ASJ: *International Journal of Health, Safety and Environments (IJHSE)*
Vol. 3(4) 28 June, 2017, Pp. 57-69
www.academiascholarlyjournal.org/ijhse/index_ijhse.htm
ISSN: 2360-9311©Academia Scholarly Journals
Indexed In: Directory of Research Journals Indexing - http://www.drji.org
Also Available@; https://archive.org/details/Oraegbune_and_Waziri
Open access

Case Study

ALTERNATIVE DISPOSAL SYSTEM OF HOSPITAL MEDICAL SOLID WASTE – A CASE STUDY OF FEDERAL MEDICAL CENTER, GOMBE, GOMBE STATE,NIGERIA

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Accepted June, 15, 2017

The high generation rate of medical waste in Gombe Federal Medical Center, Gombe, proof that medical waste management in the area is problematic. As a result of the study undertaken at FMC, this research looks into the various issues in the field of medical waste management. The study explores the perceptions toward the medical waste management and incineration technology. The study also looks into the various medical waste treatment technologies available and chosen the best available technology for the onsite treatment of medical waste. The aim of the study is to examine the knowledge level, attitude and role of health care workers toward the medical waste management. The data collected through structured questionnaires, secondary data and oral interview were analyzed by the use of multi-criteria decision-making analysis which involve the use of weighted sum model. Microsoft excel, charts and graphs were also used. The results from the study show that health care workers have a critical role in achieving efficient medical waste management and that hospital could highly benefit from an onsite incinerator coupled with an effective waste minimization. The study recommended strategies to encourage greater engagement, change the intended behaviour to more sustainable behavior, while incinerator technology was strongly considered to be the best alternative for final disposal system for hospital medical solid waste in Gombe state. However, the outcome of the study, if not properly managed may expose the workers and sick persons to more diseases .It may also increase the cost of running the hospital.

Key words: Health care workers, incinerator technology, hospital/medical solid waste management and treatment technologies.

INTRODUCTION

Great strides have been made in the field of health care system over the years. Ironically, along with restoring and maintaining community health, health care setting also threaten their wellbeing. The health of public, patients and professionals alike are affected by poor waste management practices (Shinee et al., 2008). In addition to this, it also contributes to environmental degradation. In 1983 a meeting was convened by World Health Organization (WHO) held at Bergu, Norway for the

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European regional office. The meeting highlighted for the first time the biomedical waste management issue. Another was the bench wash-ups of Summer 1988 brought this to the lime light (Lee and Huffman, 1996). Some years later, it turned/become a global humanitarian issue. All the wastes generated by medical activities come under health care wastes. They are involved in diagnostic activities and preventive, curative and palliative treatments in both the human and veterinary fields of medicine. Health care waste is all the waste produced or generated by a medical institution (public or private), a medical research facility or laboratory (Graiko et al., 2010). Similarly long term contamination released to the environment produces surface water, ground water and soil contamination as a leachate production (James, 2010).

In spite of the many technological advances in solid waste incineration, increasing opposition is common among many officials and vocal portions of the resident tending to prevent the use of incineration as waste management strategy. This opposition is the outcome of many forces, containing memories and knowledge of earlier incineration technologies that have now been abandoned and information concerning potential problem that could be caused by extreme emission from incinerators and general public skepticism concerning incineration as a solution to hospital waste disposal problems.

The aim of this study is to identify the current medical solid waste management practices and treatment technology involved, while the objectives is find out the best suitable waste treatment technology for the onsite treatment of medical waste in Federal Medical Centre, Gombe.

Best Practices for Hospital Waste Management

Major changes have been made in the management of hazardous waste so that the requirements of the European Hazardous Waste Directive are met (Waziri, 2015). In accordance with this, there has been a revision of the guidance document Safe Disposal of Chemical Waste by NHS Estates. On the basis of this, the department of Health revised the joint agency guidance and it's publishing its final form as a 119 page document was done on the 30th November, 2006, under the gateway reference 6874 (Department of Health, 2006). As far as the best practice of hospital waste is concerned, this document is the latest reference from the governments end. Moreover, it is very detailed and gives information regarding all aspects of waste management. It also gives the mandatory and optional setting. Revision and updating of the 1999 – guidance was done so that we can take into consideration, the changes in legislation regulating the management of waste, its storage, transportation, treatment, disposal, health and safety (Tudor et al., 2009). On the bases of this, concise 17 page guidance on health care waste had been published by the Royal College of Nursing. This guidance is widely used in UK as the best management practice (Waziri, 2015) and (Tudor et al., 2009). The RCN guidance include guidelines about the definition and classification of medical waste, waste segregation, waste assessments, waste audits, accident and competence and community nursing.

