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COST ANALYSIS OF INCINERATION AND AUTOCLAVE TECHNOLOGIES FOR BIOMEDICAL WASTE MANAGEMENT IN MYSURU CITY

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ABSTRACT
Biomedical Waste is a worldwide problem. Currently there is a steady increase in its generation associated with increasing demand of healthcare, thus leading to establishment of more Health Care Centres. Sustainable management of hospital waste requires an active involvement of all key players. The cost of disposal of biomedical waste using incineration and autoclave was calculated.

Keywords: *Biomedical Waste Management, health care personnel, cost analysis.*

INTRODUCTION
The rising burden of chronic diseases in India has significantly increased the demand for healthcare services, resulting in the rapid expansion of healthcare facilities, particularly in urban areas. Healthcare delivery is indispensable for human well-being and encompasses a spectrum of interventions, ranging from minor treatments to complex surgical procedures. In the process of providing medical care, hospitals and related institutions generate diverse categories of waste, including anatomical materials, chemicals, pharmaceuticals, medical devices, and radioactive substances. With the advancement of healthcare technologies and the widespread adoption of disposable medical products, the volume of biomedical waste generated has escalated substantially, posing growing challenges for effective waste management.

These wastes because of their hazardous nature have undesirable effects on the environment causing pollution and also affecting individual health.

Hospital waste: refers to all waste, biological or non-biological, that is discarded and is not intended for further use.

Medical waste: refers to materials generated as a result of patient diagnoses, treatment, and immunization of human beings or animals.

Bio-medical Waste Management in India[1]

No. of HCFs	4,35,257
No. of bedded HCFs	1,37,132
No. of non-bedded HCFs	2,98,125
No. of beds	30,91,847
No. of CBWTFs	No. of CBWTFs
No. of HCFs utilizing CBWTFs	3,14,586
Quantity of BMW generated in tons/day	743
Quantity of BMW treated in tons/day	694
No. of HCFs/CBWTFs violated BMW Rules	20,081

Comparison of Biomedical Waste Management between year 2022 and 2023[1]
According to the Central Pollution Control Board Annual Report for 2023 on biomedical waste management, India generated approximately 743 tons of biomedical waste per day, an increase from 705 tons per day reported in 2022. This upward trend reflects a notable rise in waste generation, largely attributable to the 9.4% increase in the number of healthcare facilities established in 2023 compared to the previous year. The report also highlights a rise in the number of CBWTFs, increasing from 218 in 2022 to 234 in 2023, facilitating the treatment and disposal of biomedical waste.

As per BMWM Rules, 2016, "Health Care Facility means a place where diagnosis, treatment or immunization of human beings or animals is provided irrespective of type, size of health treatment system, and research activity pertaining thereto. It includes bedded and non-bedded HCFs".

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Maharashtra(76413) has the highest number of HCFs followed by Karnataka(54594) and Uttar Pradesh(43860). Sikkim(344) has the lowest number of HCFs followed by Mizoram(393) and Arunachal Pradesh(450) 1.

Status of Biomedical Waste Generation & Treatment[1]

Biomedical Waste Generation

Bio-medical waste "means any waste which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps, including the categories mentioned in Schedule I of BMWM Rules, 2016". As reported by SPCBs/PCCs, about 743 tons/day of biomedical waste was generated during the year 2023 by 4,35,257 numbers of HCFs. The biomedical waste generation generally depends on the number of healthcare facilities present in the State, population density, type of healthcare facility, etc.

Quantity of waste generated tonnes per day :Uttar Pradesh generates the highest at 99.12 tonnes per day, followed by Maharashtra at 77.86 tonnes per day and Karnataka produces around74.01 tonnes per day.

Treatment of Biomedical Waste

As per Rule 7 (1), biomedical waste is required to be treated and disposed of in accordance with Schedule I, and in compliance with the standards provided in Schedule-II of BMWM Rules, 2016. Out of 859 tons/day of biomedical waste generated in the country, 694 tons/day of BMW is treated and disposed of by CBWTFs and CTFs installed by HCFs. For environment friendly disposal of biomedical waste, there should be no gap between generation and treatment & disposal of biomedical waste.

