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SOLID WASTE INCINERATION AND ENERGY RECOVERY IN HOSPITALS

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ABSTRACT

Small-scale, on-site incineration is examined as one practical method for disposing of hospital solid waste. On-site incineration-energy recovery systems are reviewed and potential annual savings of conventional fuel costs are computed as a function of bed capacity and fuel costs. Potential savings in a 500 bed hospital, for example, are found to range from 19,000 to 57,000 dollars per year for a fuel price range of one to three dollars per million Btu. A market survey of 492 hospitals in Pennsylvania, New Jersey and Delaware indicates a strong potential interest in on-site incineration-energy recovery systems. Extrapolation of the survey results to the northeast and middle atlantic regions shows a potential market of 500 to 600 small-scale units. Potential blockages to the hospital market, such as particulate emissions and auxiliary fuel requirements, are discussed.

Introduction

Hospitals, together with nearly all other sectors of the economy, face a growing technical and economic burden associated with solid waste disposal. Solid waste generation rates in hospitals increased by nearly a factor of three since 1960. Presently an average of fifteen to twenty pounds per bed per day are produced [1], and estimated rates of thirty pounds per bed per day and higher have been reported for individual hospitals [2].

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The practical alternatives of hospital solid waste disposal include sanitary landfill, on-site incineration, and municipal incineration. Landfill may involve disposal of waste in the original volume in which it was produced, or the volume may be reduced prior to transportation to the disposal site by compacting, pulping or chopping followed by compacting. Incineration is viewed as both a weight and volume reduction process, and must be followed by residue disposal. Either alternative offers both environmental and economic advantages and disadvantages to hospital solid waste management programs.

The present study considers the question of on-site incineration as a viable method for the disposal of hospital solid waste. Following a brief review of past and current hospital waste management techniques we present a solid waste profile for hospital waste, including a description of hospital waste, waste generation rates, waste compositions, and waste heating values. Data for this profile have been gathered from several recent studies found in the literature and from incinerator manufacturers and engineering consultants working in the area of hospital waste disposal. Current on-site incinerator technology, suitable for hospital waste disposal, and energy recovery techniques are then reviewed. Energy recovery considerations include estimates of potential amounts of energy recovery from a representative hospital waste, equivalent amounts of hot water and low pressure steam, and potential savings on the cost of conventional fuel requirements. The next section presents a summary of a survey of 492 hospitals in Pennsylvania, Delaware, and New Jersey, carried out during the summer of 1974. This survey was designed to evaluate the market opportunity for on-site incineration, with and without energy recovery considerations, in the hospital market. Finally, we consider potential blockages to the development of the hospital market.

Hospital Waste Disposal Techniques

In the past, dumping and incineration, which were and still are the most widely used methods for final disposal of hospital solid waste, were both carried out with little regard for the environment. Dumping simply meant throwing the waste into the nearest available open pit. Incinerators usually lacked gaseous and particulate emission controls and were often a source of smoke and odor to the nearby community. Recent public awareness and concern for the environment has led to legislation regulating landfill and incineration operation. As a result, solid waste management in hospitals has become more complex and costly.

In general, current hospital waste management involves four main stages [2]:

1. waste collection within the hospital;
2. waste treatment on the hospital premises;
3. transportation to the final disposal site; and
4. final treatment and disposal.

Landfill is now the predominant method used for the final disposal of hospital waste. Most hospitals contract with private haulers for pickup at regular intervals. Larger hospitals usually compact waste prior to pickup, a step which may save as much as 70 per cent in hauling charges [3]. The expense of landfill disposal has risen sharply in recent years however, due mainly to increased hauling costs, labor costs for in-hospital collection and capital investment in compactors, pulpers, etc. to reduce the volume of solid waste to be hauled. In addition, there are disadvantages connected with the landfill operation itself. Those frequently cited include:

1. unavailability of landfill sites near the solid waste source;
2. the potential for pollution of ground water by leachate from the landfilled material; and
3. potential limitations on subsequent use of completed landfills.

On-site incineration is less frequently used for hospital waste disposal, and has in fact declined in recent years. Several reasons may be cited for this situation, however, the principal cause appears to be the inability of older on-site incinerator technology to meet air pollution standards on particulate emissions. Recent developments in incinerator design have resulted in controlled air incinerators, based on the concept of two-step combustion [4-6]. Such incinerators satisfy most existing state and local emission standards without the use of emission control devices (wet scrubbers, electrostatic precipitators, etc.), and are available in sizes suited to the waste disposal needs of hospitals.