A colour coded system is now used for the segregation of waste and is linked to an appropriate disposal path (Department of Health, 2006), RCN guidance on health care waste). Staff is provided with different colour coded receptacles and sack holders which should be positioned in locations close to the point of waste productivity and should be replaced when 3/4 full securely tied and appropriately labeled (Tudor et al., 2009). The argument here is that although this system helps in separating different types of waste, it doesn't actually reduce the amount of waste produced. In fact, it has created some confusion among the workers to put which waste in which bin, hence there is every chance that the waste ends up in a wrong bin especially when the bins are kept together. In a study conducted by (Sainin et al., 2008), they found that there is a significant gap of knowledge, attitude and practices among the health care employees at the hospital.

World Health Organization (WHO) has identified that the percentage of infectious waste in health care wastes is between 10 – 25% (Pruss et al., 1999). The various studies show that the amount of wastes which require special attention is just a fraction of total health care waste generated (Tsakona et al., 2007; Jang et al., 2006; Blenkharn, 2005; Lee et al., 2001; Ozbek and Sainin, 2004; Park and Jeong, 2001; Patil and Shekadar, 2001). Studies by Lee and Huffman (1996) have reported that the percentage of hazardous waste in various hospitals in UK is as high as 40 – 60%.

A few researches have shown that percentage of

non-hazardous waste disposal of, in the hazardous/clinical waste stream can often be 50 – 90% (Karagiannids et al., 2010; Krisiumas et al., 2000 and Woolridge et al., 2005). In the study conducted by Chung and Lo (2003) demonstrated that more than 25% of the clinical waste can be classified as domestic waste. Another study conducted by Sainin et al., 2008, found that by the careful segregation of items like paper, cardboards, plastics and bio-degradable wastes, the medical waste stream can be reduced by 60%. Therefore, the literature shows that the lack of knowledge and inefficient waste management practices are the reasons for high generation of wastes.

Medical Waste Treatment Technologies

Literature reviews on waste disposal/waste treatment technologies are rather contradictory. Some of the most common technologies include incinerators, sterilization or Autoclaves irradiation, microwave, chemical disinfection and secured land fill. According to previous studies (Lee et al., 2001; Park and Jeong, 2001), about 49-60% of medical waste is treated by various incinerations, 20 – 37% by autoclave sterilization, and 4 – 5% by other method. Incineration and steam autoclave sterilization are the main methods currently being used and are considered mature technologies. Each of the technologies mentioned above has some advantages and some disadvantages. Incineration utilizes thermal energy to decline waste materials to non-combustible residue or ash and exhaust gasses (Dursun et al., 2011). The fly and bottom residues produced after medical waste incineration contain high level of heavy metal like Pb, Cl, Ni, Cr, Cu and Zn. Medical waste high values of medical leachability prohibit the land filling of these ashes as imposed by European directives (Gotsis, 2008). Medical waste is the 3rd largest sources of dioxin air emission. However, despite of public concerns about incinerations, it is the most frequently used option, due to its advantages regarding the sterilization of pathological and atomic waste, volume and mass reduction and energy recovery (Zhao et al., 2005).

Autoclaving/ Sterilization is the second most commonly used waste disposal technology. The process involves steaming the waste materials at lethal temperatures to penetrate and potentially kill pathogens (Armstrong and Reinhardt, 2010). Autoclave is viewed as a more costly method than incineration (Jang et al., 2006). One of the major disadvantages of autoclave is that it does not reduce the size of waste fed into the system. The treated waste then has to go to the landfill sites which again cause many environmental threats. Many studies again show that a shredder incorporated with an autoclave can be the best option to treat the medical waste (Armstrong and Reinhardt, 2010; Hossain et al., 2010). The microwave process utilizes the radiant energy to kill infections agents by covering radiant energy to heat and pressure. Shredding is usually combined with microwave technology. Combination onsite of microwave and small scale incinerator technology is the most cost effective and environmental friendly treatment technology (Ellsberg and Heise, 2005). The disinfection efficiency of microwave can be a performance issue for microwave (Bryman, 2004). In chemical treatment, chemicals like chlorine, formaldehyde, ethylene oxide etcetera are used as disinfectants. Again the effectiveness of disinfection is questioned as it is dependent on the temperature pH, and surface area (Bryman, 2004).

The above literatures show the contradictory views regarding the medical waste treatment. One thing to be noted in these literatures is the difference in the type of waste they have examined. The compositions of wastes that have been examined vary, showing that the best treatment should be selected depending on the characteristic of the waste. Also with the proper reduction of waste and preventing the waste containing chlorine, mercury entering the incinerator can reduce the environmental impacts of medical waste incinerators. While none of the alternative technologies are totally risk free, they can be combined with an effective programme of waste reduction and segregation to reduce the environmental impacts and financial cost of medical waste disposal. The criteria used to evaluate technological option should consider environmental, health and economic factors (Zhao et al., 2005). The best technology for the medical waste treatment will be different for different hospitals. It may depend on the local conditions and the requirement of the hospital. However, WHO gives a list of factors to guide the selection of best technology for treating medical waste (Pruss et al., 1999).

i) Disinfecting efficiency
ii) Volume and mass reduction
iii) Quantity of wastes for treatment

Table 1. Age distribution of the surveyed respondents.