Waste generated in Karnataka for the year 2022- 2023 [1]

No. of HCFs	54,594
No. of bedded HCFs	10,183
No. of non-bedded HCFs	44,411
No. of beds	2,43,071
No. of CBWTFs	26
Quantity of BMW generated in kg/day	74,013.82
Quantity of BMW treated in kg/day	45,738

Different technologies are available currently for the treatment and disposal of biomedical waste. The management of clinical waste is mandated to follow government-authorized methods to ensure safety and compliance with regulatory standards. Particular attention is required in the handling and treatment of hazardous and infectious waste streams, as these pose heightened risks to public health and the environment.

Aim

To assess costs associated with BMW management technologies Incineration and autoclaving

Objectives

The objectives of the present study was to assess the cost per cycle of the various technologies in the disposal practice of biomedical waste management in Mysuru city

Financial Aspects Relating to Biomedical Waste

The most important aspect in waste management is waste reduction. Waste reduction means cost reduction. One should limit the waste management cost by cutting waste generation (Mathias 2 and Paul 3, Hemchandra et al 4)

Segregation at the point of generation is the essence of BMW management. The BMW constitutes only 15-20 per cent of total waste generated in the hospital. If the BMW is not segregated at the point of generation, the whole hospital waste (approx. 1.5 kg/bed/day) will be infectious/ BMW that requires high cost of treatment. (Hemchandra et al 4)

Common Treatment and Disposal Facility:

The minimum investment for an on-site integrated waste management system in an individual healthcare setting is approximately Rs. 50 lakhs. In contrast, an integrated common treatment and disposal facility will cost a maximum of Rs. 3-15 / kg/ day with the added benefit of no capital investment being required. The company / private entrepreneur setting up such a centralized facility will stand to make a profit of about 30 percent making it a sustainable venture.

Advantages of a centralized facility are a reduction in pollution and energy consumption, streamlined collection, and treatment of waste. An onsite integrated waste management facility must meet certain statutory

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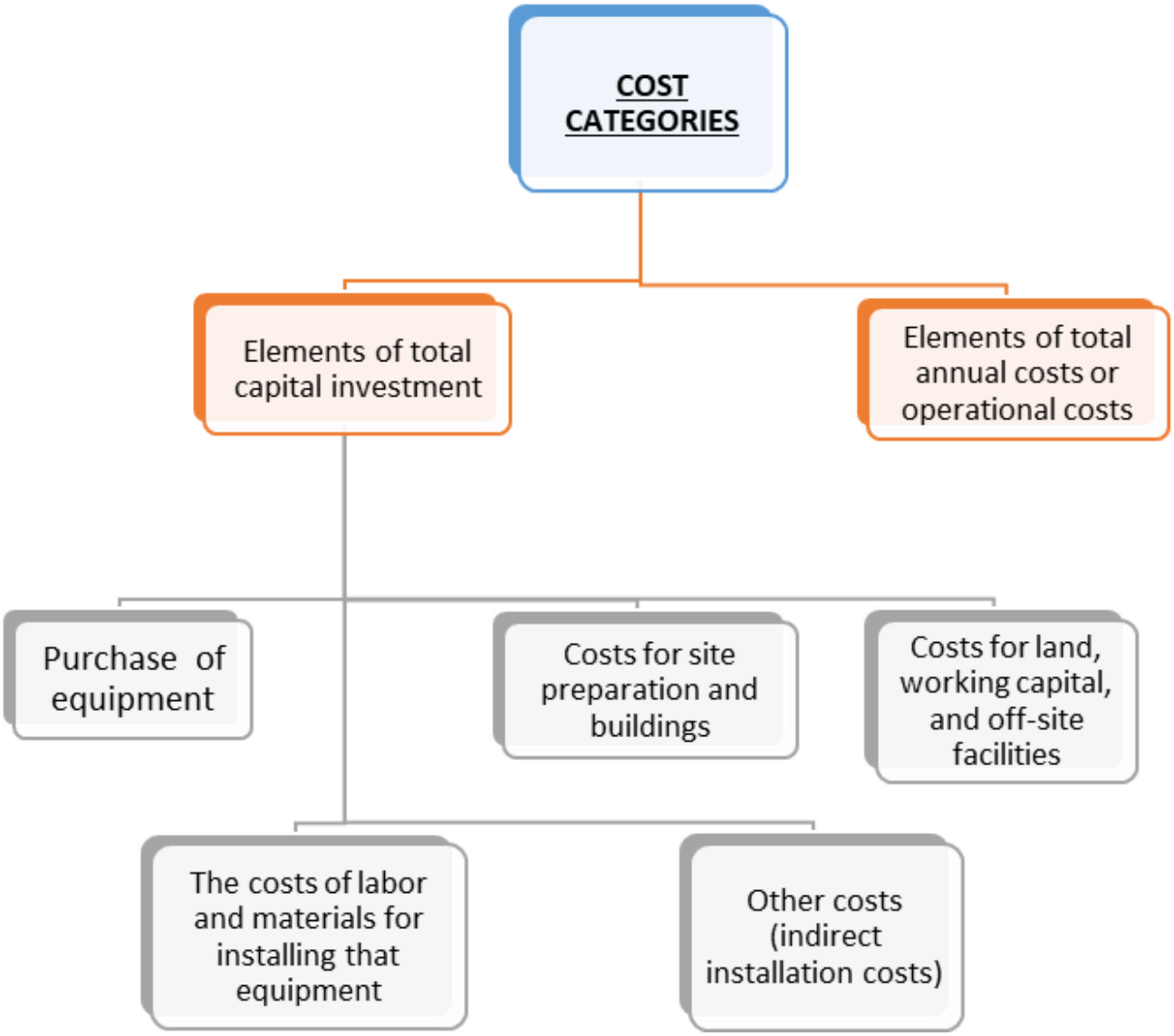
requirements of the State Pollution Control Board. The healthcare setting will have to maintain records, renew authorizations, and submit reports and liaison with the authorities.

