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*Full Length Research Paper*

# Analysis of the measured medical waste generation rate in Tanzanian district hospitals using statistical methods

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**In this study the medical waste generation rates at Amana and Ligula hospitals were measured and analyzed. The rate of medical waste generation is high; about 2,250 kg/day in Amana and 2,500 kg/day in Ligula hospital. The waste generation rate per patient per day is also high about 1.8 (Amana) and 2.0 (Ligula) kg/patient.day. The daily medical waste generation rate is not constant, and fluctuates randomly. About 6 to 10% of waste generated is left uncollected. Eight medical waste categories were measured and compared: general waste, pathological waste, radioactive waste, chemical waste, infectious waste, sharps waste, pharmaceutical waste, and pressurized containers. The results indicated general waste to have high generation rate while others waste types such as chemical and radioactive wastes have low generation rates. Due to differences in generation rates, the data was normalized in order to compare statistical parameters used to assess medical waste generation rates. The statistical parameters used include: range, skewness, kurtosis, probability density functions and histograms. The study revealed that management of medical waste is still facing critical problems and requires skilled health workers, appropriate technologies and suitable equipment for collection, storage and transportation. The study will enable hospitals to understand trends in variations of medical waste generation and accommodate fluctuations in their plans and budgets.**

**Key words:** Measured medical waste in selected Tanzania district hospitals, variations of waste generation, average waste generation, waste collection efficiency; range of waste generation, normalized waste generation.

## INTRODUCTION

This paper gives picture and more insight to hospital managers and health workers on the actual medical waste generation, its handling and major challenges of medical waste management. The study has established a database of information and statistics on medical waste management from generation to final disposal which will then form the basis for realistic planning, designing, budgeting and implementation of medical waste management procedures that is economical, effective and efficient. The area of study included Amana hospital in Dar es Salaam and Ligula hospital in Mtwara, and the analysis covered such parameters as: average medical waste generation, fluctuations of medical waste generation, waste collection efficiency, variations of daily medical waste generation over a period of time and distributions of medical waste generation by categories. Medical waste collected and measured in those facilities included two groups: clinical and non clinical waste. Clinical waste contained: pathological waste (human tissues, organs and body fluid), infectious waste (containing pathogenic organisms), sharp waste (needle, syringe, blades), pharmaceutical waste (drugs, vaccines spoiled or expired), chemical waste (detergents, dressing solutions), genotoxic (radioactive films and fluids), pressurized containers used for treatment, and radioactive waste (x-ray, ultrasound). While the non clinical waste included: kitchen waste, left over, packages (glass, plastic and boxes) and clerical waste.

Capacity building to hospitals is of vital importance. To

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**Table 1**. Medical waste generation rate in Dar es Salaam (Kaseva et al., 1999).

| No. | Hospital | No. of beds | kg/patient per day |
|---|---|---|---|
| 1 | Hindu Mandal | 70 | 0.37 |
| 2 | Amana, Ilala | 130 | 0.26 |
| 3 | UDSM Health Centre | 24 | 0.41 |
| 4 | Temeke | 140 | 0.15 |
| 5 | Kariuki Mikocheni | 150 | 0.79 |
| 6 | Aga Khan | 88 | 1.3 |

manage their medical waste properly, hospitals need to invest on trained/skilled health workers, good appropriate technologies, enough and special designed facilities for collection, storage and transportation. Hospitals are also required to develop realistic plan and budgets, observe trend and seasonal variations of medical waste generations and understand better the recurring fluctuations and accommodate them in their plan and budgets and have a scientific model to guide the operational procedures.

This waste type has been given special attention due to the following hazards it can cause: injury from sharps to staff and waste handlers associated with the health care establishment; hospital acquired infection (HAI) (Nosocomial) of patients due to spread of infection; risk of infection outside the hospital for waste handlers/scavengers and eventually general public; occupational risk associated with hazardous chemicals, drugs etc.; and, unauthorised repackaging and sale of disposable items and unused/date expired drugs.

## LITERATURE REVIEW

### Overview of medical waste generation in hospitals

The improper medical waste management is a serious environmental problem not only in Tanzania but also throughout the World. The death of six nursing staff following two separate outbreaks of hepatitis in Renal failure units in hospitals in the United Kingdom during 1969 to 1971 and 1985 to 1986 dramatically illustrate the health and safety hazards associated with the handling of infectious medical waste (USEPA, 1990).

The majority of medical waste generated in the United States is regulated at the state and local level. State regulations generally cover potentially infectious medical waste, sometimes referred to as regulated medical waste. There are several categories of medical waste, however, that are governed by federal regulations; medical wastes containing mercury (Hg) or other toxic metals such as lead (Pb), cadmium (Cd) and arsenic (As), are governed by the resource conservation and recovery act (RCRA) hazardous waste regulations, while medical wastes containing radioactive isotopes or materials are covered by nuclear regulatory commission (NRC) regulations (US DOE, 1996).

Medical waste contains different items making it a special type of waste. If not properly sorted during generation, its handling becomes even more difficult. It can contain soiled or blood soaked bandages, culture dishes and other glassware, discarded surgical gloves and surgical instruments (like scalpels). Needles (used to give shots or draw blood); cultures, stocks and swabs used to inoculate cultures are the most common items in MW and well known to the health-care staff. Waste from operation theaters will also contain removed body organs (like tonsils, appendices, limbs etc.), which renders the medical waste scary, and nuisance. Medical waste will also contain lancets (the little blades the doctor pricks your finger with to get a drop of blood). However, during immunization campaign, medical waste will contain safety boxes and leftovers of empty boxes, cotton wool and bandages (Lloyd, 2003). Thus, if the waste is not segregated properly at the point of generation it will be a mixture of all these items plus kitchen waste, office waste and floor wastes which do not arise as a result of patients being attended.

### Medical waste generation in Tanzania

In Dar es Salaam city, study done by Mato et al. (1997) showed that medical waste generation rates in the surveyed hospitals were obtained by actual measurements and through assessment of the storage facilities empting frequencies and degree of filling of the waste receptacles. Table 1 compares the medical waste generation rates in surveyed hospitals. The hospitals with better medical facilities were found to have higher waste generation rates of up to 1.3 kg/patient per day. For the case of Aga Khan Hospital, this value is nine times that of Temeke hospital (0.15 kg/patient per day). However the average waste generation rate is estimated to be 0.66 kg/patient per day with a range of 0.3 to1.8 kg /patient per day (Kaseva et al., 1999).

Another study done in Dar es Salaam; four sampled hospitals were used to study the rate of MW generation: Muhimbili National Hospital (MNH), which represents other referral hospitals; Mwananyamala hospital, which

**Table 2.** Medical waste generation rates in different countries (Hamoda et al., 2005).

| Country | Generation rate (kg/bed/day) |
|---|---|
| North America | 7.0 to 10.0 |
| Western Europe | 3.0 to 6.0 |
| Middle East | 1.3 to 3.0 |
| Latin America | 1.0 to 4.5 |
| India | 1.0 to 2.0 |

represents district hospitals; and Agha Khan hospital representing private hospitals and the University of Dar es Salaam health center representing other health centers (Manyele, 2004).

The generation rate at MNH was the highest where more emphasis has been placed for the last few years. The generation rate reported based on the overall waste generation per day, different from kg per bed per day. Moreover, the data presented was only for infectious waste despite the fact that hospitals generate both infectious and non-infectious wastes. There is also a marked difference between University of Dar es Salaam health center and the Agha Khan hospital in terms of the amounts of waste generated which necessitates further research.

A study conducted outside Dar es Salaam on medical waste generation was in Mtwara region putting into consideration the number of hospital beds in a given hospital as indicated in the national health-care waste management plan (NHCWMP, 2003). The rate of waste generation at a given hospital increases with the number of beds available and the occupancy rate. Four hospitals were distributed as follows: 2 in Masasi, 1 each for Newala and Mtwara Urban and none in Mtwara Rural and Tandahimba districts. The quantities of medical waste generated follow the same trend similar to that of number of beds (Manyele, 2004).

Another survey conducted in Tanzania involved 9 hospitals, all hospitals showed higher values of occupancy rates with a corresponding wide variation in this parameter, ranging from 44 to 200%. With an average value of 101%, it shows that all hospital beds are occupied at all times of the day. The values of occupancy rates and the estimated medical waste generation per bed per day were presented by Manyele et al. (2003a), based on a survey conducted in 2001 (NHCWMP, 2003).

Based on this data it was possible to estimate the waste generation rates for different hospitals, and sum of the wastes for each region (NHCWMP, 2003). The clinical waste generation in some regions of Tanzania for the non-priority areas (which produce less than 800 kg of waste/day) and for the priority areas (which produces more than 800 kg of waste/day) were also presented (Manyele, 20034). Mwanza region is the leading area, basically due to high population (high occupancy rate), large number of hospitals (and hence many hospital beds). However, to compare different regions, is advised to use actual measurements of waste generated disregarding the number of beds.

Another way of expressing the medical waste generation in the hospital is the sectional overview, that is, waste generation per section of the hospital. In most hospitals, the dominant trend (in descending order) is large amounts of waste in the surgical, gynecology, orthopedic and medical sections produce smallest amounts (Manyele, 2004). The psychology and pediatric sections give the least amounts of waste similar to the data reported by Ahmed (1997).