Age	Number of Employees	Percentage
16 – 20	32	16
21 – 30	29	14.5
31 – 40	65	32.5
41 – 50	54	27
51 - 61	15	7.5
61 and above	5	2.5
Total	**200**	**100**

iv) Infrastructure requirements
v) Options available for final disposal
vi) Operation and maintenance consideration
vii) Location and surroundings of the treatment site and disposal facility.
viii) Public acceptability
ix) Available space
x) Investment and operating cost.
xi) Health and environmental considerations
xii) Types of wastes for treatment and disposal
xiii) Regulatory requirements
xiv) Occupational health and safety considerations
xv) Training requirements.

Hence, it can be interpreted from the literature that, medical waste management is an area of high concern due to the high generation of medical waste improper segregation and also due to contradictory news about the various technologies. Medical Waste Management is an area which needs more research and study to gear it towards sustainability.

Research Methodology

Basically, two sources of data were used to pursue the aim and objectives of this study; primary data and secondary data. The primary data was obtained through well-structured questionnaires, admitted to hospitals professionals for e.g., Doctors, Nurses, paramedical workers and other ancillary workers. Oral interviews were also used to collect vital information, while secondary data were collected through literature review of relevance textbooks, journals, conference papers, internet sources, workshops, seminars proceedings etc. A total number of 330 questionnaires were distributed during the field survey, while only 220 numbers of questionnaires about (60%) were returned.

Method of Data Analysis

Data collected via primary and secondary services were analyzed by the use of Microsoft excel, charts and graphs and multi criteria decision-making analysis (MCDA) which uses weight sum model (WSM).

Observations and Results

Demographics of the Survey Respondents

Table 1 below, shows the distribution of respondents based on their ages. The results shows that (32.5%) of the respondents age were between 31 – 40 years and only 2.5% of the respondents were 60 years and above.

Professions of Respondents

In Table 2 below, out of the 200 respondents 65 (32.5%) are paramedical workers, 40 (20%) are ancillary workers, while only 20 (10%) are doctors showing that paramedical workers have the highest percentage in the survey.

Issues on Medical Waste Management Practices

General details of Medical Waste at Federal Medical Centre, Gombe

Figure 1: Shows the composition of the waste generated at Federal Medical Centre, Gombe. About 49.03% of the total waste generated is clinical waste, 19.35% of the waste is recycled or recyclable, while the remaining 31.62% is of domestic waste. The clinical waste generation data at the Federal Medical Centre, Gombe hospital for the year 2015 is shown below:

Total quantity of domestic wastes produced in the year 2015 is 558.14 tones.

Total quantity of recyclable wastes produced in the year 205 is 341.56 tones

Total quantity of clinical wastes produced in the year 2015 is 865.41 tones.

From above data, the average quantity of clinical waste generated per day can be calculated by dividing the above quantities by 365 days. Quantity of general clinical waste generated is 2.3275 tons per day = 2.3275tons/day.

Quantity of special clinical waste generated is 0.16226tons/day (0.16226 tons per day).

Table 2. Occupational status of the staff surveyed.

S/NO.	PROFESSION	NUMBER	PERCENTAGE
1	Doctors	20	10
2	Nurses	50	25
3	Paramedical workers	65	32.5
4	Ancillary	40	20
5	Others	25	12.5
Total		**200**	**100**