COSTS RELATED TO HEALTH-CARE WASTE MANAGEMENT:

Principles:
Cost is a measurement in monetary terms, of the amount of resources used for the purpose of production of goods or for rendering services. Cost is measured by the sacrifice made in terms of resource or price paid to acquire goods and services.

Analysis of Costs:
Cost analysis is defined as "rearranging and reclassifying cost and income data in such a manner and detail as to reveal significant relationships to management". A cost is an identifiable and accountable expense incurred in the production of a product or service.

Cost Categories Defined:



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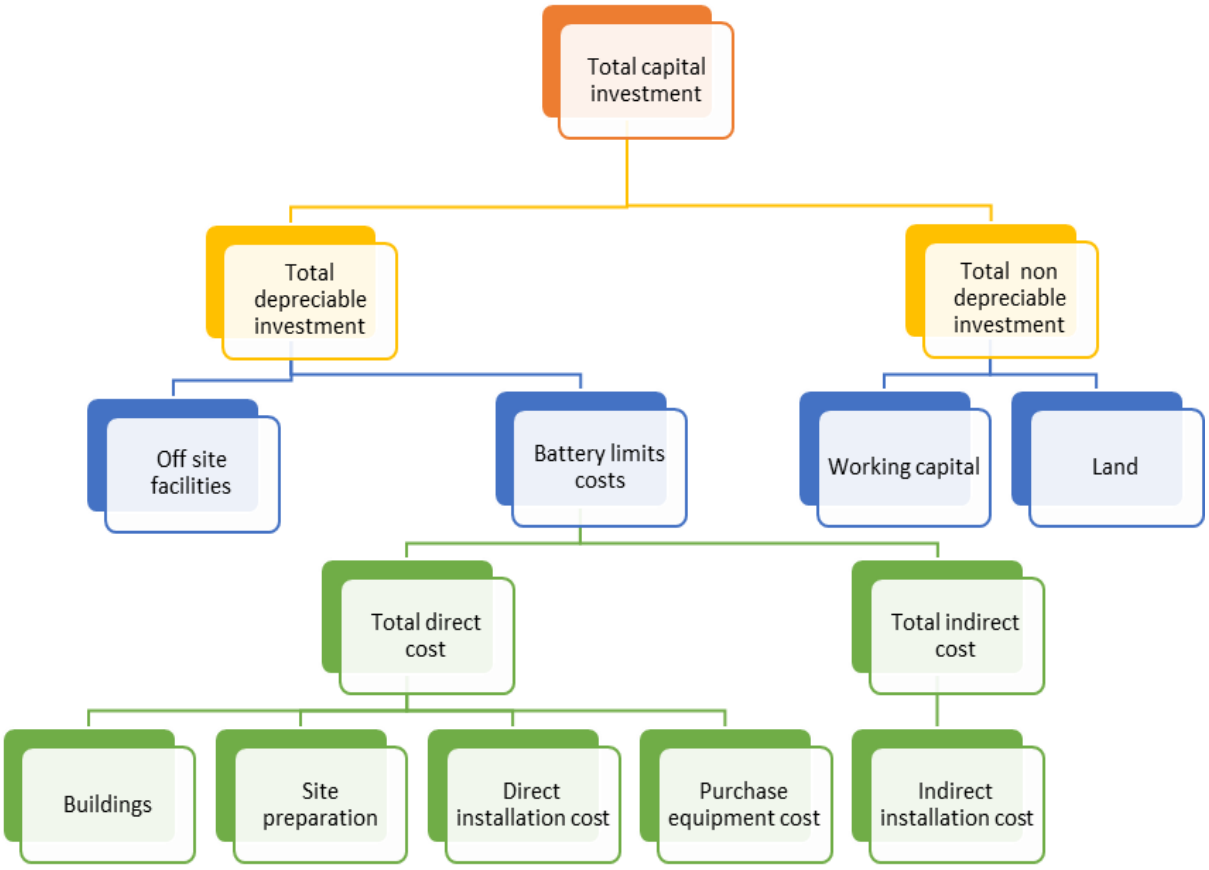
Elements of Total Capital Investment:



Elements Of Total Annual Costs/ Operating Costs:

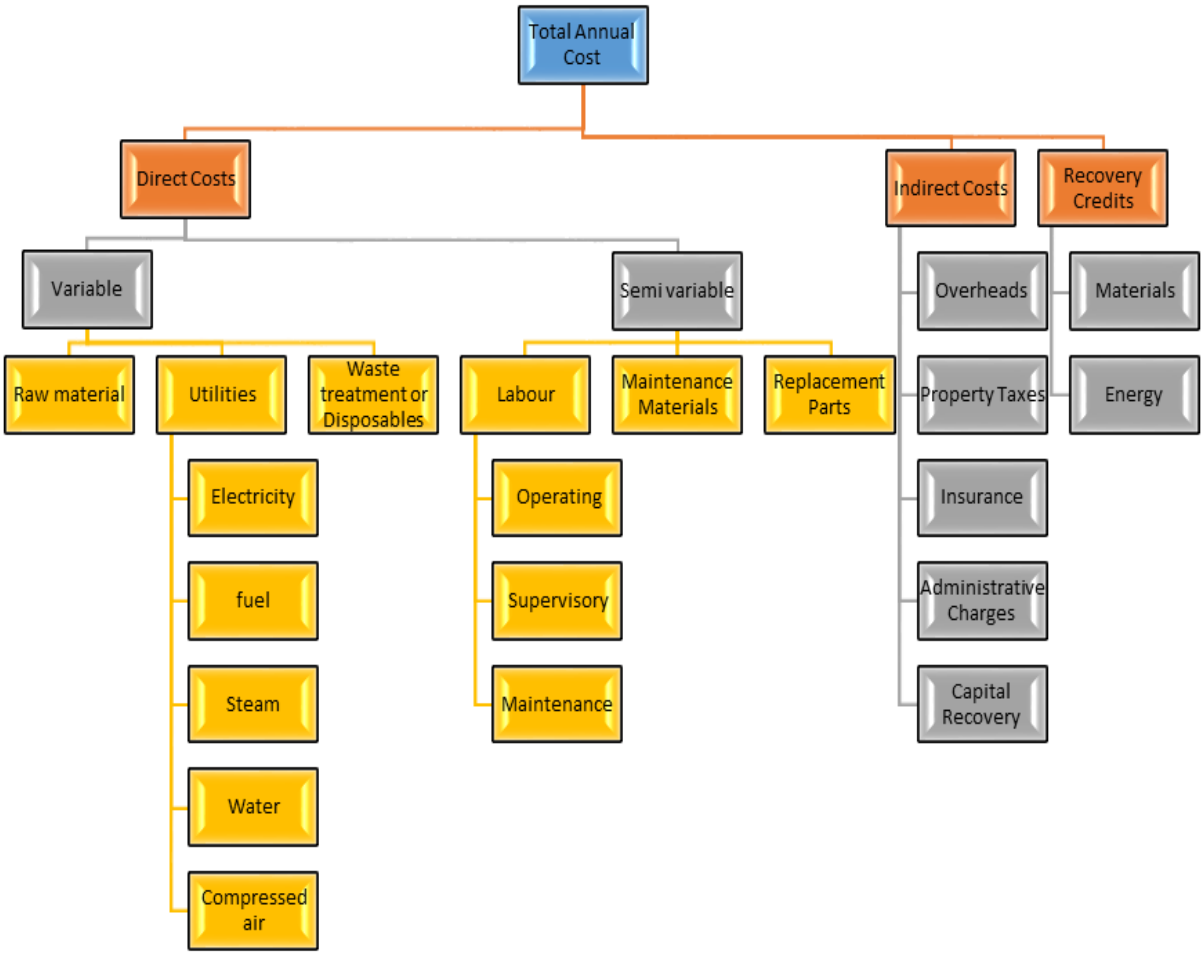


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Table 1. Capital and Operating Cost Items

Capital Costs	
Equipment	Equipment purchase cost including taxes Auxiliary equipment (e.g., computer controls, boilers, shredders, compactors, air pollution control devices, required instrumentation, etc.) Cost of accessories (e.g., bins, carts, bin dumpers, trolleys, weighing scale, roll-off containers, etc.) Spare parts
Shipment	Costs associated with shipment, including customs fees, insurance, etc. Storage charges
Site preparation	Cost of land and right of way New construction or renovation of treatment plant and waste storage area Electrical service including lighting Provision of utilities (water, steam) and sewer drain Heating and ventilation
Indirect costs	Project management Architecture and Engineering Consultancy fees Construction fees Permitting and other legal fees Start-up costs, performance testing, commissioning Regulatory testing
Operating Costs	
Labor	Operators' wages and benefits Supervisor wages and benefits
Utilities	Electricity Steam Diesel, natural gas, LPG or other fuels Water Compressed air
Supplies	Color-coded plastic bags, boxes or containers Sharps containers Personal protective equipment Labels Disinfectants and cleaning supplies Chemicals (for chemical treatment or for flue gas cleaning) Spill kits
Maintenance	Materials and replacement parts Maintenance labour or service costs Maintenance of vehicles
Repairs	Materials and replacement parts Repair labour or service costs
Landfill costs	Transportation costs Tipping or disposal fees
Indirect costs	General and administrative costs Insurance Annual permitting fees Periodic training Taxes Cost of periodic emission testing or validation testing Training Maintenance and parts replacement Vehicle maintenance Uniforms and safety equipment Ash disposal cost Compliance monitoring of flue-gas emissions

MATERIALS AND METHODS

Methods of Cost Estimation