Such an overview will assist the hospital management to direct their waste management resources in the critical areas (Manyele et al., 2003b). However, each hospital needs to generate its own data. This analysis will help the management to know exactly where to place more emphasis like waste collection frequency, number of containers required, and the number of waste handling staff. This will also lead to preparation of effective weekly rosters, and estimation of annual costs for medical waste management to improve the budgetary system.

### Medical waste generation outside Tanzania

Among studies conducted out of Tanzania, is the one conducted in Kuwait which showed the generation rates in the range of 3.65 to 5.4 kg/patient/day. However the total generation rate differs from one country to another. Table 2, show waste generation rates in different countries.

The study done at the City of Mesa, Arizona in USA, indicated waste collection efficiency to be an important aspect in medical waste management as resource are always scarce. Hospitals need to cut down costs and still provide all the services required without negotiating the quality. The collection efficiency can help in achieving greater success through system improvements such as installing new technologies, better collection systems, equipments and collection vehicles, proper operational procedures and capacity building to health workers. These developments in the medical waste industry improve the service and reduce costs as well as eliminating waste left uncollected in hospitals (USEPA, 1997).

The study done in Kuwait on variations in hospital

**Table 3**. Details of the study areas.

| No. | Details | Amana hospital | Ligula hospital |
|---|---|---|---|
| 1. | District | Ilala m/c | Mtwara m/c |
| 2. | Region | Dar es Salaam | Mtwara |
| 3. | No of beds | 290 | 360 |
| 4. | Daily in patient (patients occupying a bed) | 400 | 500 |
| 5. | Bed occupancy rate (person/bed) for 24 h | 1.4 | 1.4 |
| 6. | Daily outpatient (patient’s receiving hospital services but not admitted) | 860 | 720 |
| 7. | No of staff | 296 | 223 |
| 8. | Ownership | Government hospital | Government hospital |

**Table 4.** Different types of medical waste studied.

| S/N | Waste type | Acronyms |
|---|---|---|
| 1 | General waste | General |
| 2 | Pathological waste | Pathol |
| 3 | Radioactive waste | Radio act |
| 4 | Chemical waste | Chem |
| 5 | Infectious waste | Infec |
| 6 | Sharp waste | Sharps |
| 7 | Pharmaceutical waste | Pharm |
| 8 | Pressurized containers | Pres cont |

waste quantities and generation rates showed, the relationship between public health and improper collection, handling, and disposal of medical wastes is quite clear. Hazardous and nonhazardous wastes generated from different divisions of two of the largest public hospitals (capacity of approximately 400 beds each) in Kuwait were quantified and generation rates were determined. The generation rates were related to some important factors such as the number of patients, number of beds, and the type of activity conducted in different sections of the hospitals. The relationship between the waste generation rate and the number of patients was more applicable than that expressed in terms of the number of beds. The rates observed were in the range of 4.89 to 5.4 kg/patient/day, which corresponds to 3.65 to 3.97 kg/bed/day, respectively. These generation rates were comparable with those reported in the literature for similar hospitals. Minimal waste quantities were collected in the weekends. The study indicated that the hospitals surveyed provide some segregation of hazardous and nonhazardous wastes. Hazardous wastes contributed about 53% of the total quantity of wastes generated at the hospitals (Hamoda et al., 2005).

Handling of medical wastes is among the most important environmental problems in Turkey as it is in the whole world. Approximately 25 to 30 tons of medical wastes, in addition to the domestic and recyclable wastes, are generated from hospitals, clinics and other small health-care institutions daily in Istanbul (Kocasoy et al., 2004). Unfortunately, these wastes are not handled, collected or temporarily stored at the institutions properly according to Kocasoy et al. (2004). Besides inappropriate handling at the institutions, there is no systematic program for the transportation of the medical wastes to the final disposal sites. The transportation of these wastes is realized by the vehicles of the municipalities in an uncontrolled, very primitive way. As a consequence, these improperly managed medical wastes cause many risks to the public health and people who handle them.

## RESEARCH METHODOLOGY

### Study areas

Amana and Ligula hospitals were chosen to be study areas as to have comparison between hospitals in large and crowd cities and that of up countries with moderate interactions as shown in Table 3. Also these hospitals are Government facilities full registered with all departments and services needed by the study; they are also convenient to the researcher in terms of time, cost and management willingness.

### Study units and quantity of waste generated

Study unit was the actual measured medical waste generated in 91 days at each hospital in kg/day, collected and measured at every hospital section (generation point) as shown in Table 4.

**Data collection**

The hospital in charges supervised the data collection exercise. The in charges who took over the night shift started with empty receptacles. Before exchanging the shift, medical waste generated from night shift was handled over to the day shift section in charges. Each day during afternoon around 6.00 pm, all medical waste collected in both shifts in a given section was measured and recorded, covering date, shift, category of waste and quantity in kg.

**Data analysis techniques**

Data captured were entered in the Microsoft Excel program. Most of quantitative data were analyzed using Microsoft Excel program and SPSS 13.0 software.

The parameters developed include:

**Waste generation rates:** Waste generation per day, $W_d$, is defined as the total weight of waste (in kg) generated per day, that is,

$$W_d = \frac{Total\_kg\_generated}{day} \quad (1)$$

If $N_b$ = Number of beds in the hospital, (bed not occupied does not count in the calculation) then, patient/bed/day is defined as:

$$W_{db} = \frac{W_d}{N_b} \quad (2)$$

If $N_p$ = Number of patients attended in a hospital per day (inpatient and outpatients), then, waste generation rate per patient per day is defined as:

$$W_{dp} = \frac{W_d}{N_p} \quad (3)$$

**Medical waste collection efficiency, $E_c$:** Defining $W_{dc}$ as total waste collected per day, then, collection efficiency was determined as

$$E_c = \frac{W_{dc}}{W_d} \times 100\% \quad (4)$$

From which, percent of waste uncollected:

$$E_{c'} = 100 - E_c = 100 \times (1 - \frac{W_{dc}}{W_d}) \quad (5)$$

Equation (3) and (4) can also be used to different waste categories. That is, for each category, *i*

$$E_{c,i} = \frac{W_{dc,i}}{W_{d,i}} \times 100\% \quad (6)$$

$$E_{c',i} = 100 \times (1 - \frac{W_{dc,i}}{W_{d,i}}) \quad (7)$$

**Range of medical waste generation, $R_w$:** $R_w$ for each waste category was determined by

$$R_{w,i} = \lfloor W_{d,i} \rfloor_{max} - \lfloor W_{d,i} \rfloor_{min} \quad (8)$$

For each waste category, *i*

**Normalization of data on medical waste generation:** Due to differences in the magnitudes of waste generation by categories and between hospitals, the values of waste generation were normalized to yield values between 0 and 1, that is, $X_{nm,k}$ using equation:

$$X_{nm,k} = \frac{X_k - X_{min,k}}{X_{max,k} - X_{min,k}} \quad (9)$$

Whereby;

$X_k$ = *i*th value in the waste generation data
$X_{min,k}$ = minimum value in the time series being analyzed
$X_{max,k}$ = maximum value in the time series being analyzed
$X_{nm,k}$ was then determined for different waste categories on monthly basis or overall basis in 3 months period

**Number of data points analyzed (length of time series):** The overall length of time series was $N$ = 91, but in cases where monthly analysis were conducted $N$ = 30, 31 and 30 for September, October and November.

**Statistical analysis**

The probability density function (PDF) reveals quantitatively the scatter of values of a time series from the mean value. Examining the shape of PDFs and quantifying their peaks and tails can reveal the details of the changes in medical waste generation data (Mudde et al., 1999; Manyele et al., 2003b). The standard deviation and other measures of spread give spread of values in the PDF; however, they provide little information about the shape characteristics of the PDF. The probability density function gives a better overall picture of the temporal behavior in the process. We have one probability density function plot for each measurement considered, from which statistical inferences could be made.