In light of the above mentioned developments, on-site incineration offers a potential solution to the solid waste disposal needs of hospitals. Several advantages of on-site incineration may be noted. Generally the volume reduction of solid waste processed by an incinerator ranges between 80 and 95 per cent, depending on the noncombustible fraction of the waste. Significant savings in collection and hauling costs may thus be realized by on-site incineration. Potential application of energy recovery for on-site incinerator systems may provide distinct opportunities to partially alleviate the increasing scarcity and costs of conventional fuel sources. In addition, on-site incineration of the pathological portion of hospital wastes is especially attractive since it minimizes handling and transportation of potentially infectious wastes.

Disadvantages often cited for incineration include:

1. potential for high emissions;
2. requirement for auxiliary fuel; and
3. economic considerations.

Each of these play an important role in hospital waste management decisions on incineration as an alternative to sanitary landfill disposal.

Hospital Solid Waste Profile

WASTE CLASSIFICATION

Hospital waste is, in general, composed of several different types of solid materials. At least seven descriptions of hospital waste have appeared in the literature since 1956 [7]. Terminology and definitions often differ, and in many cases waste descriptions are suited to a particular application or waste disposal study. For the present study, a simplified classification of hospital solid waste is adopted [1]. Hospital solid waste is considered to be composed of the following:

Trash—This is a mixture of paper, cardboard, cartons, plastics, disposable linens, wooden boxes, dunnage, furniture, cans, bottles, and glass. Trash is similar to I.I.A Type 0 waste and has a heating value of 8500 Btu/lb as fired.

Garbage—This consists of animal and vegetable waste from the preparation, cooking, and serving of food. This type of waste corresponds to I.I.A Type 3 waste with a heating value of 2500 Btu/lb as fired.

Food service waste—This category includes garbage and all kitchen, cafeteria, and patient tray scrappings, paper, plastic, wax containers, and solid and liquid food wastes. Heating value varies, depending on the ratio of garbage to paper, plastic, and wax containers.

Pathological waste—Human tissues, animal carcasses, organs, animal bedding, and animal feces make up this category. In addition, material from some laboratory experiments may be included. Pathological waste is similar to I.I.A Type 4 waste and has a low heating value of 1000 Btu/lb.

Contaminated waste—This includes all waste that has been in contact with a patient or patient area and, as a result, may be infectious. Heating values depend on the type of waste involved.

In addition to the above mentioned waste types, street refuse such as sweepings, leaves, and the contents of litter baskets and construction waste such as metal partitions, sheet rock, masonry, etc. are often found. Special or hazardous types are also present. These include discarded sharp operating room instruments, needles, radioactive wastes, and possibly explosives. Recent years have seen the increased use of plastics and single-use disposable items. In addition, the newest type of waste material appearing in hospital waste is flame-retardant paper, used for bedding and gowns.

SOLID WASTE GENERATION RATES

The literature contains a number of studies, dating from 1937 to the present day, which estimate the amount of solid waste produced by hospitals [7]. In these, waste amounts are usually expressed as a generation rate in pounds/day/bed or pounds/day/patient. Prior to the early 1960's estimated generation rates showed little year to year variation; approximately 7 lb/day/bed is a typical figure for this period. Reports issued since 1968, however, show a marked increase in solid waste generation rates, coinciding with the increased use of single-use disposable items seen in recent years [2]. Estimated rates also vary widely, ranging from 5 to 30 lb/day/bed, but in many cases the higher rates are associated with a single hospital or with unusual conditions.

The most recent comprehensive studies appear to be those of Iglar and Bond [7], and Bond et al. [2]. The former reports the results of a 1967-1969 survey of 100 hospitals selected at random across the nation. Solid waste amounts were directly measured and the data was found to correlate with bed capacity. Based on this correlation, solid waste generation rates of 7.2, 9.1, and 9.7 lb/day/bed are computed for hospitals having 200, 400 and 600 beds respectively. In a follow-up survey, conducted during 1971-1972. Bond again surveyed the same 100 hospitals [2]. Apparently, new data on solid waste generation was not gathered at this time. The earlier data was, however, re-examined, and the effects of such factors as hospital location in SMSA and non SMSA areas, (Standard Metropolitan Statistical Area, SMSA, is defined as an area including one city with 50,000 inhabitants or more) the use of single-use dietary items, patient items, and surgical items, and computer services on solid waste generation rates were determined. A solid waste generation of 9.7 lb/day/bed for a representative 500 bed hospital is indicated.