The operational cost was compiled by examining the previous year's records, and prospectively documenting the scale of operations at the common treatment facility.

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The average life span and annual cost for maintenance and repair were estimated to be 7 years and 10 percent of the total value, respectively

Operational Cost of Equipment's (Replacement of Spares):
The amount actually spent towards the replacement of spares for equipment's over a period of 2 years was obtained from the maintenance record.

Ancillary Services and Ancillary Personnel Salary Cost:
Staff was defined as " all personnel employed fully or partly within the common treatment facility, both permanent and bank staff. The costs included all costs such as insurance, benefits, superannuation contributions, sick leave, maternity leave and annual leave."

RESULTS:

Cost of Waste Generation
The management of waste generated at the hospital is not only the responsibility of the administration but of every department as well as every healthcare providing care in the hospital. Biomedical Waste Management is a process that begins at the site of generation where waste has to be properly collected and segregated from the other non-hazardous waste in the specific color-coded receptacles.

The overall annual costs of disposal of the wastes include the waste generation as well as the waste disposal costs. (i.e. waste collection and transportation from the internal waste storage area to the interim storage in the hospital and then to the final treatment plant.) Due to the increasing spending on healthcare, there is a growing focus on more sustainable approach to managing HCW from point of generation to the final disposal and the costs associated with it.

The capital costs, is the total construction cost and the capital recovery factor can be calculated from a power plant's total lifetime and interest rate. The cost of installation of the facility was not considered for the study.