To describe the asymmetric properties and peakedness of the probability density functions (PDFs), the skewness factor, $S_k$, and kurtosis, $K_u$, can be used, respectively. The skewness factor gives a measure of the degree of asymmetry of a PDF around its mean value, while kurtosis is a measure of the relative peakedness of a PDF compared to a normal distribution. Higher positive skewness factor signifies a PDF with relatively longer tails towards right hand side while lower positive $S_k$ signifies PDF with shorter tails towards higher values. Thus, higher $S_k$ shows strong variation in medical waste generation. Skewness factor was determined using the equation,

$$S_k = \frac{1}{N_1} \sum_{i=1}^{N_1} \left[ \frac{\varepsilon_{si} - \overline{\varepsilon_s}}{\sigma} \right]^3 \quad (10)$$

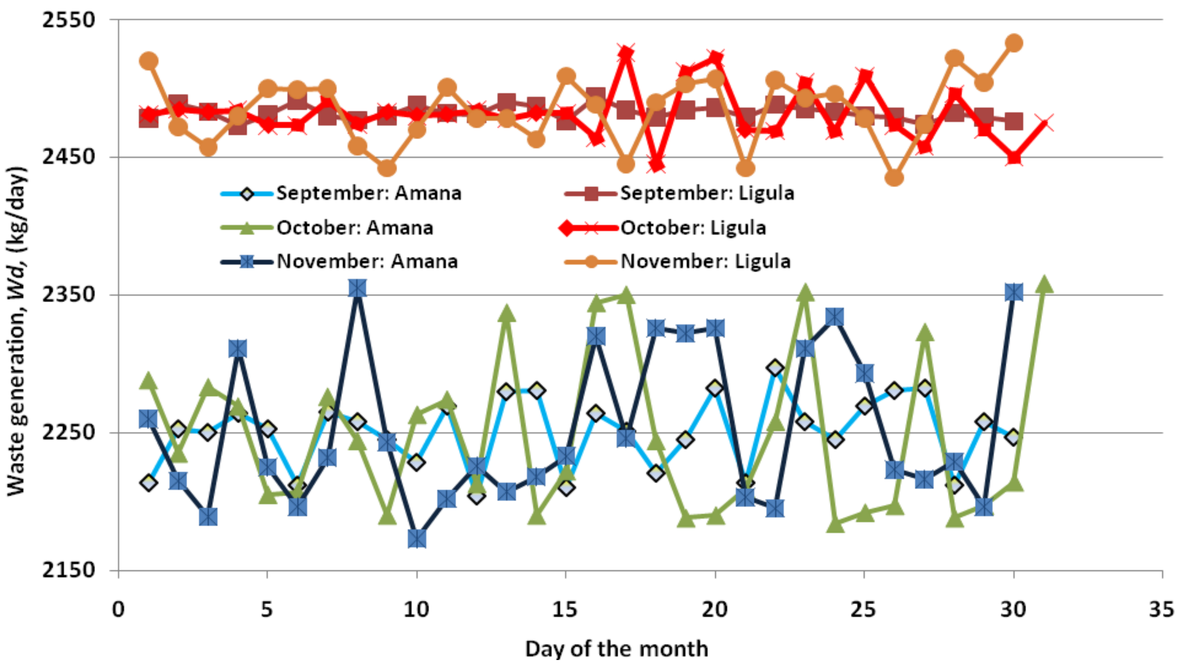



**Figure 1.** Variation of daily medical waste generation at Amana and Ligula hospitals in a perod of three months (September to November, 2009).

The values were computed automatically using SPSS. While higher values of $K_u$ signify a peaky PDF than that of a normal distribution, lower value of $K_u$ signifies flatter PDF. When the values of the time series are concentrated on one portion of a PDF, the peak becomes high and a high degree of kurtosis is implied. Thus, lower $K_u$ (flatter PDF) signifies strong variation in medical waste generation. Kurtosis was determined using the equation,

$$K_u = \frac{1}{N_1}\sum_{i=1}^{N_1}\left[\frac{\varepsilon_{si} - \overline{\varepsilon_s}}{\sigma}\right]^4 - 3 \quad (11)$$

The values were also computed automatically using SPSS. Being higher moments of the time series, the skewness and kurtosis are more sensitive to dynamics of the process than the standard deviation and the mean values.

## RESULTS AND DISCUSSION

### Variations of daily medical waste generation

The trend of daily medical waste generation was analyzed. Medical waste were collected, weighted, and recorded consecutively for 3 months where by one month was taken to be a season (September, October and November) as shown in Figure 1. In September, medical waste generation monthly trend movement at Ligula hospital was regular as there was no much variation in daily rates, but for Amana the trend movement was somehow irregular with its peak period lying at 11th to 21st. In October, the trend movement variation was irregular in both hospitals, where by Ligula peak period lied between 17th to 27th and Amana starting a little bit early in 13th to 31st. In November, the daily trend movement for both hospitals was quite different as the variation movements started fluctuating from fist date of the month to the end. The variation was irregular and random making it difficult to predict peak periods. The trend movement analysis and seasonal variations help hospitals to observe and understand peak, down and normal periods of medical waste generation within the season, and be in position to prepare realistic and cost-effective plan and budgets to deal with proportional of medical waste they generate in a particular season. Since the random variations are not expected to repeat again in the same way, the data presented is useful in indicating highest and lowest (as discussed using range values) so that the planning and budgeting can include the maximum values to be on the safe side.

### Average medical waste generation

The study analyzed daily average medical waste generation rates. At Amana hospital it was observed that, the generation rate is 2,250 kg/day. The generation by category (Figure 2) indicates that, general waste amounts to (739 kg/day), followed by infectious waste (649 kg/day), pathological waste (433 kg/day), sharp waste

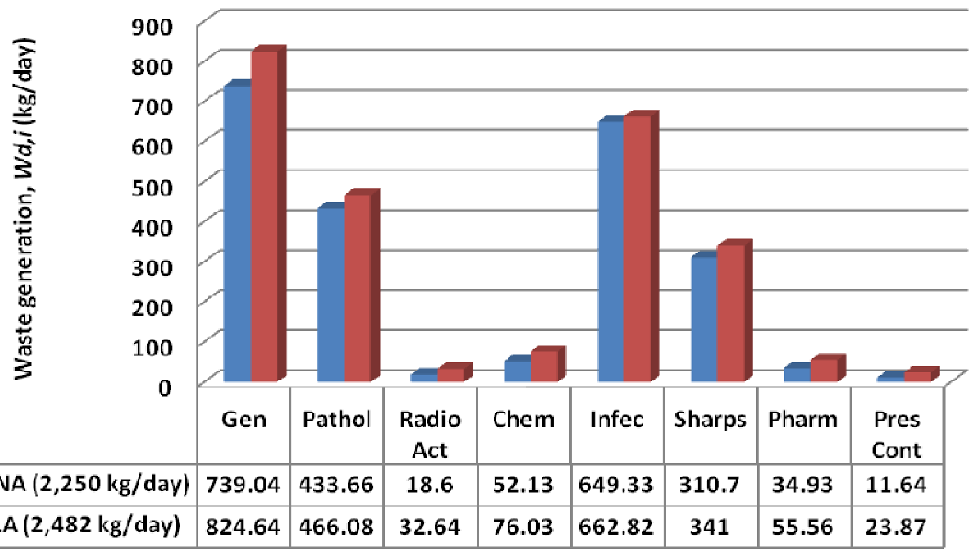



**Figure 2**. Average medical waste generations in Amana and Ligula Hospitals.

**Table 5**. Summary of medical waste generation rates for Ligula and Amana hospitals.

| Generation rate | Ligula | Amana |
|---|---|---|
| Total waste (kg/day) | 2,482 | 2,250 |
| No of patients/day | 1,220 | 1,260 |
| No of beds | 360 | 290 |
| Bed occupancy rate (person/bed) for 24 h | 1.4 | 1.4 |
| Waste generation rate per patient/day (inpatient and outpatient) | 2.0 kg/patient.day | 1.8 kg/patient.day |
| Waste generation rate per bed/day (bed not occupied does not count in the calculation) | 7.0 kg/bed.day | 7.8 kg/bed.day |

(310 kg/day), chemical waste (52 kg/day), pharmaceutical (34 kg/day), radioactive (18 kg/day) and pressurized containers (11 kg/day).

The average medical waste generation was also analyzed in terms of kg waste/patient.day. It was revealed that average daily medical waste generation per patient is 1.8 kg/day which agrees with the range of 0.3 - 1.8 kg/day established by Mato et al., (1997). On the other hand, the average daily medical waste generation per patient is 2.0 kg/patient.day, for Ligula hospital which is slightly different from Amana hospital (1.8 kg/patient. day). This value resembles the results reported in Middle East, Latin America and India which ranged between 1.0 - 3.0 kg/day (Hamoda et al., 2005).

Based on generation rate per bed, Amana produces 7.8 kg/bed.day while Ligula produces 7.0 kg/bed, day as shown in Table 5. Since the bed occupancy rate is the same between the two hospitals, it is evident that Amana produces more waste per bed than Ligula, which is in the agreement with the fact that urban hospitals generate more waste per bed due to high standard of living. The two hospitals resemble data reported in the literature by (Hamoda et al., 2005) for North America, and Western Europe, as shown in Table 2.

Number of beds in the hospital also affects waste generation rates. Ligula hospital has 360 beds and Amana has 290 beds, when number of beds was cross analyzed with average daily generation rates results showed that, as the number of beds increases the waste generation per bed becomes low. Ligula and Amana (Tanzania hospitals) have few beds and high waste generation rate per bed. day (7.0 to 7.8) compare to countries like Latin America and India where by waste generation per bed is low about 1.0 as reported in the literature by (Hamoda et al., 2005) in Table 2.

At Ligula hospital, the average generation rate was revealed to be 2,482 kg/day. Its composition varied as shown in Figure 3. General waste was the highest about (33%), followed by infectious waste (27%), pathological waste (19%), sharp waste (14%), chemical waste (3%), pharmaceutical (2%), radioactive waste 1% and pressurized containers (1%).