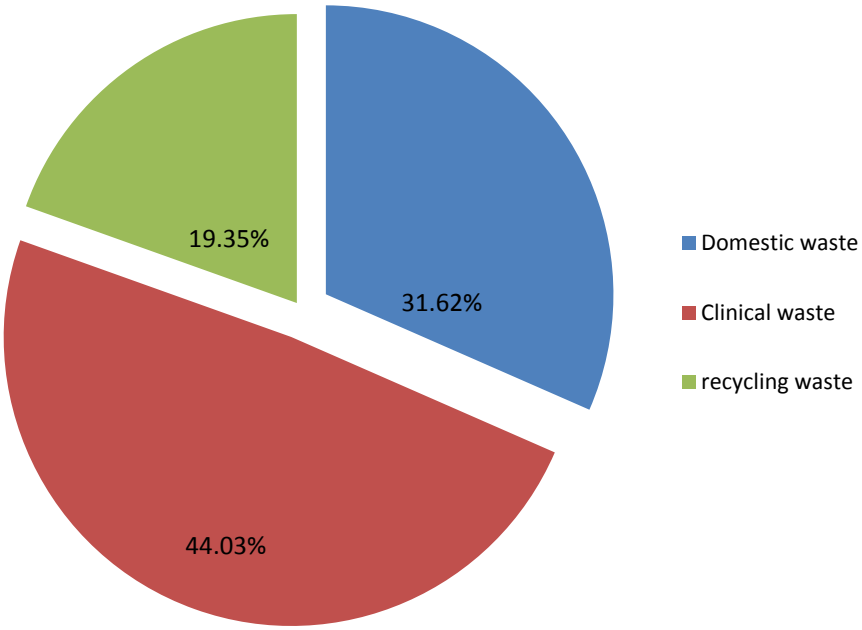

Figure 1. Shows chart composition of health care waste at FMCG for year 2015.

Total clinical waste generated at the hospital in a day is 2.3275 plus 0.16226 = 2.4898tons per day. These data are important in later stages of this research to decide the capacity of the onsite treatment technology.

Average money spent for the treatment of clinical waste is N500 per ton.

Composition of health care waste at Federal Medical Centre, Gombe for the year 2015 are as follows:

Domestic waste is 31.62%

Clinical waste is 49.03%

Recyclable waste is 19.35%

Total money spent for treating clinical waste is N500 x 816.8618 = N408,430.09.

According to WHO the amount of medical waste is about 25% of the total health -care waste. That is, the proper segregation at Federal Medical Centre, Gombe has the potential to prevent 50% of the domestics waste going to clinical waste. This means that the hospital could save N204, 215 every year by improving the waste minimization and waste management.

Workers Perception on the Concern of Medical Waste and Its Management

Figure 2 below shows workers perceptions on the concern of medical waste management 44% (87) of the respondents are highly concerned about medical waste, 33% (70) are neutral, about 15% (28) of the respondents are slightly concerned with

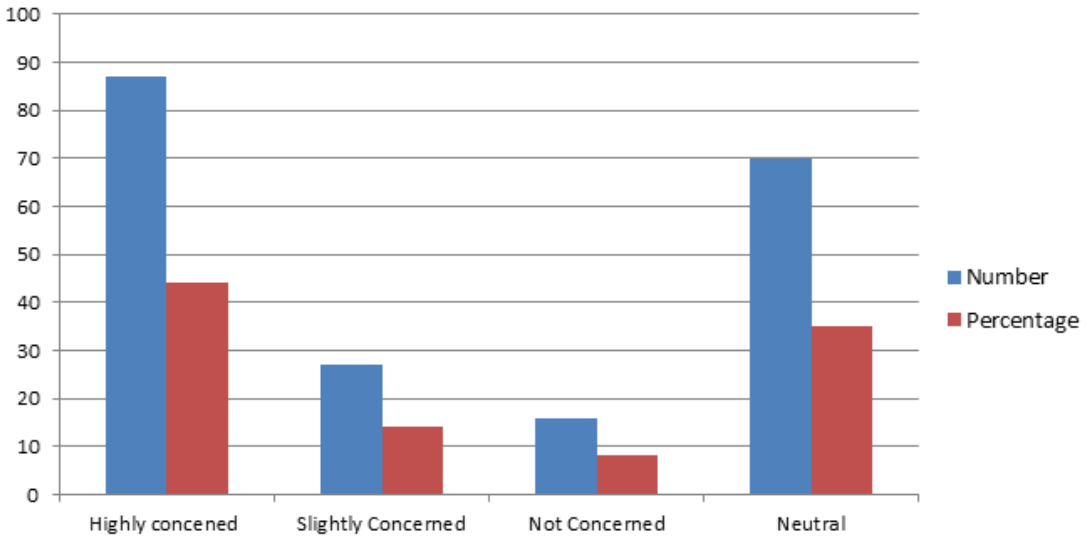

Figure 2. Shows workers perception chart.