The rate of depreciation was calculated by the straight line method assuming the life time of the equipment to be ten years.

The cost of overall operation calculates the facility operation unit price using the cost and treatment quantity. This method was used to calculate the unit price of the operation of the incineration as well as microwaving

The operational costs of the considered for the study were the lifespan of the equipment, depreciation of the equipment , capital cost of the equipment, total labour for the facility, utilities' and supplies required for operating the facility, maintenance and Repairs of the equipment landfill costs and Indirect costs which are the overheads incurred in operating the facility.

Table: 2: Distribution of the various cost heads in operating costs of incinerator and the cycle cost of incineration **Operating Costs**		Cost per month in Rupees	% of the total cost
Labor	Operators' wages and benefits Supervisor wages and benefits	50000	11.11
Utilities	Electricity Steam Diesel, natural gas, LPG or other fuels Water Compressed air	2,50,000	55.56
Supplies	Color-coded plastic bags, boxes or containers Sharps containers Personal protective equipment Labels Disinfectants and cleaning supplies Chemicals (for chemical treatment or for flue gas cleaning) Spill kits	15000	3.33
Maintenance	Materials and replacement parts Maintenance labor or service costs Maintenance of vehicles	5000	1.11
Repairs	Materials and replacement parts Repair labor or service costs	12500	2.77

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Landfill costs	Transportation costs Tipping or disposal fees	5000	1.11
Indirect costs	General and administrative costs Annual permitting fees Periodic training Cost of periodic emission testing or validation testing Training maintenance and parts replacement Vehicle maintenance Uniforms and safety equipment Ash disposal cost Compliance monitoring of flue-gas emissions	80000	17.77
Insurance		Not considered for the study	
Capital cost of the equipment (as a part of the cycle per month)		50000	11.11
Taxes		0	
Total number of cycles in a month		100	
Total cost		450000	
Cycle cost per month		4500	

