500 per site. Thereafter, there is an annual permitting of \$1,000 per site.

Table 1. Collection, treatment, and disposal costs included in the study.

	cost (\$)	Unit
Collection		
Bags, Liner	0.20	per bag
Bags, All Other	0.50	per box
Boxes, 4.5 Cu. Ft.	1.25	per box
Loading*	100	per ton
Shipping**	0.66	per ton-mile
Disposal		
Hauling****	0.17	per ton-mile
Transfer*****	3.54	per ton
Sharps Shredder		
Capital	95,000	per unit
Operating & maintenance	0.075	per lb
Permitting Fees		
Initial Fee	3,500	per site
Annual Fee	1,000	per site
Treatment		
6 Ton, Capital***	220,000	per unit
6 Ton, O&M	0.07	per lb
35 Ton, Capital***	346,000	per unit
35 Ton, O&M	0.05	per lb
50 Ton, Capital***	390,000	per unit
50 Ton, O&M	0.05	per lb
94 Ton, Capital***	500,000	per unit
94 Ton, O&M	0.05	per lb
100 Ton, Capital***	460,000	per unit
100 Ton, O&M	0.04	per lb
130 Ton, Capital***	495,000	per unit
130 Ton, O&M	0.04	per lb
210 Ton, Capital***	595,000	per unit
210 Ton, O&M	0.05	per lb

*Consists of the time it takes to prepare and load boxes

**Consists of \$60/hr for use of box van, 30 mile/hr average travel time (including stops), and 3-ton capacity of box van

***Includes cost of shredder

****Consists of \$85/hr for truck, 12-ton capacity of truck, and 42 mile/hr average speed

*****Consists of \$85/hr for truck, 12-ton capacity of truck, and 0.5 hours for unloading

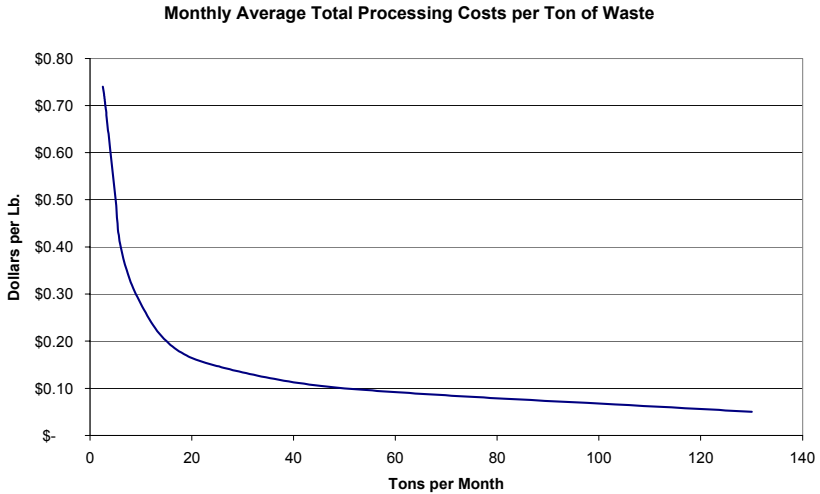


Figure 3. Average total costs of processing biomedical wastes, by volume of waste processed.

treatment is approximately \$0.50 per pound. However, if that hospital were to collaborate with other hospitals to buy and operate a large machine (i.e., 100-ton-per-month capacity), the average total cost for treatment drops to less than \$0.10 per pound. Thus, there are processing cost benefits (economies of size) to collaboration.

Disposal Costs

The last aspect of biomedical waste collection, treatment and disposal options is the disposal of the treated waste. Historically, Maine DEP policy has required that all biomedical wastes be unrecognizable. Shredding the waste to make it unrecognizable provides an indication that the waste has been treated and reduces the potential for anxiety over the presence of intact biomedical waste in public landfills. After shredding, the treated waste is shipped to any of six landfills in the state that have been included in the model as hypothetical disposal locations. The cost for disposal consists of the hauling cost from the treatment site to the landfill, the cost of transferring the waste at the landfill, and the per-ton tipping fee at the landfill.

The hauling cost is calculated using estimates of the cost and the capacity of the hauling trucks as well as a travel-time estimate between hospitals and landfills. The cost of transferring the waste at the landfill consists of the estimated time it takes to dump the waste

multiplied by the hourly cost of the truck. The per-ton tipping fee is based on rates published by each landfill.

In addition to the least-cost scenarios described earlier, this project also estimates the cost of biomedical waste disposal for each hospital under the current approach of shipping all waste out of state. Using recorded costs per ton of waste for various hospitals, a linear regression model was used to estimate costs per ton for each hospital in the state.