Recent (1974) guidelines published by Syska and Hennessy, Inc. [1] show increased waste generation rates over the earlier studies mentioned above. Rates of 15 lb/day/bed of trash for hospitals with less than 400 beds and 20 lb/day/bed for hospitals with 400 beds or more are recommended. In addition, food service waste guidelines indicate 1.5 lb/meal for patient and restaurant service, and 0.25 lb/transaction for coffee shop service. The approximate daily load for a 500 bed hospital is estimated to be 16,000 lb of trash and food service waste.

It appears that pathological and contaminated wastes do not contribute greatly to the solid waste load of a hospital. Moreover, such waste material is nearly always segregated and disposed of in a pathological incinerator or by autoclave methods [1].

SOLID WASTE COMPOSITION

Hospital waste compositions tend to vary, depending on factors such as the amount of single-use disposable items used, the use of prepared foods, the degree of teaching and research activity, and others. In their 100 hospital survey, Iglar and Bond report mean values of 50 per cent combustibles, 28 per cent garbage, and 9.2 per cent incombustibles [7]. Syska and Hennessy, Inc. indicate that paper products usually constitute about 70 per cent of the total waste load [1]. Other products are found in the following approximate proportions: plastic (10%), food (10%), glass (5%), metal, rubber, linen, etc. (5%). Other evidence indicates that the amount of plastic found in hospital waste may be as high as 20 per cent by weight [8]. The newest development in the changing character of hospital waste is the use of flame-retardant paper bedding and gowns. If this material is to be incinerated, its flame-retardant characteristics are quite important; however, information on this point does not appear to be available in the literature or from manufacturers of these items.

Estimated Heating Values

If the garbage content of hospital waste is excluded, approximate heating values, expressed in Btu/lb as fired, are given by

$$\text{H.V.} = 8{,}500(1 - X_p) + 18{,}000(X_p), \qquad (1)$$

where X_p is the mass fraction of plastic contained in the waste, Equation (1) assumes that the non-plastic portion of the waste is similar to I.I.A. Type 0 trash (8,500 Btu/lb) and 18,000 Btu/lb is taken as an average heating value for plastics. Since plastic content can range from 10 to 20 per cent by weight, on a garbage free basis, heating values of 9,500 to 10,500 Btu/lb can be expected. If food wastes are included in hospital trash, lower heating values are expected. For example, hospital waste composed of 80 per cent trash, 10 per cent plastic, and 10 per cent garbage results in an estimated heating value of 8,900 Btu/lb, while a mixture of 60 per cent trash, 10 per cent plastic, and 30 per cent garbage lowers the estimated heating value to 7,600 Btu/lb as fired.

HOSPITAL APPLICATIONS OF ON-SITE INCINERATORS

It is clear that an accurate estimate of the daily solid waste load of a given hospital requires an on-site survey. For purposes of this study, however, it is sufficient to compute an estimated range of daily waste loads based on the aforementioned most recent waste generation rates [1]. For hospitals with a bed capacity between 100 and 700 beds, daily solid waste loads are found to range between 2,000 and 17,000 lb/day respectively. It is noted that this estimate is based on the generation of general trash and food service waste for patient meals only. Restaurant, cafeteria, and coffee shop wastes will result in greater waste loads. In addition, extensive research and teaching activity may increase the above estimates by substantial amounts.

Daily waste loads of the magnitude shown above fall within the range of small-scale on-site solid waste incinerators, whose design capacity is in the range of 50 to 4,000 pounds of solid waste per hour [9]. There are, at present, several incinerator designs which fall under the small-scale definition. A complete review of all such designs is beyond the scope of the present paper (a comprehensive review may be found in Reference [9]); however, one type, the controlled air design incinerator, appears to be well suited to the needs of hospital waste disposal programs.