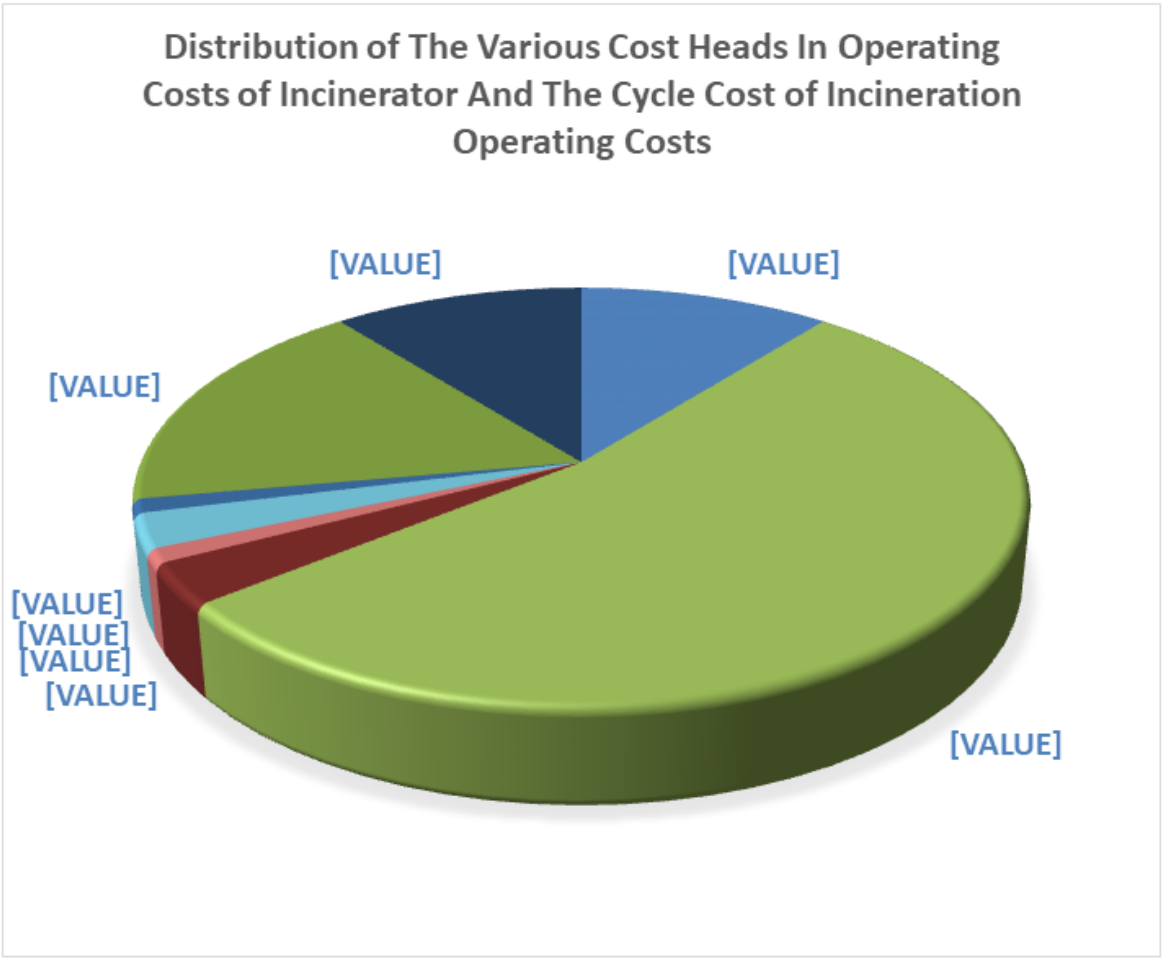

Figure 1 : Distribution of the various cost heads in operating costs of incinerator and the cycle cost of incineration

From the above table and figure the Operating Costs of incineration were labour which was 8.2 % of the total cost, Utilities which was 52.28 % of the total cost, Supplies which was 2.61 % of the total cost, Maintenance which was 0.65 % of the total cost, Repairs which was 2.77 % of the total cost, Landfill costs which accounted to 0.81%, the indirect costs which was 16.34% of the cost and the Capital cost of the equipment was 16.34% of the total cost of the cycle.

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Table:3: Distribution of the various cost heads in operating costs of autoclave and the cycle cost of autoclave

Operating Costs		Cost per month in Rupees	% of the total cost
Labor	Operators' wages and benefits Supervisor wages and benefits	25000	27.47
Utilities	Electricity Steam Diesel, natural gas, LPG or other fuels Water Compressed air	7500	8.25
Supplies	Color-coded plastic bags, boxes or containers Sharps containers Personal protective equipment Labels Disinfectants and cleaning supplies Chemicals (for chemical treatment or for flue gas cleaning) Spill kits	8000	8.79
Maintenance	Materials and replacement parts Maintenance labor or service costs Maintenance of vehicles	5000	5.49
Repairs	Materials and Replacement parts Repair labor or service costs	10000	10.99
Landfill costs	Transportation costs Tipping or disposal fees	5000	5.49
Indirect costs	General and administrative costs Annual permitting fees Periodic training Cost of periodic emission testing or validation testing Training maintenance and parts replacement Vehicle maintenance Uniforms and safety equipment Ash disposal cost Compliance monitoring of flue-gas emissions	18000	19.78
	Insurance	Not considered for the study	
	Capital cost of the equipment(as a part of the cycle cost)	12500	13.74
	Taxes	0	
	Total cost	91000	

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	Total number of cycles in a month	200	
	Cycle cost per month	455	