The fraction of sharps waste was observed to be 14% in both hospitals, while the fraction of chemical waste was higher for Ligula (3%) than Amana (2%). The fraction of sharps waste can look small, but poses most of the

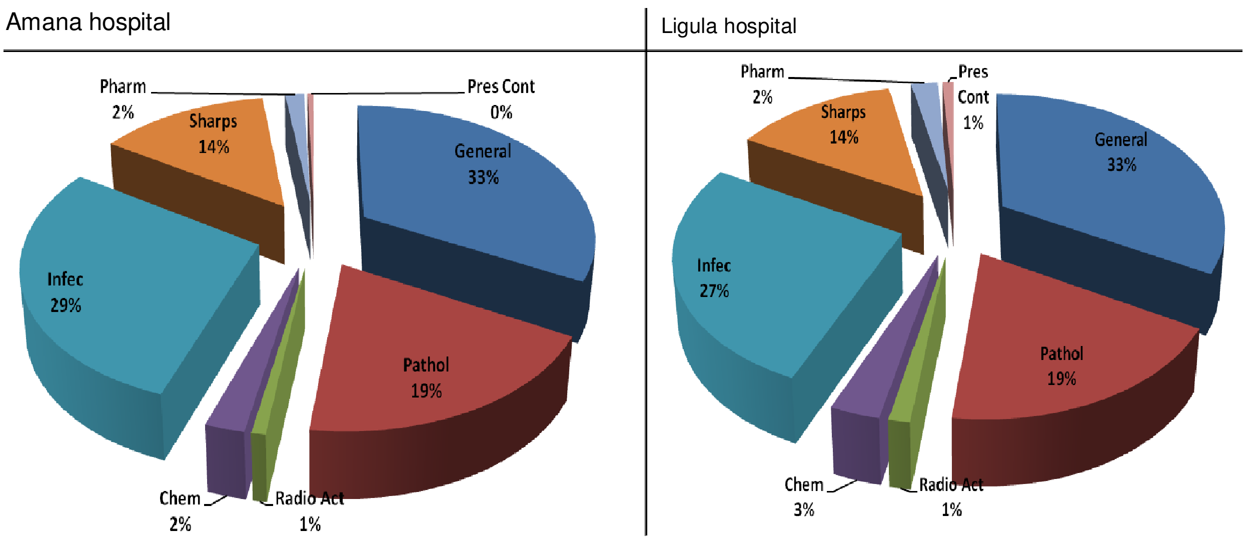



**Figure 3.** Composition of medical waste generated by categories in Amana and Ligula Hospitals.


**Figure 4.** Average medical waste collection efficiency in Amana and Ligula Hospitals.

risk to health workers and community especially on needle stick injuries necessitating more attention. Currently, such waste is collected in special safety boxes supplied by WHO/UNICEF and EPI/MOHSW. Efficiency of medical waste collection in comparison with generation.

### Overall daily medical waste collection efficiency

The waste collection efficiency was determined to compare medical waste generation and medical waste collection in both hospitals. When the results were cross analyzed, it was revealed that, at Amana hospital out of 2,250 kg of waste generated per day about 6% is left uncollected, while at Ligula hospital out of 2,482 kg of waste generated per day, 10% is not collected as shown in Figure 4. Generally it was observed in both hospitals that, substantial amount of waste is left uncollected due to low capacity of hospitals in managing medical waste. This situation need great attention as waste left uncollected can be source of nosocomial infection in hospitals and can pollute environment in terms of water, soil and air leading to dangerous diseases to the community.

### Monthly medical waste collection efficiency

The waste collection efficiency was also analyzed on monthly basis, with the results indicating an increase in uncollected waste. At Ligula hospital, the situation was worse compare to Amana hospital as shown in Figure 5. The amount of waste left uncollected in September was (4% Amana, 7% Ligula), October (6% Amana, 11% Ligula), November (8% Amana, 12% Ligula). The results indicate that, some of the waste in all categories is left uncollected which is the reflection of little commitment given by hospital administrators in medical waste management especially in planning and budgeting associated with poor technology in use as the situation

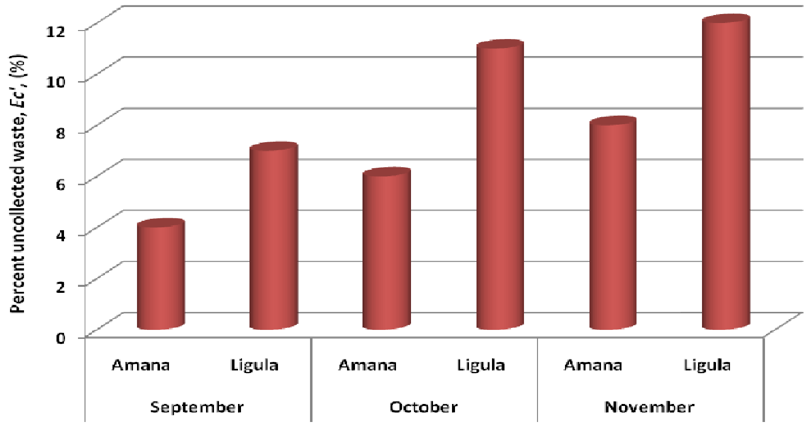
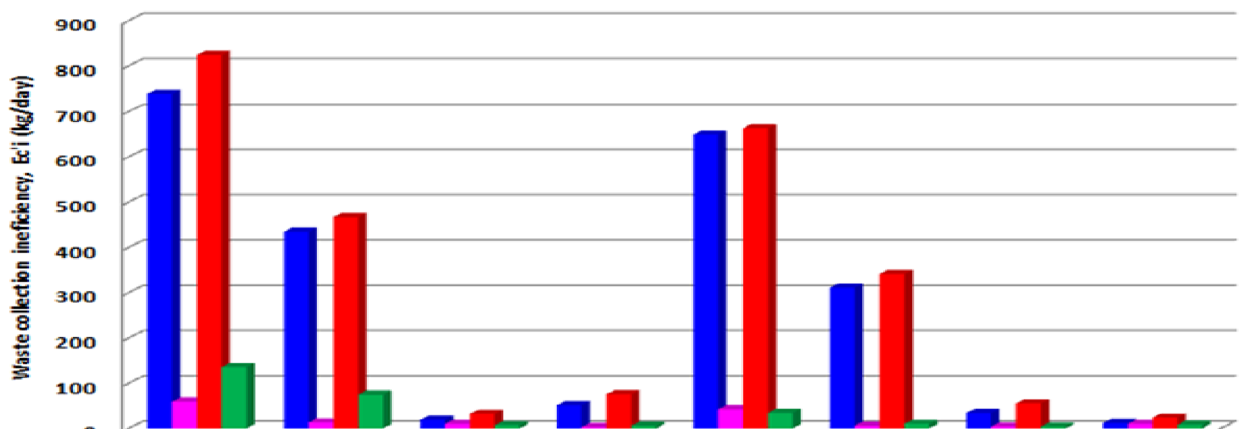



**Figure 5.** Comparison of the percent uncollected medical waste for Amana and Ligula Hospitals.




| | General | Pathol | Radio Act | Chem | Infec | Sharps | Pharm | Pres Cont |
|---|---|---|---|---|---|---|---|---|
| Generation Amana | 739 | 434 | 19 | 52 | 649 | 311 | 35 | 12 |
| Not collected Amana | 60 | 13 | 10 | 3 | 43 | 6 | 4 | 10 |
| Generation Ligula | 825 | 466 | 33 | 76 | 663 | 341 | 56 | 24 |
| Not collected Ligula | 136 | 75 | 7 | 6 | 35 | 10 | 4 | 8 |

**Figure 6.** Medical waste collection efficiency by categories at Amana and Ligula hospitals.

becomes worse as the months goes on.

## Daily medical waste collection efficiency by categories

The waste collection efficiency was also analyzed by categories. The analysis showed generation rate for general waste to be higher (739 kg/day at Amana and 825 kg/day at Ligula) compared to other categories of waste such as pathological waste (434 kg/day at Amana and 466 kg/day at Ligula) and chemical waste (52 kg/day at Amana and 76 kg/day at Ligula) as shown in Figure 2. That is good news to hospital administrators, as general waste can easily and economically be collected, treated and disposed of using normal municipal technologies to reduce cost and help hospitals to concentrate with much hazardous waste which are dangerous and costly to handle.