Controlled air incinerators are based on the concept of two-step combustion [4-6]. Essential components of these systems include a primary chamber, a low-velocity settling section, a secondary reaction chamber, auxiliary fuel burners, and distribution and control systems for air modulation. Often, these incinerators employ controlled amounts of combustion air in both the primary and secondary chambers. Secondary chamber designs vary. Two designs use the lower portion of the stack as a secondary reaction chamber equipped with an afterburner. In other designs the afterburner is located in a secondary settling chamber which is equal in volume to the primary chamber, and which is connected to the primary chamber by a short duct.

In controlled air incinerators, waste is first burned in the absence of sufficient oxygen for complete combustion in the primary chamber. This process generates a highly combustible gas mixture that is then burned with excess air by gas or oil fired afterburners in the secondary chamber. This two-step combustion process results in highly efficient combustion with little or no gaseous emissions released to the surroundings. Furthermore, particulate emissions are minimized, apparently as a result of particulate settling promoted by low-velocity, recirculating flow fields in the primary and secondary chambers. Indeed, at this time, controlled air incinerators are the only small-scale incinerators which consistently meet existing particulate emission standards without the use of additional control devices, such as wet scrubbers, cyclone dust collectors, etc., used on other small-scale designs (particulate emissions will be discussed more fully below).

ENERGY RECOVERY POTENTIAL

In the light of the increasing scarcity and costs of conventional fuel sources, small-scale incinerator systems which employ energy recovery may offer distinct opportunities to hospitals. The technology of such systems is at this time still developing, and papers discussing energy recovery from small-scale units have been relatively limited until recently. Recent applications with energy recovery for units with capacities in the range 200 to 2000 lb/hr have been developed in Europe; these have been summarized in a recent paper [10]. A number of United States controlled air incinerator manufacturers now offer small-scale energy recovery systems. In some cases, a heat exchanger is mounted directly in the incinerator stack. In large capacity units, the exchanger is usually located adjacent to the incinerator. Options for processing steam, hot water, or hot air are available.

All of the energy liberated by combustion (e.g., higher heating value of the solid waste times the burning rate) plus the energy liberated due to the combustion of any secondary fuel is not available for energy recovery. A number of factors define the maximum usable energy which may be extracted in a particular application. These include:

1. energy required to evaporate water in the waste material;

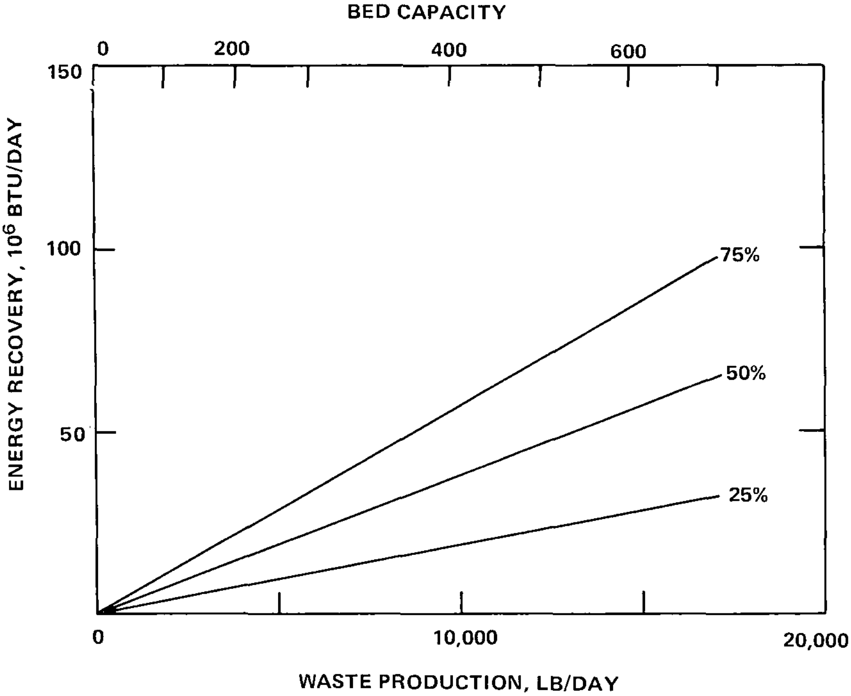

Figure 1. Estimated daily energy recovery from hospital waste as a function of daily waste load and energy recovery efficiency.

2. heat transfer losses from the incinerator to the surroundings;
3. minimum flue gas exhaust temperatures from the heat transfer device to eliminate corrosion and condensation problems;
4. overall heat exchanger or boiler efficiency.