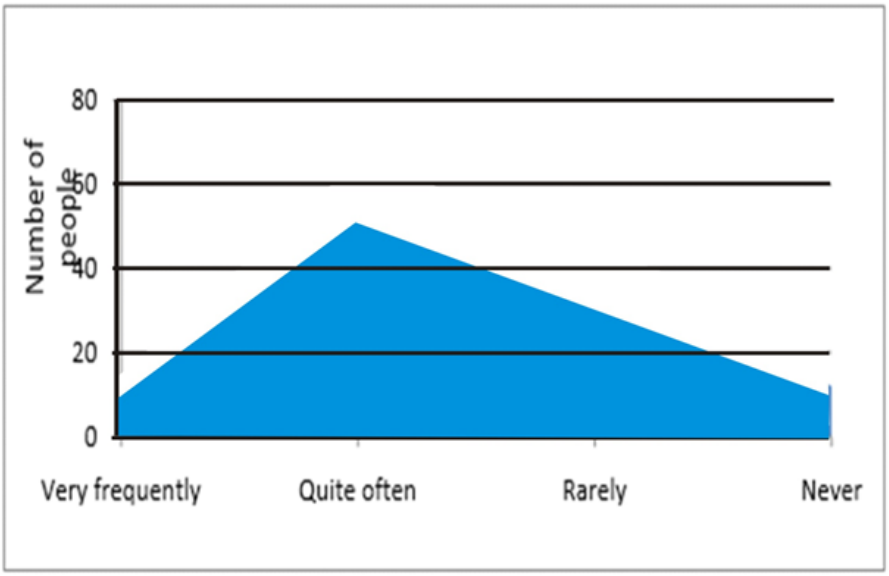

Figure 3. Shows frequency of waste going to wrong bin.

medical waste, while 8% (16) of the respondents were not concerned.

Employees Perception Towards Current Waste Management Practices.

Figure 3 below shows frequency of waste going to wrong bin. Professions and age group seems to have some effects or impacts on segregation practice. Fifty percent of Doctors that took part in the survey felt lack of knowledge about medical waste constituent as the primary reason for waste being put in wrong bin whereas only few nurses felt the same. More mixed opinions were seen or noticed for other professionals .All of them who said or have i do not care attitude were either in the age group 16-20 or 21-30.

All the workers were either very comfortable or

Table 3. Perception of Workers Towards Various Treatment Technology.

S/No.	Perception Towards Best Treatment Technology	Number	Percentage
1.	Autoclaving and Landfill	16	14
2.	Incineration	24	20
3.	Incineration with energy recovery	79	60
4.	Microwave and shredding	0	0
5.	Chemical disinfection and shredding	8	6

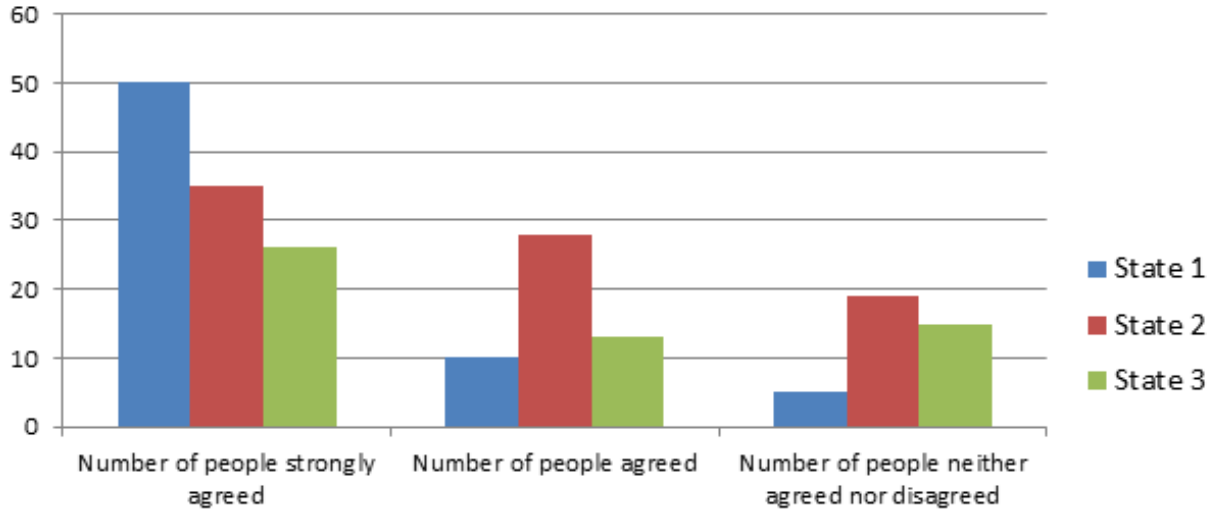

Figure 4. Shows the knowledge of people about medical waste.

slightly comfortable with the current colour coding system in the hospital. Although, the study had shown that around 10% of the workers put the waste in wrong bin very frequently. Another 50% of the workers put wastes in wrong bin quite often and 30% of the workers put wastes in wrong bin rarely. About ten percent (10%) workers claimed that they never put waste in the wrong bin as shown in Figure 3 triangular graph.

Perception Towards Best Treatment Technology

When employees were asked which treatment technology does they considered as the best treatment towards waste management more than 70% of the employees selected incinerator or incinerator with energy recovery as their preferred choice. This might be due to their awareness about the characteristics of medical waste. About 184 out of 200 employees felt that the hospital will be benefitted from having an on site treatment technology. See Table 3 above showing worker's perceptions toward various treatment technology.