A problem was noted when the amounts generated was compared with the amounts of waste collected. For example Amana hospital generates general waste amounting to 739 kg/day and 60 kg/day is not collected. Ligula hospital generates general waste amounting to 825 kg/day and 136 kg/day is not collected. The collected amounts were lower than the generated amounts, indicating that some of the waste was not collected. Figure 6 compares the daily amounts generated and amounts left uncollected for different medical waste categories. The largest amount of uncollected waste was

**Table 6**. Analysis of medical waste collection inefficiency in hospitals.

| No | Collection inefficiency, $E_c'$ | | Amana (%) | Ligula (%) |
|---|---|---|---|---|
| 1 | Overall collection inefficiency, $E_c'$, (% uncollected) | | 6 | 10 |
| 2 | Monthly collection inefficiency, $E_{c',k}$, (% uncollected) | September | 4 | 7 |
| | | October | 6 | 11 |
| | | November | 8 | 12 |
| 3 | Collection inefficiency by category, $E_{c',i}$, (% uncollected) | General | 8 | 16 |
| | | Pathological | 3 | 16 |
| | | Radio active | 53 | 21 |
| | | Chemical | 6 | 8 |
| | | Infectious | 7 | 5 |
| | | Sharps | 2 | 3 |
| | | Pharmaceutical | 11 | 7 |
| | | Pressurized containers | 83 | 33 |

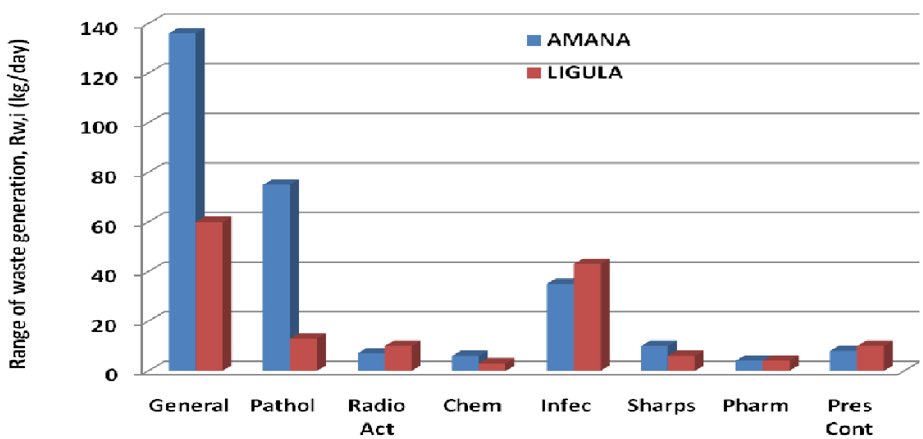



**Figure 7.** Range of variation in the medical waste generation by categories in Amana and Ligula hospitals.

observed at Ligula for general waste (136 kg/day), followed by pathological (75 kg/day) and infectious wastes (35 kg/day) at the same hospital. Amana hospital had lower amounts of uncollected waste for all cases of waste categories as shown in Figure 6.

Waste collection is very important. Table 6 summarizes the waste collection status of both hospitals and locating the uncollected waste. Generally overall waste collection is worse at Ligula hospital (10%) compare to Amana hospital (6%). The monthly collection inefficiency increases as the months goes on in both hospitals. The categories observe to be more affected as far as collection inefficiency is concerned was pressurized containers (Amana 83% and Ligula 33%) and radioactive waste (Amana 53% and Ligula 21%) are not properly collected. These categories are handled haphazardly by hospitals as pressurized containers are seen nearby hospitals sold by scavengers as bottles for collecting fluid medicines such as cough expectorants and most of radioactive waste such as x-ray films are left with patients to be taken home which is very dangerous as they can emit hazard rays causing cancer.

## Measuring variations in the actual medical waste generation

### *Range of medical waste generation for the whole period of study*

The daily fluctuations of medical waste generation were studied by examining the range of amount of waste generated from daily records as shown in Figure 7. The results show that, daily generation rates are not constant. There are high fluctuations for general waste ranging up

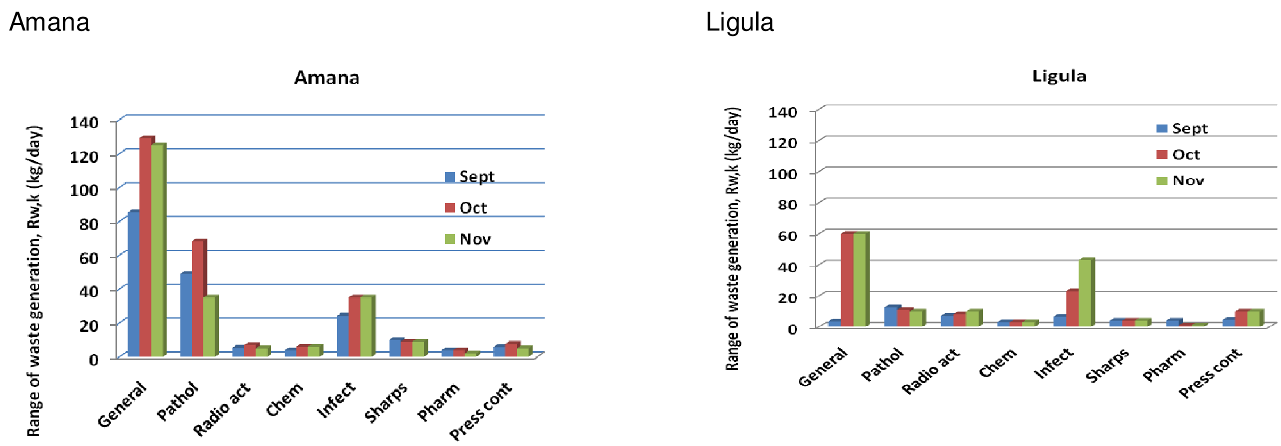



**Figure 8**. Comparison between monthly medical waste generation fluctuations by categories for Amana and Ligula hospitals.

to 136 and 60 kg/day for Amana and Ligula hospital respectively. The study also indicated the strong high fluctuation in pathological waste at Amana hospital (75 kg/day) compared to Ligula (13 kg/day) which can be attributed to the large number and type of surgical procedures conducted on that day. Also the fluctuations in infectious waste at Ligula hospital (43 kg/day) compared to Amana hospital (35 kg/day) can be due to large number of in-patients admissions. There's no difference in the range for other waste categories (radioactive, chemical, sharps, pharmaceutical and pressurized containers). Moreover other categories of waste had small fluctuations as indicated by lower range. This assessment gives hospital administrators picture that, when there is increase in patients (in and out patients) and where hospitals expand their services to accommodate more procedures, they are also required to invest more resources financially, human and materials for the management of additional medical waste to be generated.

### *Range of medical waste generation on monthly basis*

The range of medical waste generations was also analyzed on monthly basis with the aim of observing trend of fluctuations over a period of time. Amana hospital was observed to have high range of general waste at September (90 kg/day), October (125 kg/day) and November (130 kg/day), followed by pathological and infectious waste. Other waste was observed to have low range as indicated in Figure 8. Ligula hospital was observed to have high range of general waste in October and November about 60 kg/day in both months, while September had low range, followed by infectious waste in all three months, other categories of waste had low range. However generally, Amana hospital was observed to have high range compare to Ligula hospital due to its nature of location being in the big city, the number of daily patient's attendance and admissions is not predictable as it varies a lot. These results give picture to hospital administrators that, the location of a hospital can affect the amount of waste generated, so it should be in their mind during planning and resource allocation.

## Analysis of actual medical waste generation using probability density function

### *Need for normalization of data*

The comparison of medical waste generation between the two hospitals and between different waste categories was not possible because of wide differences in the range of values. To elaborate this problem, different waste categories between Amana and Ligula Hospitals are compared as shown in Figure 9 and 10, for total waste generation, monthly generation and generation by categories. When the analysis was done in Figure 9, the actual medical waste generation values were not comparable as it was observed to have big differences in the magnitudes of waste generation by categories and between hospitals, though histogram gives a rough picture of Amana hospital to have unpredictable daily average generation and Ligula hospital to have almost constant daily average generation rates. For that reason the need for data normalization was observed, where by data from both hospitals were made to rank and read at one scale of frequency in "Y" axis and scale of ("0" to "1) in "X" axis. The normalized total waste generation rates, monthly waste generation rates and waste generation by categories were then properly analyzed as shown in Figure 10.

It should be noted that the frequency values for September waste generation are lower than those for average total waste and infectious waste generation because the latter uses overall data for three month period ($N$ = 91) while the former used data collected in