Therefore, a detailed thermodynamic and heat transfer analysis is required to determine the potential of any projected energy recovery system. Depending on the specific application, the useful energy derived in a typical energy recovery system may range from 25 to 75 per cent of the energy released by combustion.

A specific example may serve to indicate the potential for energy recovery from small-scale incineration of hospital waste. In Figure 1, the amount of useful energy recovered per day is plotted against daily solid waste load for 25, 50, and 75 per cent recovery of the energy released by combustion. This calculation assumes a waste consisting of 60 per cent trash, 30 per cent garbage, and 10 per cent plastic, with a heating value of 7,600 Btu/lb as fired. Energy contributions from auxiliary burner fuel have been neglected;

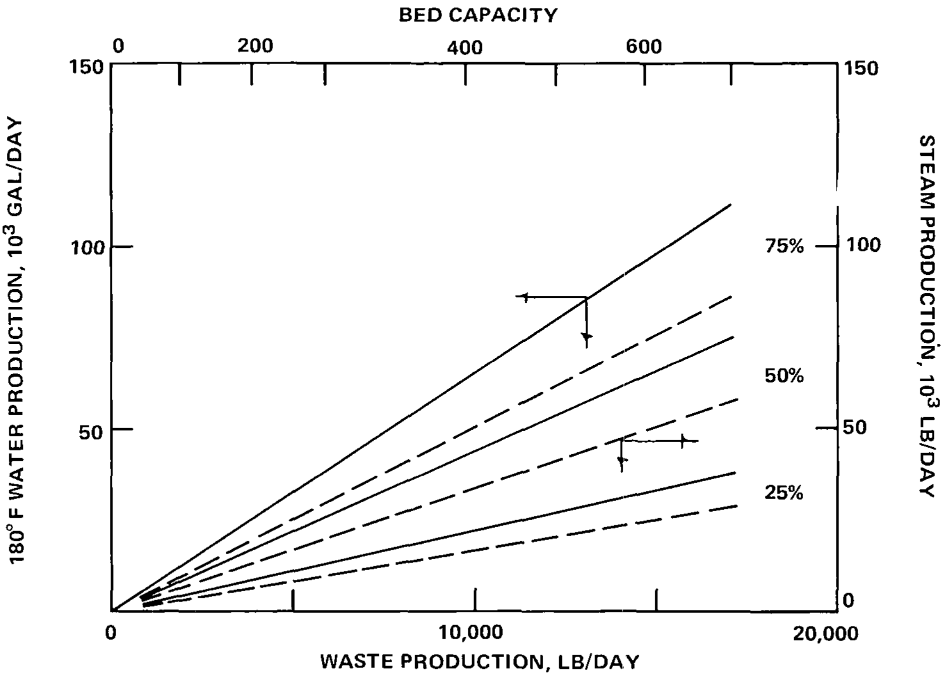

Figure 2. Estimated daily production of 180°F hot water and 15 psig, 250°F steam as a function of daily waste load and energy recovery efficiency.

thus, these results may in fact represent low values. Selected hospital bed capacities are shown on the same figure. These have been computed using the latest available waste generation data [1], as previously discussed in the hospital solid waste generation profile. Only trash and patient food service wastes have been included and the daily waste loads corresponding to a given bed capacity may represent minimum values.

In all probability, energy recovery in hospitals will be in the form of hot water or low pressure steam generation. Figure 2 shows daily amounts of 180°F water, in gal/day, and 15 psig, 250°F steam, in lb/day, corresponding to the daily energy recovery values shown in Figure 1. It is evident that energy recovery assumes significant values for bed capacities in the 300 to 700 bed range. In addition, energy recovery from solid waste incineration will not supply the total energy needs of a large hospital.