Based on the cost information noted above, the model evaluates the total cost of all the possible permutations of the collection, treatment, and disposal of all hospital-generated biomedical waste in Maine and selects the least-cost option². In doing so, the model determines the size of treatment equipment to use, how many pieces of each size of treatment equipment to use, at which hospital(s) the treatment equipment will be located, the optimal disposal site(s) for the treated waste, and which hospitals, if any, should continue to ship their waste out of state.

RESULTS

The model solution identifies significant cost savings compared to Maine hospitals' current approach to biomedical waste disposal. The model estimates the weighted average cost per ton of waste for all Maine hospitals as a group. Some hospitals will have a lower cost while other hospitals will have a higher cost. Currently, with all of Maine's biomedical waste shipped out of state, the estimated weighted average cost for each Maine hospital is \$685 per ton of waste.

In the base scenario, where all hospitals are potential waste treatment sites, the model determines that the least-cost option consists of two treatment machines—a very large treatment machine at Eastern Maine Medical Center (EMMC) in Bangor and a medium-sized treatment machine at Maine Medical Center (MMC) in Portland.

The facility in Bangor treats a total of 71 tons at an average cost of \$446 per ton. In Portland, the medium-sized facility would operate at full capacity to treat 35 tons of waste at an average cost of \$446 per ton. Sanford and York hospitals continue to ship their waste out of state, while Biddeford ships some of its waste to Portland and some out of state. For this solution, the weighted average cost for all Maine hospitals is \$445 per ton of waste (see Figure 4).

²The model was constructed with the spreadsheet optimization program What'sBest!, version 5.0, from LINDO Systems, Inc. The model includes 2,106 variables (156 integer variables) and 468 linear constraints. The base scenario required 1.9 million iterations to generate a solution.

Medical Waste Management Mode Base Scenario

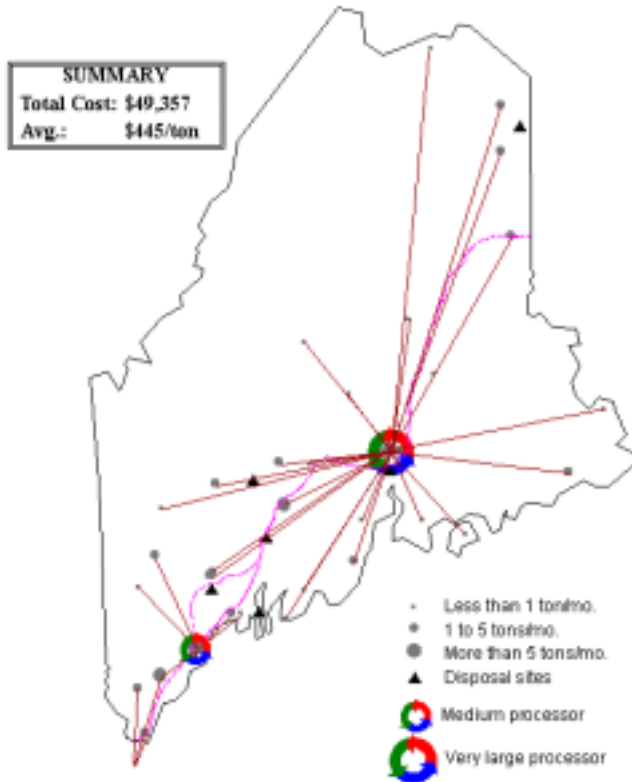


Figure 4. Model results under assumptions of the base scenario.

In the big four scenario, the four larger hospitals (MMC in Portland, EMMC in Bangor, and Maine General Medical Center and Inland Hospitals in Waterville) are evaluated individually while the least-cost solution for the remaining 35 hospitals is determined for those hospitals as group. In this scenario, EMMC processes its own waste on-site with a medium-sized machine. The Waterville hospitals and MMC in Portland continue to ship their waste out of state. To process the waste generated by the remaining hospitals, the model situates one very large treatment machine at Central Maine

Medical Center (CMMC) in Lewiston, while York continues to ship its waste out of state. The facility in Lewiston processes a total of 63 tons of waste at an average cost of \$516 per ton. The weighted average cost for all Maine hospitals under this scenario, including the four larger hospitals, is \$518 per ton of waste (see Figure 5).