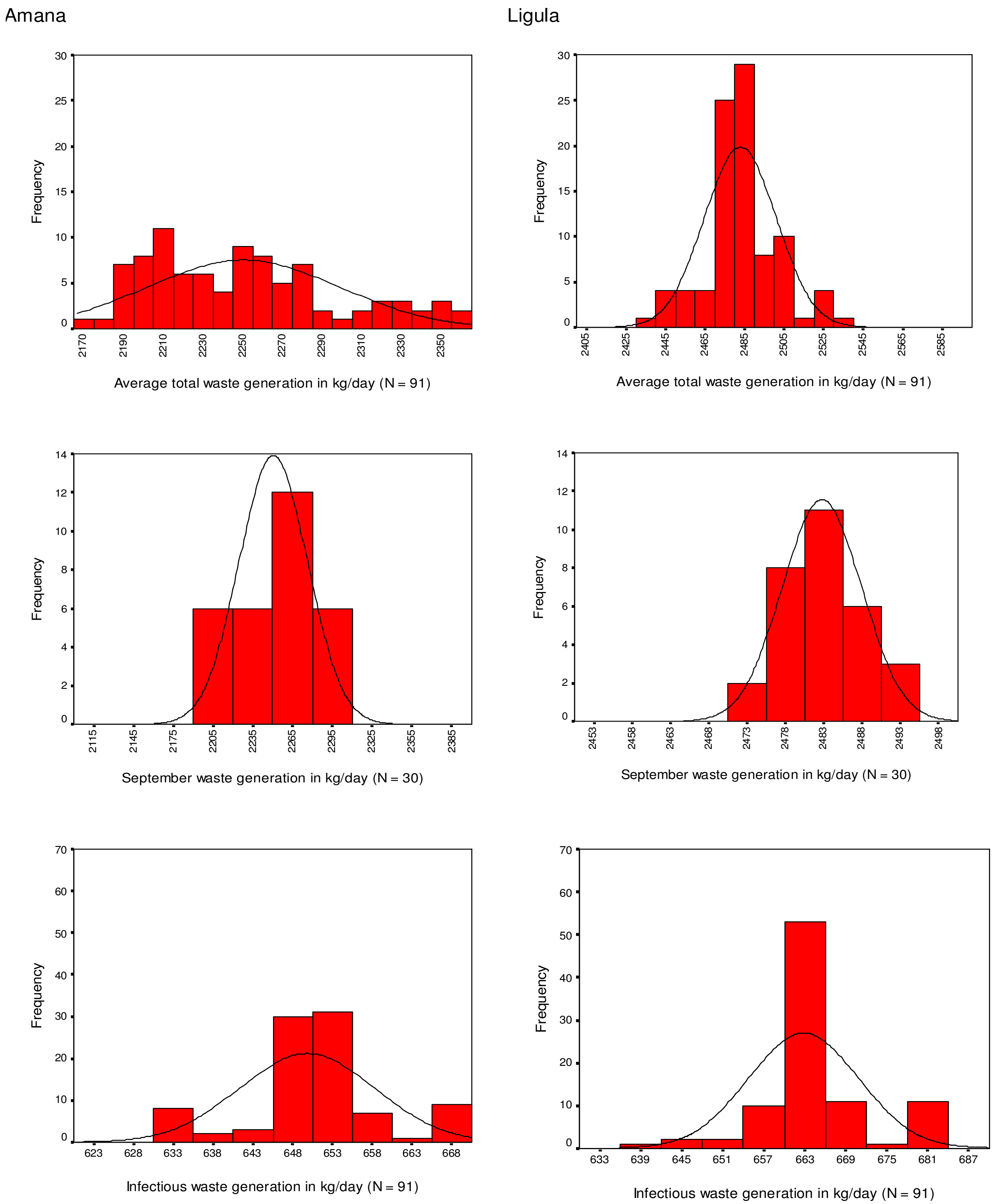



**Figure 9.** Distribution of the actual medical waste generation at Amana and Ligula hospitals.

one month period ($N$ = 30), that's different value of N.

When the data were normalized it was then easy to compare as shown in Figure 10. Amana hospital daily average waste generation was observed to have

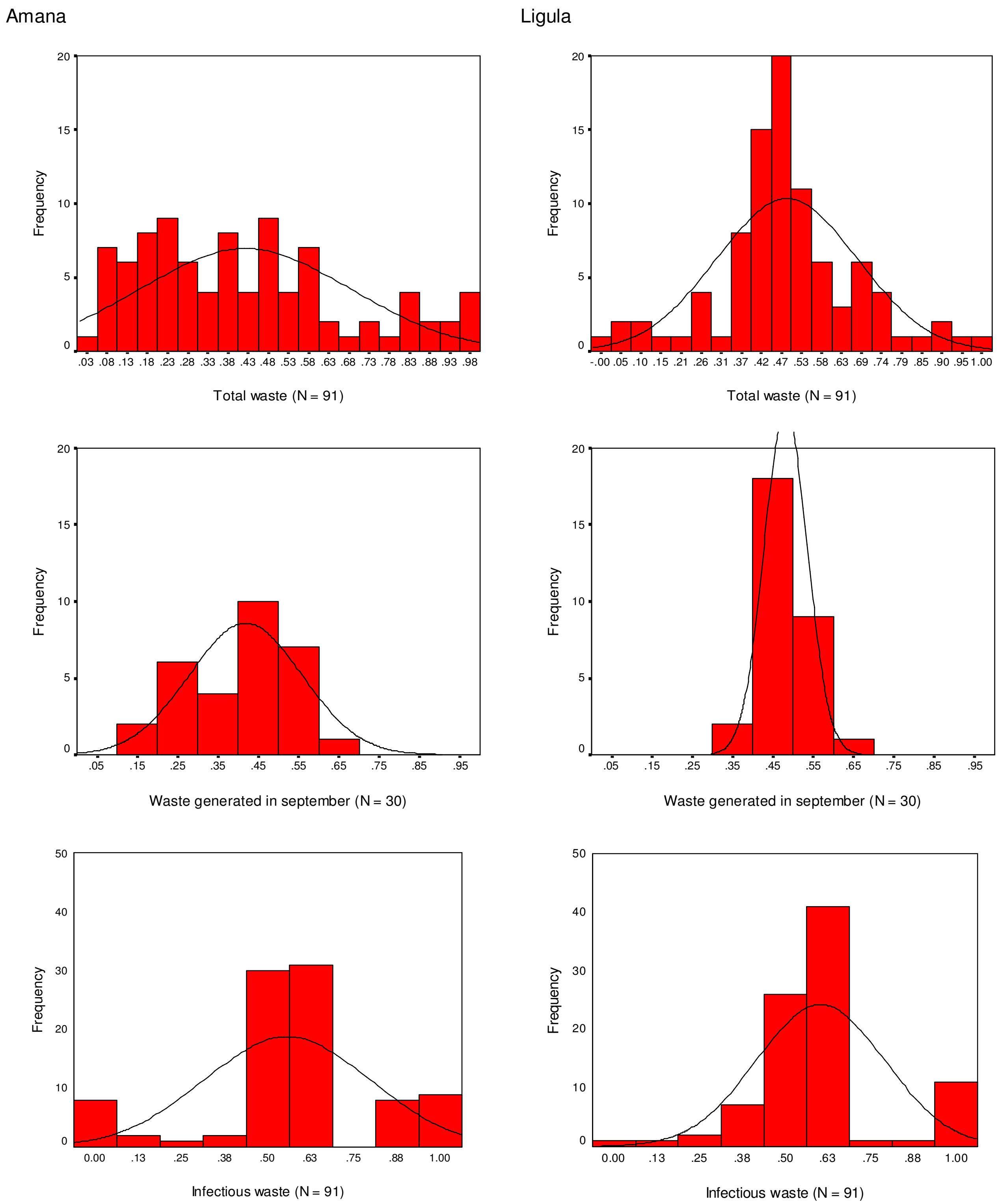



**Figure 10**. Normalized waste generation data at Amana and Ligula hospitals.

unpredictable rates. It was widely distributed with variations in generation rates showing high frequency at lower values, which poses difficult to administrators during planning and budgeting. This situation happened due to its location in the big city as there's a lot of unplanned emergency services which need to be attended daily. The situation with Ligula hospital is much better as high frequency lies around the mean which indicate that, most of daily generation rates are constant; for monthly waste generation the situation was observed to be the same as discussed in the average generation, but when analysis was done by categories, the infectious waste showed high frequency around the mean in both hospitals with slightly low frequency distributions at each ends in both hospitals, which indicate some difficult in planning and budgeting, however most of the daily generation was almost constant. It should be noted that the lower frequency values for September is due to lower N used that is 30 (days in a month) while the rest of data spans for 3 months, with $N = 91$.

## Analysis of normalized total medical waste generation

The trend of total daily average medical waste generation was studied to establish the magnitude of variation. The result in Amana hospital showed a wide frequency distribution indicating a wide variation in daily average medical waste generation. The distribution is also with slightly high frequencies at lower generation values as indicated in Figure 11. For Ligula hospital the curve is evenly distributed with very little frequency variation at the ends, which indicate that most of generation values are concentrated around the mean, which means daily waste generation rates are almost constant with little variations, also shown in Figure 11. These results indicate that, the trend Amana hospital waste generation have a lot of variations in daily generation making the situation difficult to administrators to plan and budget. The situation with Amana hospital is due to its location in the big city where by a lot of unplanned activities happened i.e., emergency in obstetric care, accidents etc., making it difficult to predict number of patients. The living standard of Dar es Salaam is also different to Mtwara as people live sophisticated life, such as using bottled water and packed food which increases the amount of waste to be generated.

Administrators are required to be kin in locating the high waste generation seasons, its trend in daily, monthly, annually variations and be able to accommodate them in their management plan and budgets.

## Analysis of normalized monthly medical waste generation

The trend of total daily average generation results necessitated monthly analysis to be done. The monthly waste generation trend was analyzed as shown in Figure 12. In September, Amana hospital was observed to have wide distribution frequencies with variations while at Ligula there were evenly distributed frequencies concentrating at 0.35 to 5.55. In October at Amana hospital there were wide frequency distribution concentrating on the lower values (0 to 0.15), at Ligula the generation was evenly distributed concentrating around the mean (0.25 to 0.55). In November the daily waste generation frequencies was widely distributed with very high variations in both hospitals.

General observation showed that, in both hospitals the waste generation frequency distributions are not equally nor constant distributed, they vary in every month. This situation need hospital administrator’s attention to be able to locate the pick, low and moderate variation periods and accommodate that in their plans to help hospitals be able to deal with all the waste they generate through out without emergencies. These results insist on hospitals having proper medical waste management plans developed from trend analysis and/or researched data.