There is, however, a potential for significant savings in fuel costs when energy recovery is used to supplement conventional fuel requirements. This is shown in Figure 3, where annual savings on

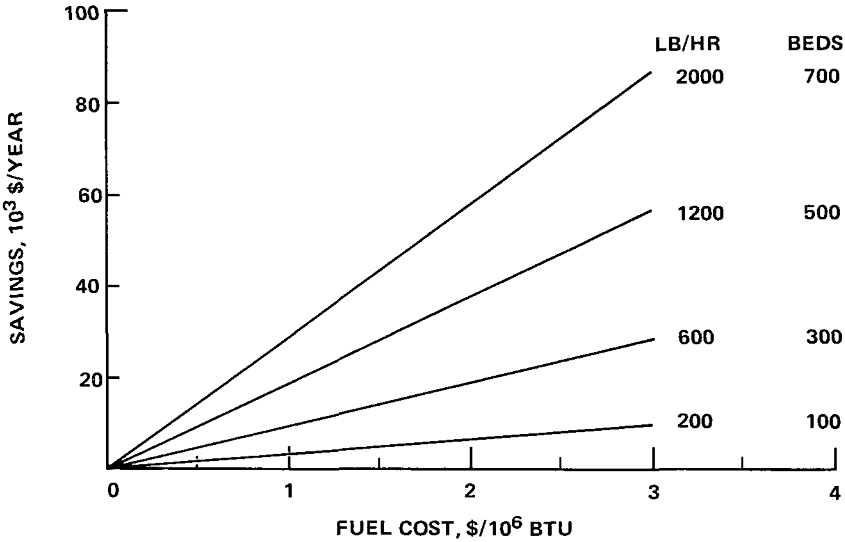

Figure 3. Estimated annual savings on conventional fuel costs resulting from solid waste incineration with energy recovery for constant values of incinerator charging rate. Corresponding hospital bed capacities are based on 10 hr/day operation at the indicated waste charging rate.

fuel charges are plotted against fuel costs, expressed in dollars per million Btu, for selected values of incinerator charging rate. Corresponding hospital bed capacities, based on incinerator operation for ten hours per day at the indicated charging rates, are also shown. It is assumed that the incinerator-energy recovery system operates at 50 per cent overall energy recovery efficiency, and that a conventional gas or oil fired system, supplying energy at the same rate as the incineration system, operates at 75 per cent overall efficiency. Auxiliary fuel requirements of 10^6 Btu per ton of waste have been included in determining the net annual savings in fuel costs resulting from incineration with energy recovery. Conversion of the results shown in Figure 3 to amounts of fuel saved per year may be accomplished using 150,000 Btu/gal and 1000 Btu/scf as the average heating value of fuel oil and natural gas respectively. It is seen that annual fuel costs savings can reach significant amounts, particularly in large hospitals.

HOSPITAL SURVEY RESULTS

In order to establish an estimate of the current market for small-scale incineration systems in the hospital area, a market survey was carried out during the summer of 1974. Since a complete national survey was not feasible, questionnaires were sent to 492 hospitals in the states of Pennsylvania, New Jersey, and Delaware. This sample represents 6.8 per cent of the nation's 7200 hospitals and comprises a cross section of geographic and economic conditions, i.e., both rural areas and the large urban-industrial Delaware River Valley region. Replies were received from 172 of the hospitals surveyed—a 35 per cent return—and for the most part, all questions were answered. Details of the sample are summarized in Figure 4 which shows the per cent distribution according to selected bed capacity ranges for: (A) all hospitals in the nation, (B) all hospitals in the tri-state survey. In comparison with the national distribution, it is evident that the sample favors large hospitals with bed capacities of 100 and more; however, these are the hospitals which face large waste disposal burdens.

It was felt that enough information for completing the solid waste profile was available in the literature; therefore questions related to this topic were not asked. Instead, the survey concentrated on three key areas:

1. the methods currently used to dispose of solid waste;
2. the interest on the part of hospitals in purchasing small-scale on-site incinerators to dispose of solid waste;
3. the interest on the part of hospitals in small-scale incinerator-energy recovery units.

A summary of the response in the above three areas is presented in Table 1. It is first seen that nearly one-half of the hospitals currently use landfill for disposal. In addition most of the hospitals which indicated other methods listed contract-hauling, which undoubtedly indicates final disposal in a landfill. Approximately 20 to 30 per cent of the hospitals now use on-site incineration while a small percentage use municipal incinerators. It is noted that the use of compactors increases with bed capacity with 77 per cent of the hospitals having 500 and more beds using this method of volume reduction.