The capital cost of a shredder is a significant proportion of the equipment costs. As a result, the no-shred scenario produces substantially different results. By removing the shredding requirement, the capital costs are reduced, but the boxing and transporting costs are relatively more expensive. Thus, it becomes cost effective to operate a larger number of small and medium machines across the

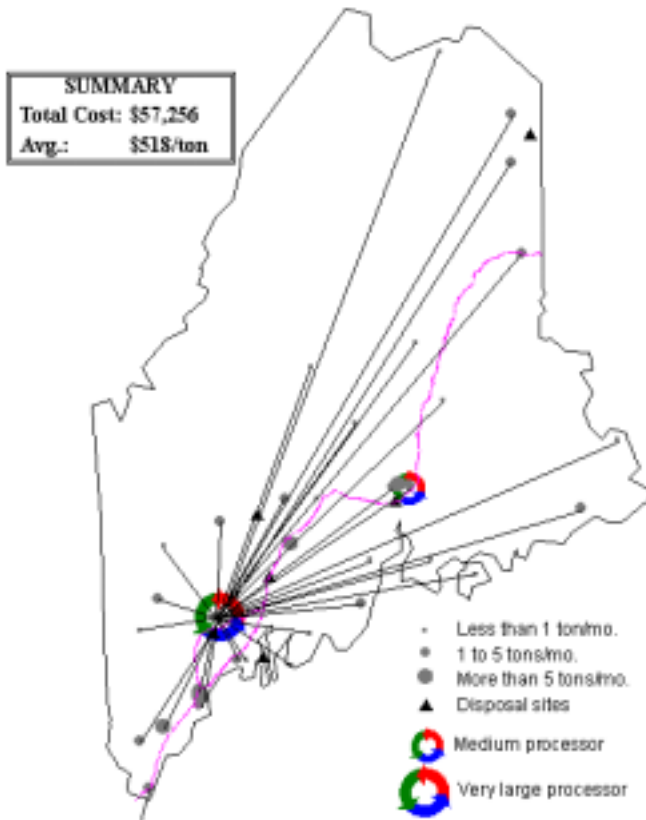


Figure 5. Model results under assumptions of the big four scenario.

state to treat the non-sharps portion of the waste stream. Under this scenario, there are eight small machines scattered around the state and two medium machines—one each at EMMC in Bangor and at MMC in Portland. The sharps are treated and shredded with a single machine located at EMMC in Bangor.

The weighted average cost of treating the non-sharps biomedical wastes (i.e., 95% of the biomedical waste stream) without shredding is \$391 per ton. The cost to treat and shred the sharps (i.e., 5% of the biomedical waste stream) separately is \$817 per ton. The combined total to treat all of the biomedical waste under this scenario is \$412 per ton (see Figure 6).

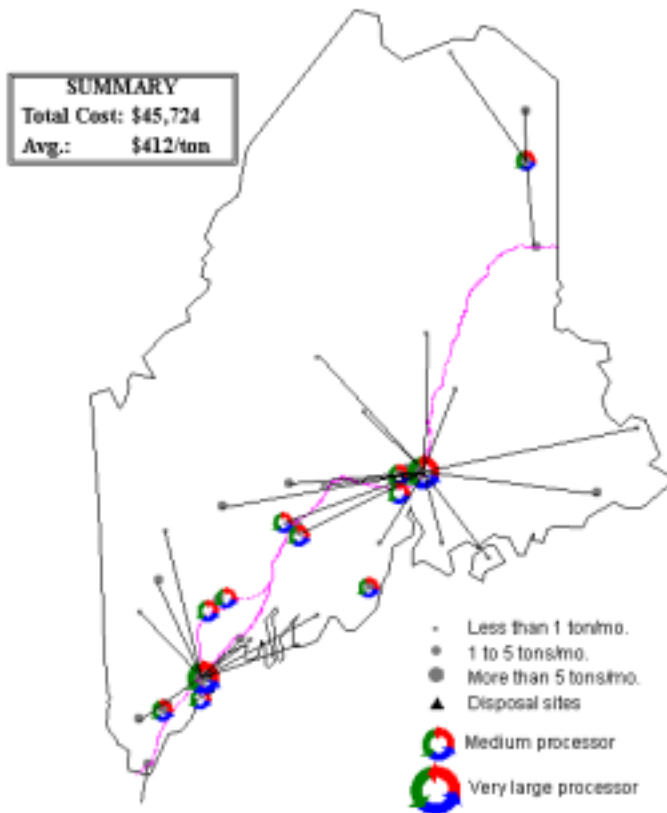


Figure 6. Model results under assumptions of the no shred scenario.

CONCLUSIONS

These results are only applicable where Maine hospitals are willing to collaborate with regards to biomedical waste disposal options. As the model has shown, it may still be cost effective for some hospitals to ship out of state. However, concerns over future availability and potential cost increases associated with out-of-state options may also lead those hospitals to collaborate. Each of the scenarios examined in this study involved some degree of collaboration that resulted in overall cost savings compared to the current situation (see Figure 7).