## Analysis of normalized medical waste generation by categories

The variation of medical waste generation was also analyzed by categories. The result revealed that at Amana hospital chemical, pathological and pharmaceutical waste has high frequency variations while other categories are evenly generated with little variations. At Ligula hospital chemical and pharmaceutical waste have high frequency variations and the other categories are normally distributed as indicated in Figure 13. These results give insight to hospital administrators that, high attention is required to chemical and pharmaceutical waste as its generation is not predictable, and thus a medical waste management plan accommodating the situation revealed by the study is of vital importance.

These results indicate that, different categories of waste are not equally generated as some categories such as general waste have high rate of generation while others such as chemical and radioactive wastes which are hard and cost to dispose have low generation rates, which is advantage to hospital administrators as general waste can easily and economically be disposed of using the normal technologies to lower the cost and help hospitals to concentrate with hazardous medical waste which are dangerous and costly to handle.

## Skewness and kurtosis of medical waste generation data

The skewness and kurtosis was also assessed by studying mean and median of different distributions of medical waste categories. Where distribution was skewed, mean and median were not equal. In negatively skewed distributions, mean of medical waste generations were lower than median which indicated lower generation rates in low frequencies and high generation rates in higher frequencies among waste categories. In positive

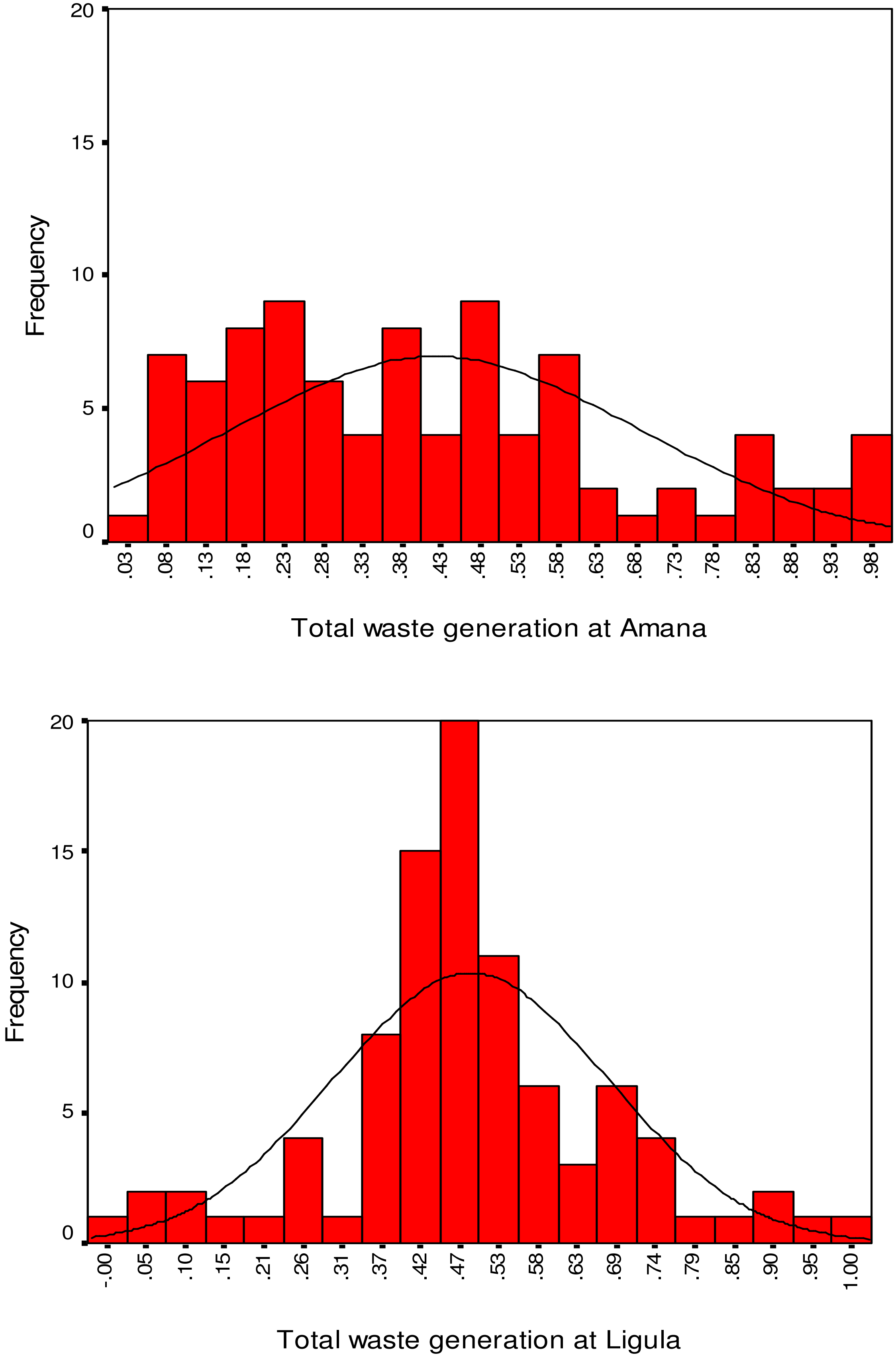



**Figure 11.** Normalized total waste generation data for Amana and Ligula hospitals ($N$ = 91).

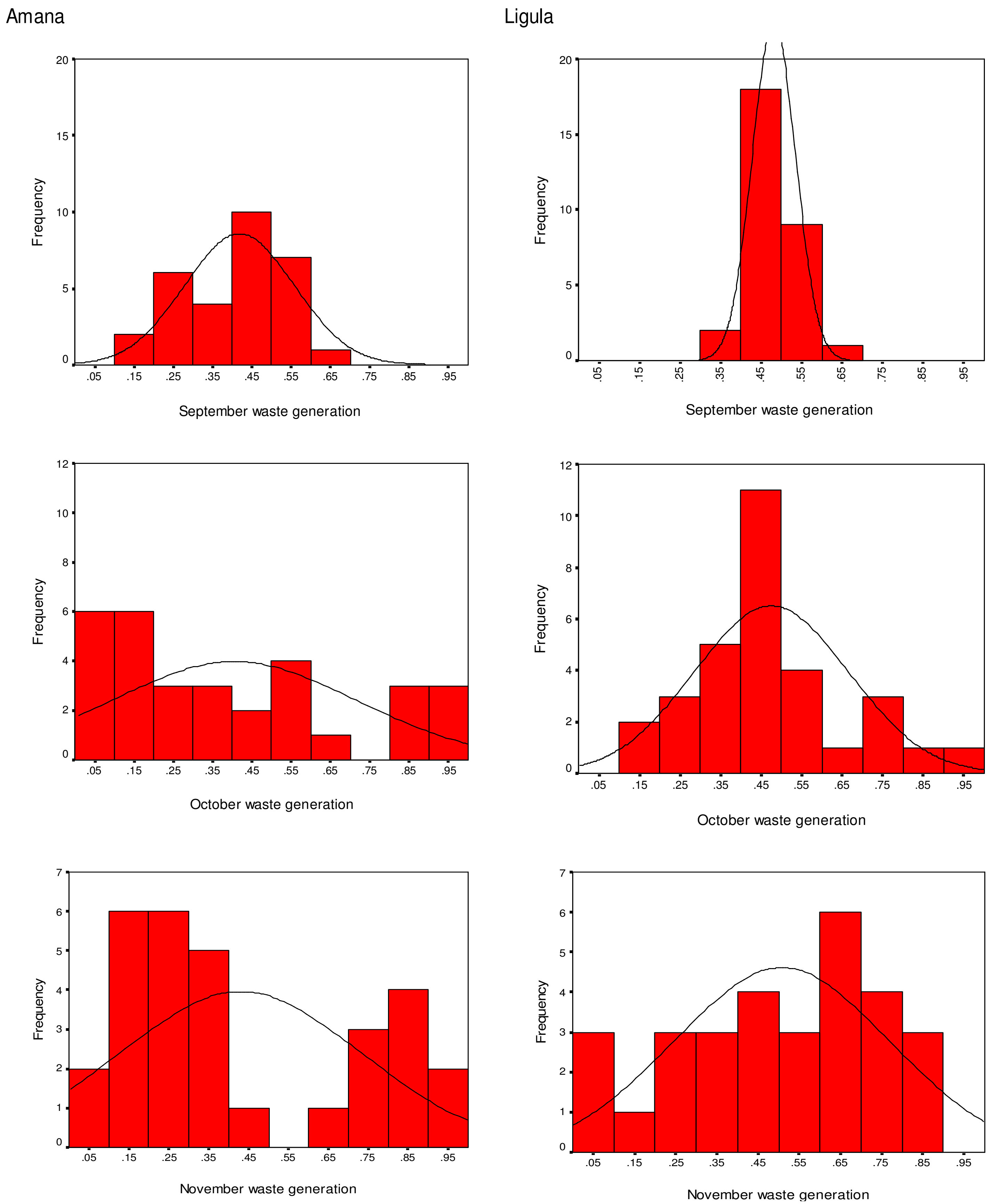



**Figure 12.** Comparison between Amana and Ligula hospitals using normalized monthly waste generation data (*N* = 30).

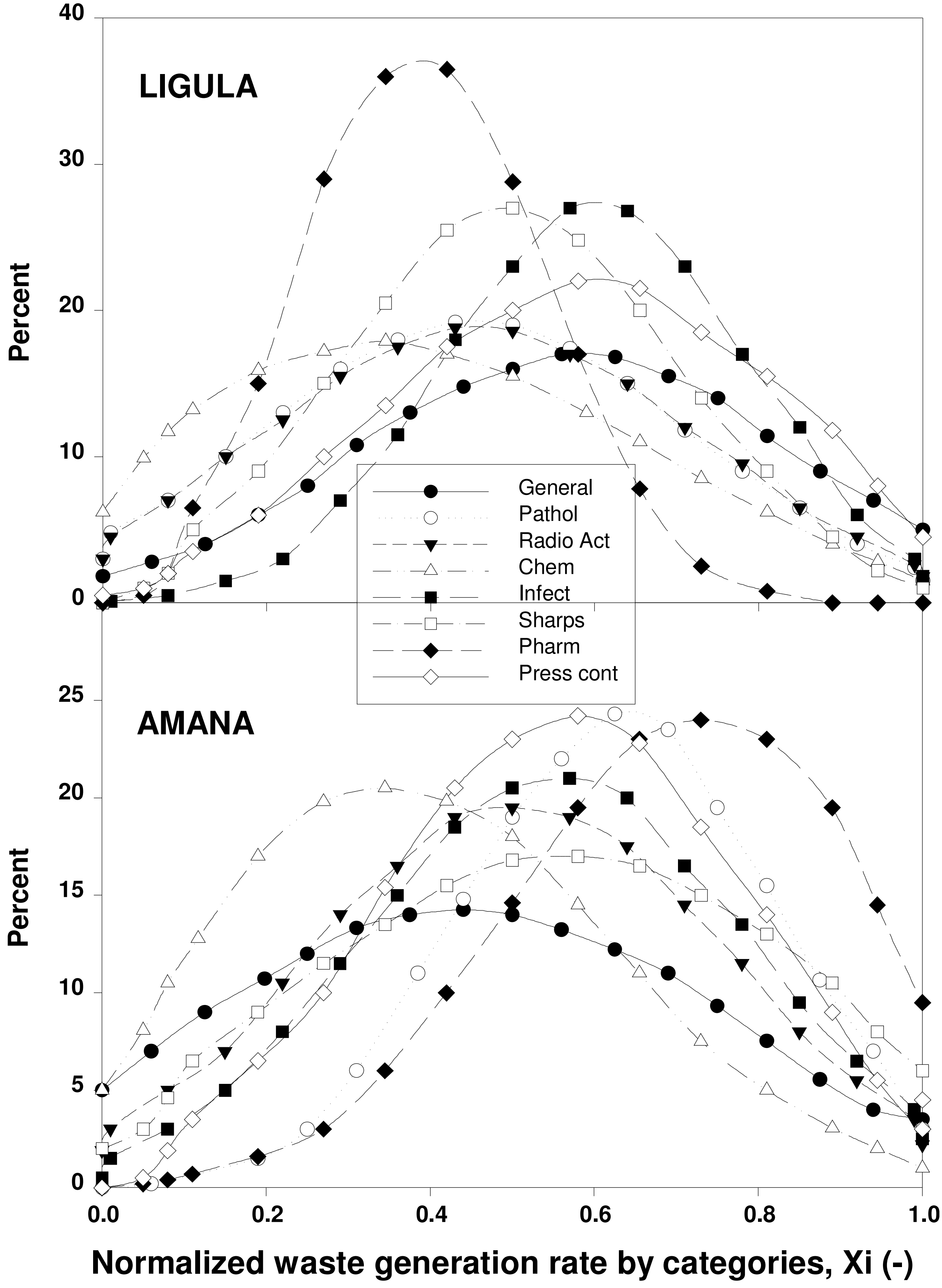



**Figure 13.** Histograms of normalized waste generation data for different waste categories at Amana and Ligula hospitals.

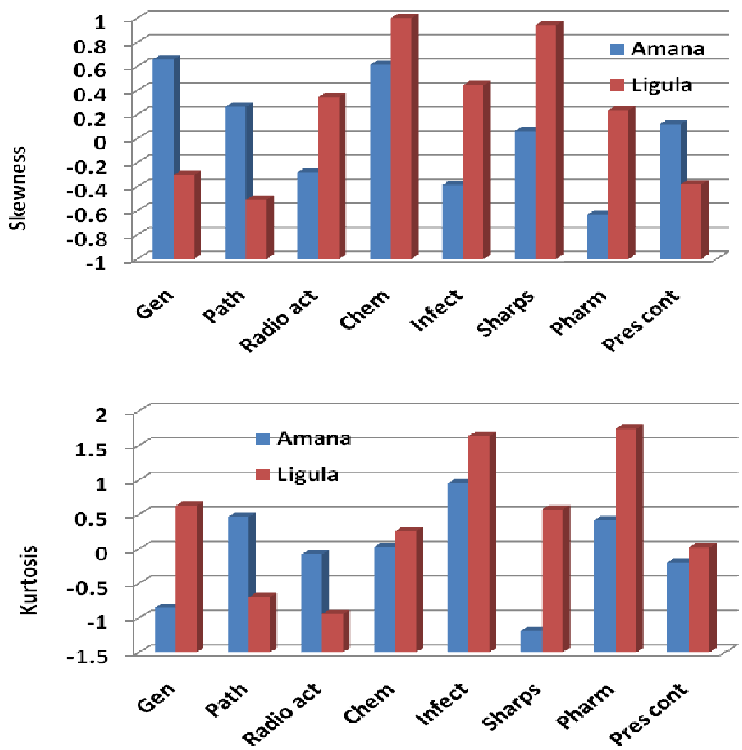



**Figure 14.** Skewness and Kurtosis of MW generation data in Amana and Ligula hospitals.

skewness mean were larger than median which indicated high waste generation rates in lower values and low generation rates in higher frequencies as shown in Figure 14. Such categories like pressurized containers in Amana and radioactive waste in Ligula lies near "0" which shows normal distribution. The categories such as general waste in Amana and sharps waste in Ligula have positive skewness indicating variations in daily waste generation rates, higher waste generation rate at low frequency values. The categories like pharmaceutical waste in Amana and pathological waste in Ligula have negative skewness also indicating variations in daily waste generation rates but more waste generated at higher frequency values.

Kurtosis was used to measure whether the data are peaked or flat relative to a normal distribution as shown in Figure 14. Waste such as infectious, sharps and pharmaceutical has high kurtosis as they have a distinct peak distribution near the mean, indicating small variations in its generation rates. Waste with low kurtosis such as radioactive, chemical and pressurized containers have a flat top near the mean indicating wide variations in generation rates.