When asked if they would consider the purchase of an incinerator which meets all air pollution standards to dispose of solid waste (Table 1, Section C) more than one-half of the hospitals indicated a negative response. It must be noted, however, that some of these hospitals use on-site incineration at this time and might not be interested in replacing their existing units. If, for example, the eight hospitals with 500 or more beds which now use

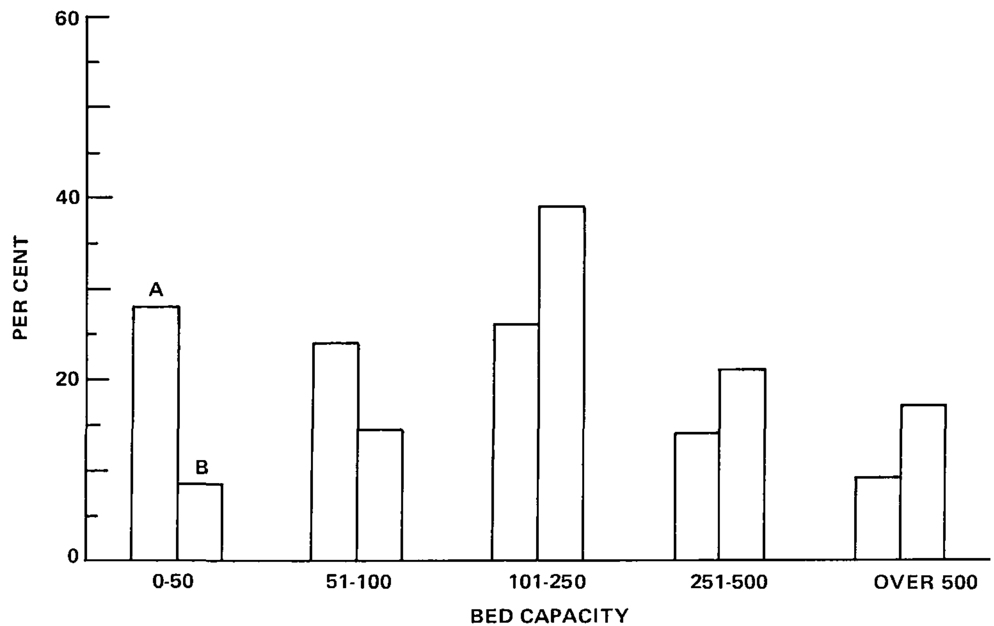

Figure 4. Per cent distribution according to selected bed capacity range for; (A) 7200 hospitals in the United States, and (B) 492 hospitals in Pennsylvania, New Jersey, and Delaware.

Table 1. Summary of Hospital Solid Waste Market Survey

A. Per cent distribution of current waste disposal methods.

Bed capacity	N_i[a]	N_j[b]	*Landfill*	*Municipal incinerator*	*On-site incinerator*	*Other*
0-50	3	4	67	–	33	–
51-100	18	18	33	5.6	49	22.4
101-250	52	53	40.5	3.9	29	26.4
251-500	58	59	41.5	6.9	27.6	24
over 500	37	38	54	5.4	21.6	19
	168	172				

B. Per cent distribution of current waste hauling methods.

Bed capacity	N_i	N_j	*Open container*	*Compacting*	*Bailing*
0-50	3	4	67	33	–
51-100	13	18	53.9	38.4	7.7
101-250	47	53	46.9	49	4.1
251-500	53	59	32	68	–
over 500	35	38	17.3	77.2	5.5
	151	172			

C. Per cent distribution of hospitals indicating interest in the purchase of an incinerator that meets all air pollution standards.

Bed capacity	N_i	N_j	*Yes*	*No*
0-50	4	4	–	100
51-100	18	18	44.5	55.5
101-250	50	53	56	44
251-500	58	59	43	57
over 500	35	38	40.5	59.5
	167	172		

D. Per cent distribution of hospitals indicating interest in the purchase of a new incinerator if fuel savings would result.

Bed capacity	N_i	N_j	*Yes*	*No*
0-50	4	4	–	100
51-100	18	18	55.5	44.5
101-250	49	53	57	43
251-500	52	59	52	48
over 500	31	38	48.5	51.5
	154	172		

[a] N_i = number of hospitals answering this survey question.
[b] N_j = number of hospitals responding to the survey.

incineration are taken into account, the percentage of hospitals in this size range interested in purchasing an incinerator increases from 40.5 per cent to 51.7 per cent—this despite the fact that 77 per cent of these large hospitals now have a capital investment in compaction equipment.