For any actions considered by hospitals with regards to the collection, treatment and disposal of biomedical wastes there are a number of key findings of this project that are significant. First, in-state collection, treatment, and disposal can provide overall cost savings, as shown by the decrease in average weighted costs in all three of the alternative scenarios. Second, while treatment costs are an integral part of the total cost of collection, treatment, and disposal of biomedical waste in Maine, the handling costs are also significant. Savings are likely to be realized by collaborating on everything from box and bag purchasing to shipping of untreated waste. Third, capital

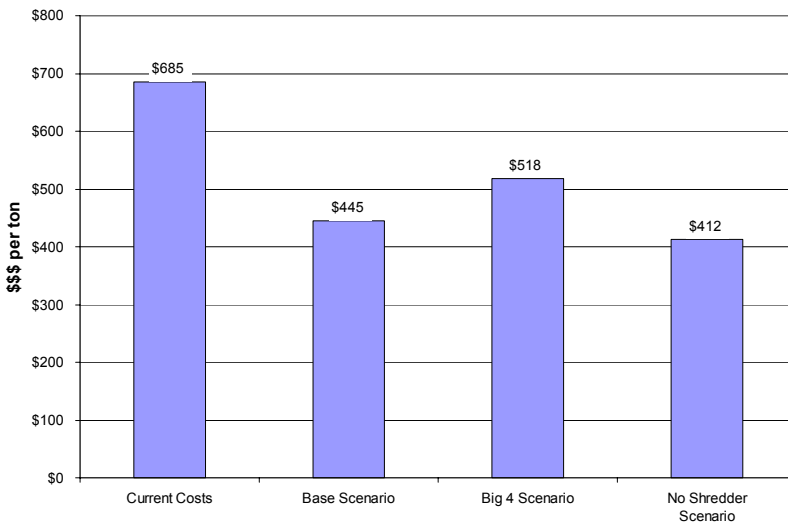


Figure 7. Weighted average statewide cost per ton for treating biomedical waste in Maine under different scenarios.

requirements of shredding are not cost effective for smaller hospitals. As shown in the first two scenarios, waste treatment with shredding is only processed at the larger hospitals; it is not until the shredding requirement is removed that on-site waste treatment becomes cost effective for smaller hospitals. And fourth, cost savings with in-state collection, treatment, and disposal of biomedical waste will vary from hospital to hospital depending upon the location of the hospital and its particular situation.

RECOMMENDATIONS

The results presented in this analysis are a significant contribution to the on-going evaluation of biomedical waste collection, treatment, and disposal in Maine. However, in order to reach a specific solution, more research is needed. The following three components are recommended: (1) evaluate alternative handling technologies; (2) examine specific treatment technologies; and (3) explore on-site versus off-site location issues and off-site treatment analysis.

Regarding the first component, an inquiry into lower-cost handling technologies should be made. For example, current boxing of untreated waste in cardboard boxes is an expensive approach that raises logistical issues. In place of cardboard boxes, perhaps biomedical waste could be transported in large, reusable, rolling tubs with water-tight lids. This seems a logical approach, but more research is needed to determine if the approach warrants serious consideration.

With regard to the second component, an examination of the specific treatment technologies is needed. The current analysis uses estimated costs of two technologies, and makes no claims regarding the specific technologies themselves. For hospitals to make appropriate choices, the advantages and disadvantages of each treatment technology must be known. Some of this work has been completed by Maine Department of Environmental Protection staff, but the final decisions must be made by the purchasers of the equipment. Contact with hospital staff where these two technologies are currently being used is strongly recommended.

This analysis assumes that the waste-treatment facilities will be located at various hospitals. While this assumption works in this analysis, it may be problematic in actual practice. First, hospitals may not have the physical space for an on-site waste treatment facility. Many hospitals use all the physical space available and have no space for a waste-treatment facility. Second, while hospitals may have the physical space to build a waste-treatment facility, they may

not want to incur legal, logistical, and public relations problems associated with a treatment facility on hospital grounds.

As a result of these impediments to locating a waste-treatment facility on hospital grounds, it is recommended that the results of this current analysis be extended by incorporating the additional costs associated with development of an off-site location for a waste-treatment facility. The determination of those added costs would be accomplished by including engineering and site development costs into the analysis. By developing such a scenario(s), hospitals are relieved of housing a waste-treatment facility on-site and the added responsibilities that go with that facility. In addition, an off-site location presents a more balanced opportunity for hospital-to-hospital collaboration. No matter the scenario, however, it is estimated that there will have to be some degree of hospital-to-hospital collaboration in order to achieve the least-cost results.

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- Health Care Without Harm. 2000. “Medical Waste Treatment Technologies: Evaluating Non-Incineration Alternatives”; May 2000. Falls Church, VA.