These results continue to insist that, different categories of waste vary in their generation. Categories like general waste have high generation rates in both hospitals while other wastes such as chemical and radioactive have low generation rates, which is an advantage to hospital administrators as general waste can easily and economically be disposed of using the normal technologies to lower the cost and help hospitals to concentrate with hazardous medical waste which are dangerous and costly to handle.

## Conclusion

This paper gives picture and more information's to hospital managers (decision makers) and health workers (implementers) to facilitate development and improvement of medical waste management framework. Study done has established a database of information and statistics on medical waste management from generation to final disposal. Actual measured medical waste generation data has been properly recorded its components, composition, and quantities, then analyzed to have information's that will form the basis for realistic planning, designing, budgeting and implementation of medical waste management procedures that will be economical, effective and efficient.

This study indicate in both hospitals to have high rate of medical waste generation as well as generation per patient per day; these results switch alarm to hospital administrators, health workers, environmental management experts and all other stakeholders to give special attention and priority in setting a related share in their budgets for proper management of medical waste in their health facilities.

The analysis also showed generation rate for general waste to be higher compare to other categories of waste such as pathological and chemical, this is a good news to hospital administrators, as if well segregated, can easily and economically be collected, treated and disposed of using the normal municipal technologies to reduce cost and help hospitals to concentrate with much hazardous waste which are dangerous and costly to handle. The rate of medical waste collection in both hospitals is not very good as some of wastes are left uncollected which call for more effort to be kept in this area as medical waste left uncollected can harm human health and environment.

The trend movement analysis and seasonal variations will help hospitals to observe and understand peak, low and normal periods of medical waste generation within the season, and be in a position to prepare realistic and cost-effective plan and budgets to deal with proportional of medical waste they generate in a particular season.

These results generally give picture that, when there is increase in patients (in and out patients) and where hospitals expand their services to accommodate more procedures, they are also required to think of investing more resources to be in pace with the management of additional medical waste to be generated. This can only be achieved by hospital managements to have detailed plans and budget which take care of waste generation variations with time.

It was concluded that, in order hospitals to be able to manage medical waste properly they are required to observe trend and seasonal variations of medical waste generation and understand better the maximum and minimum values of waste generation fluctuations and accommodate them in their plan and budgets.

## ACKNOWLEDGEMENTS

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