Apparently potential fuel cost savings and concerns over current and future increases in the scarcity and costs of conventional fuel sources influence a hospital's attitude toward incineration. This is seen in Section D of Table 1 where over 50 per cent of those hospitals having 50 to 500 beds indicated an interest in purchasing a new incinerator if savings on fuel would result. Again, some hospitals answering no may already have an incineration system.

Care must be taken in attempting to extrapolate the results of this survey to the entire nation since the region sampled may not be representative of large areas of the country. It would seem, however, that the region considered is representative of the northeast and middle atlantic sections of the country in such characteristics as industrial development, large urban centers, and rural areas. An extrapolated estimate of the market potential for small-scale incinerators for hospital use will thus be made for EPA Regions I, II, and III. This area includes the New England states, New York and New Jersey, and the Middle Atlantic states including West Virginia. There are 1,121 hospitals with 100 beds or more in this area. Assuming that an average of 45 per cent of these have an interest in on-site incineration, the potential market amounts to 504 units. If it is further assumed that an average of 55 per cent of these hospitals are interested in small-scale incineration with energy recovery, the potential market is increased to 616 units.

POTENTIAL BLOCKAGES TO THE HOSPITAL MARKET

There are at least two factors which may hinder the development of the hospital market for small-scale incinerators. For one, in nearly all instances, small-scale incinerators must be source tested to show compliance with state and/or community regulations on particulate emissions. Particulate emissions have been a problem for older small-scale incinerator designs. This is not the case with modern controlled air incinerators, and these units have been shown to produce low particulate emission levels without the use of costly flue gas treatment devices such as gas scrubbers. In a recent analysis [11], the results of source tests for particulate emissions on thirty-two controlled air incinerators of various design were evaluated. Some 75 per cent of these units were in compliance with the particulate emission standard of thirty-two states (either 0.1 lb of particulate per 100 lb of waste charged, or 0.1 grains of particulate per standard cubic foot of flue gas corrected to 12% CO_2). Ninety-seven per cent of these same units met the standard in twenty-two states.

A major problem results from the fact that certification at the state level is not binding on a community within that state. Manufacturers find that individual source tests must be carried out on the same model incinerator in adjoining cities, even though the emission standard is the same in each case, and the operating conditions are similar. Cities such as New York and Philadelphia have banned the installation of new incinerators, probably because of poor emission performance in the past. A recent survey of selected major cities across the country has shown that this is not the general case [11].

Secondary fuel requirements for primary burner and after-burner operation may also be a potential blockage to market development. Auxiliary fuel requirements may run as much as 10^6 Btu per ton of waste processed, and operating costs such as these must be offset by savings on hauling charges for loose or compacted waste. Small scale energy recovery units should, however, negate auxiliary fuel costs and may, as indicated previously, result in an overall savings on fuel costs.

Summary and Conclusions

Throughout this paper, it has been stressed that the evaluation of on-site incineration as a waste disposal technique for a given hospital requires a detailed, on-site study. Looking at the general solid waste disposal problem in hospitals, however, the following conclusions on small-scale incineration as a practical alternative to landfill may be stated.

1. Hospital solid waste disposal needs fall within the capacity range of small-scale incinerators (200 to 4,000 lb/hr). One class of modern small-scale incinerators, the controlled air designs, appear to be well suited to hospital use. These units have proven low emission levels and can meet existing air quality standards without costly control devices.
2. Small-scale incineration coupled with energy recovery offers distinct opportunities for savings on conventional fuel costs. Energy recovery from solid waste will not meet the total energy requirements of a hospital; however, a significant part of the need may be provided on a supplementary basis.

3. The potential market for small-scale incineration in hospitals is good. Approximately 45 per cent of the hospitals responding to a survey of the Pennsylvania, New Jersey and Delaware area indicate an interest in incineration alone as a waste disposal method. Approximately 55 per cent of the same hospitals indicate an interest in incineration and energy recovery.
4. Particulate emission levels in small-scale incinerators and auxiliary fuel requirements may be potential blockages to the development of the hospital market. Controlled air incinerator technology has been successful in reducing particulate emissions to levels acceptable to state emission standards. The need to test nearly every new installation of the same model incinerator may, however, place an economic burden on the customer and thus lessen the market. Auxiliary fuel costs may be compensated for by saving in hauling charges resulting from incineration. In addition incineration with energy recovery eliminates this blockage.

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