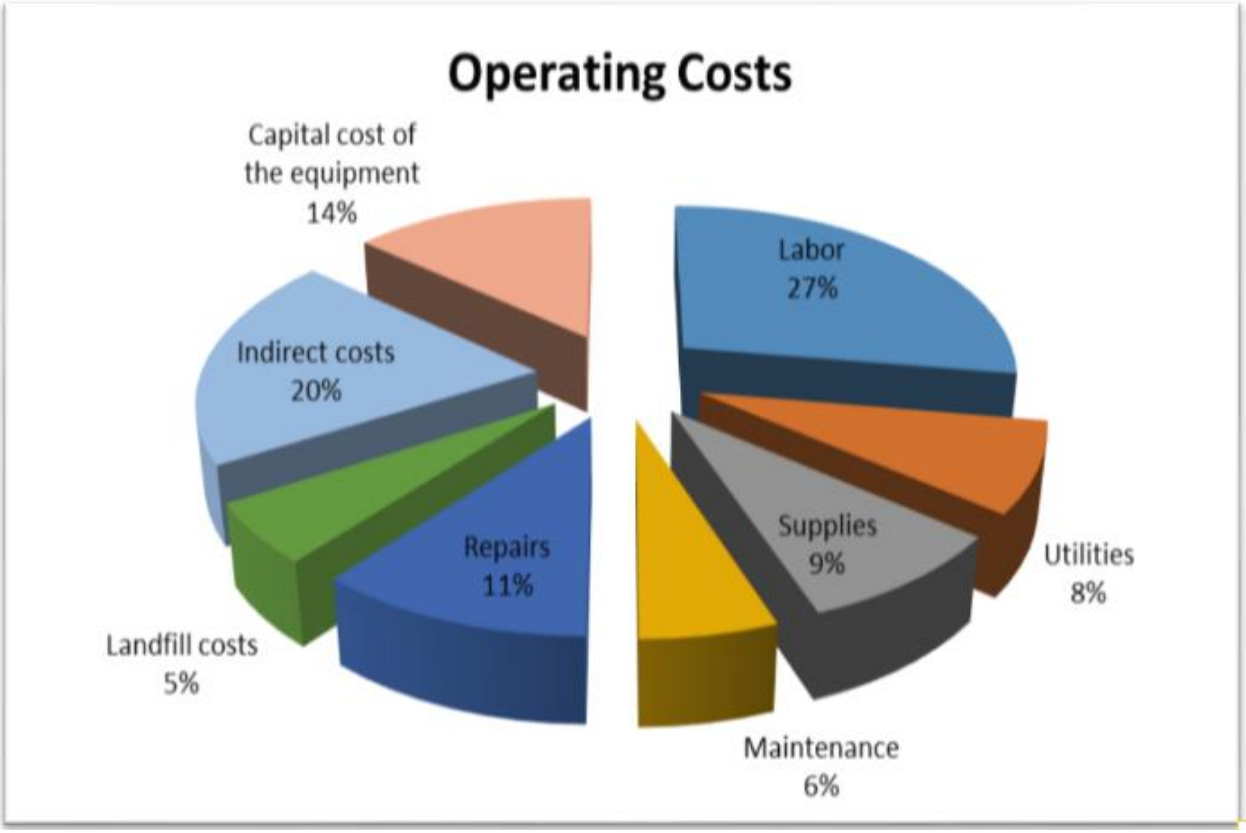

Figure 2: Distribution of the various cost heads in operating costs of autoclave and the cycle cost of autoclave

From the above table and figure the Operating Costs of autoclave were labour which was 27.47 % of the total cost, utilities which was 8.25 % of the total cost, supplies which was 8.79 % of the total cost, maintenance which was 5.49 % of the total cost, repairs which was 10.99 % of the total cost, landfill costs which accounted to 5.49 %, the indirect costs which was 19.78 % of the cost and the capital cost of the equipment was 13.74% of the total cost of the cycle.

DISCUSSION:

The method for waste disposal depends on the type of waste that is generated and the volume of waste that is generated by the healthcare sectors. The cycle cost of incineration was Rs. 3060 for an 100 kg incinerator, which accounts to around Rs 31 per kg of waste.(This was the amount when diesel cost was 60 Rs per litre.) Previously conducted study by Md.Faisal,(2004) showed the cost of incineration per kg of waste to be around 22- 25 Rs / kg. The variation in cost was not found to be significantly different (approximately around Rs 6- 9) and was probably because the establishment cost, insurance cost as well as the interest cost on the capital when not used was not considered for in the present study.

The operating cost of autoclave was between 1.26 to 1.50 / kg of waste in the same study carried out in 2004. The operating cost for autoclave that was calculated in the present study accounted for 455 Rs per cycle, which accounts to around 9 Rs per Kg. This could be due to the hike in the salary component of the workers, increase in the fuel cost as well as increase in the electricity and also the benefits given to the workers.

CONCLUSION:

The increase in the waste generated should warrant for dedicated infrastructure, national strategy on waste management, trained personnel in the health care organizations, regulatory authority that is both competent and strict in implementation of the legislations and also a cradle to grave approach for the waste management would be the road ahead in this area. The legislations of the country should regulate the rules, norms and standards to ensure the safety of the staff, patients, public and the environment.

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