Public Perception About Medical Waste Treatment Technologies

Figure 4 below shows the knowledge of people about medical waste. It can be interpreted that 55% of the people took part in the survey agreed that the municipal waste and clinical waste are different and clinical waste is more hazardous than general waste. However, only 30% of the people knew that hazardous waste and clinical waste should be treated separately.

Incineration and autoclaving seemed to be the best or most popular among public for the treatment of medical waste treatment. More than 80% of the people that took part in the survey considered autoclaving as the best method to treat the medical waste. Chemical treatment and microwaving does not have much popularity among the public. See

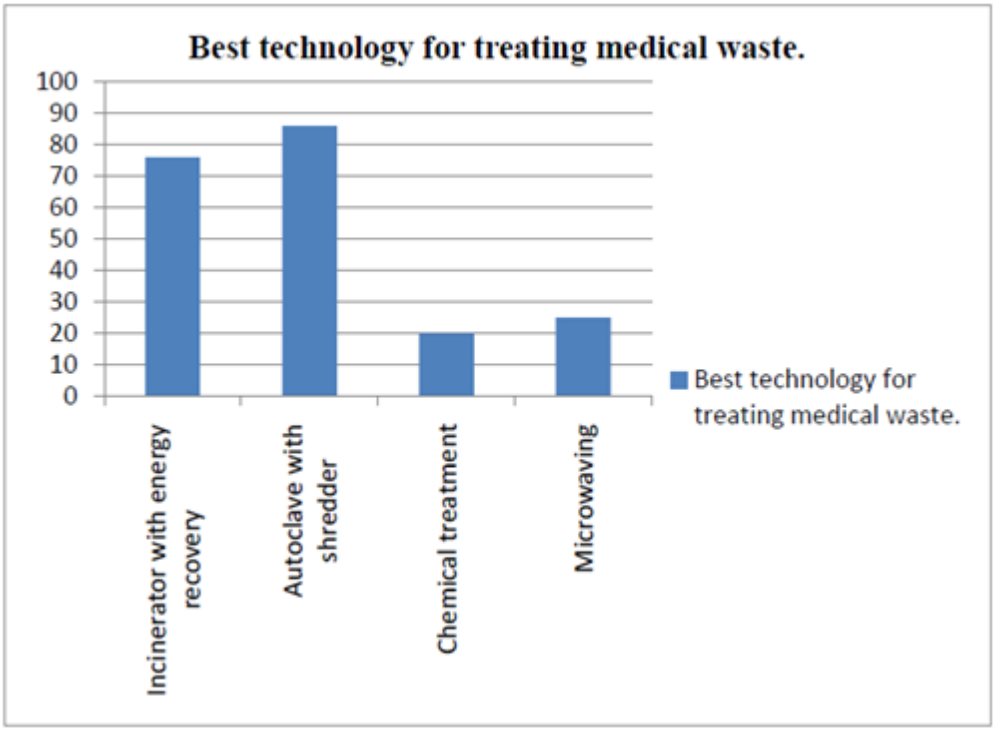

Figure 5. Public perception towards various medical waste treatment technologies.

Table 4: MCDA (Using Weighted Sum Model (WSM).

Technology →	Incineration	Autoclaving	Microwave	Chemical
Criteria Weighted ↓				
C1 (1)	1	4	2	3
C2 (1.25)	4	1	1	1
C3 (1.25)	4	2	2	3
C4 (1.25)	1	2	2	1
C5 (1)	3	4	1	1
C6 (1)	4	3	3	1
C7 (1)	4	3	3	3

Figure 5 best technology for treating medical waste.

Analysis of the Result of Perception Towards Best Treatment

The data collected for this study were analyzed with the use of multi-criteria decision-making analysis/method which employed the use of Weighted Sum Model (WSM) for the scores. See Table 4 with scores entered in the matrix format.

$$Sli = \sum^{N}_{i=1} dij\ Wj\ [for\ i = 1, 2, 3, 4.....M] \ldots 1$$

Using the equation (1) above for the maximum scores or best alternative scores

$$Sli = \sum^{N}_{i=1} dij\ Wj\ [for\ i = 1, 2, 3, 4, 5, 6, 7]$$

Where Wj = Relative weight of importance of the criteria C; and di, is the performance value of alternative Ai when it is evaluated in terms of best alternative Ai.

Incineration = 1 x 1 + 4 x 1.25 + 4x1.25 +

1x1.5 + 1x3 + 1x4 + 1x4 = 23.25
Autoclave = 1x4 + 1.25x 1 + 1.25x2 + 1.25x2 + 1x4 + 1x3 + 1x3 = 20.25
Microwave = 1x2 + 1.25x1 + 1.25x2 + 1.25x2 + 1x1 + 1x3 + 1x3 = 15.25
Chemical = 1x3 + 1.25x1 + 1.25x3 + 1.25x1 + 1x1 + 1x1 + 1x3 = 14.25

Based on the outcome of equation, it is clearly shown that incineration has the highest or best alternative option and seems to be the optional technology for the disposal of hospital/medical solid waste. See the calculations of engineering/design capacity in appendix I and incinerator elevation and section drawings in the appendix II.

DISCUSSION

(i) About forty nine percent (49.03%) of the total waste generated is clinical waste while only 19.35% of the waste is recyclable and the remaining 31.62% is domestic waste. The clinical waste generation data at FMCG for the 2015 as indicated in the text.

(ii) Forty seven percent (47%) of the workers considered pressurized containers as medical waste and the remaining fifty three percent (53%) do not consider it as medical waste

The nurses were found clearer about the constituents than doctors and other workers.

(iii) More than ninety five percent (95%) of the workers seemed to have proper knowledge about the hazardous components of medical waste. None of the profession or age group seemed to have a connection with the results obtained.

(iv) About eighty five percent (85%) or 170 of the workers understand the risk involved putting medical waste in wrong bin while around ten percent (10%) or twenty respondents felt it was low risk and the remaining five percent (5%) or ten respondents did not know about the risk involved.

(v) The waste bins are inappropriately located with forty four percent (44%) or 89 responses; there is lack of knowledge regarding the constituents of medical waste bin with twenty five percent (25%) or 50 responses and there is lack of descriptions or symbols on waste bins with about five percent (5%) or 10 responses. About forty five percent (45%) of the people were highly concerned, while fifteen percent (15%) of the people were slightly concerned and thirty eight percent (38%) were neutral in their approach. The remaining eight percent (8%) were unconcerned with the medical management.

(vi) Finally, thirty eight (38%) of the people took part in survey, while autoclaving was considered as the best method towards medical waste treatment, where thirty three percent (33%) of them think that incineration is the best method to treat medical waste because it is sustainable due to available raw materials needed.

CONCLUSION

The study has shown that hospital can benefit both environmentally and economically by improving the medical waste management through technological treatment.

The research also found out various reasons for the higher waste generation patterns at Federal Medical Centre, Gombe.

(i) Inappropriate location of waste bins.
(ii) Waste bins being over-filled before collection.
(iii) Lack of knowledge about the constituent of medical waste.

The issue of medical treatment technologies was also discussed for the onsite treatment and it was found that incineration is the best alternative technology available. This is because the main structural frame of incinerator is lined with white clay brick which is in a greater abundant in Gombe.

However, if the outcome of the study is not properly managed, may expose the workers and sick persons to more diseases .It may also increase the cost of running the hospital.

RECOMMENDATIONS

(i) Waste management policies should be applied so as to focus not only on the waste minimization strategies but should also contain strategies to encourage greater engagement and change the intended behaviour to a more sustainable behaviour.

(ii) There should be more improvement on waste management through proper arrangements to seal the medical waste bin whenever it is ¾th filled and there should be more frequent waste collection and disposal.

(iii) There should also be proper recording, tracking and monitoring for the waste generation pattern for each wards, while incinerator technology is recommended because of material availability, sustainability and the nature of the wastes.

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APPENDIX I

Engineering/Designing Capacity ForThe Fire Combustion Chamber

(i) Calculated data
Clinical Waste = 227Kg/M^3
Hospital Generated = 348 Kg/M^3

Waste

Food Kitchen Waste = 1029Kg/M^3
Domestic Waste pet year = 558.14 tomes/year
OR = 558.14 x 1000Kg/year
Clinical Waste per Year = 865.41 tones/year
Clinical Waste per day = $\frac{865.41 \times 1000}{365}$

$= \underline{2370.98Kg/Day}$
Total Clinical Waste Now = 2371Kg/Per

Domestic Waste per day = $\frac{558.14 \times 1000\ Kg/Day}{365}$
Total domestic waste per day = 1529Kg/Day
Volume of clinical waste generated per day =
Density = $\frac{Mass}{Volume}$

Thus, volume = $\frac{Mass}{Density}$

Volume of Clinical Waste per day = $\frac{2371 g/m^3}{22714}$

Clinical Waste Volume = $10.45m^3/Day$

Volume of domestic waste per day = $\frac{1527/day}{1029/m^3}$

$= 1.5m^3/day$

Thus, design maximum = $10.45m^3$/day

DOMESTIC WASTE

Domestic Waste per day = 1529Kg/Day
Domestic Waste per month = 1529Kg/day x 30 days
= 45870Kg/Month.
Calculate 3% projection domestic waste = 45870 x 3100= 1376.1Kg/month
Add domestic waste per month and 3% projection =

45870 + 136.1 = 47246.1Kg/month
Total sum of domestic waste per month = 47246Kg/Month
One year waste projection generation = 47246 x 12months = 566912Kg/Year
Five (5) years waste projection generation = 566912Kg/Year x 5 years
Domestic waste = Five (5) years waste projection generation = 2834560Kg/Year.

CLINICAL WASTE

Clinical Waste per day = 2371Kg/Day
Clinical Waste per month = 2371 x 30(kg)
= 71130Kg/month
Calculate 3% Clinical Waste projection = 71130Kg x 3/100 = 2133.9Kg.
Add clinical waste per month and 3% projected generation = 71130 + 2133.9
Total Clinical Waste per month = 73263.9Kg/month
One (1) projection for clinical waste generation = 73263.9 x 12 = 879166.8Kg/year
Five (5) years projection for clinical waste generation = 879166.8 x 5 years = 4395834Kg/years

Design Assumptions

Assume the height (h) to be = 2000mm(2m)

$$\text{Area required (clinical)} = \frac{\text{Volume}}{\text{Height}}$$

$$\text{Area} = \frac{10.45m^3}{2m}$$

$$= \frac{(10.45 \times 1000)}{2000}$$

$$= 5.23m^3$$

$$\text{Let the height be} = \frac{\text{Length}}{\text{Width}} = 1 \text{(i.e square shape)}$$

Length = width = L = W
Therefore = Length x width = Area
Since L = W
L x W = Area
L x L = Area = W x W = Area

$\therefore L \times L = 5.23^2$
$L = \sqrt{5.23}$
L = 2.29m
L = 2.3m
Lets assume the height of Ash collection chamber to be 2000mm.
Therefore; total height of incinerator = 4000mm

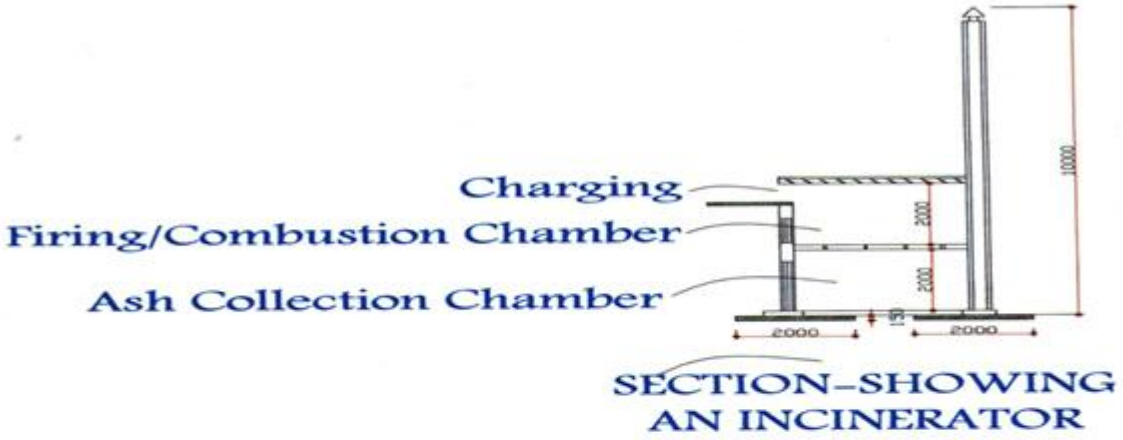
Incinerator dimensions

= Length = 2.3m
= Width = 2.3m
= Height = 4m

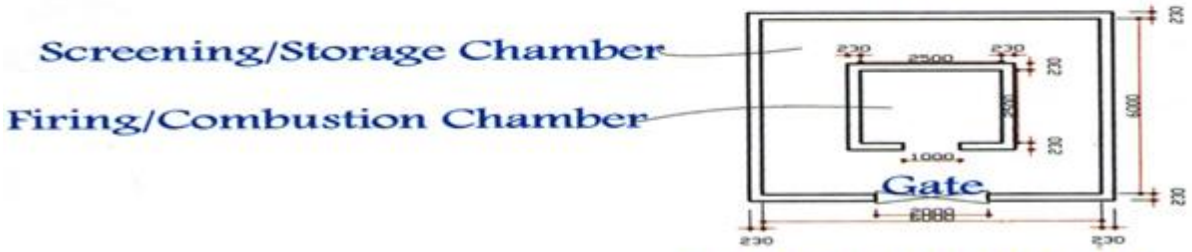
Size of the incinator = 2.3 x 2.3 x 4 (m)

APPENDIX II (Figure of an Incinerator)

(i) Plan –showing an Incinerator
(ii) Section-showing an Incinerator



SECTION–SHOWING AN INCINERATOR



PLAN–SHOWING AN INCINERATOR