Modelling, Composition and production rate of medical solid waste in Tikrit: A case study of Tikrit Teaching Hospital (TTH) in Iraq

Abstract

Tikrit Teaching Hospital (TTH), Tikrit, Iraq, was selected for investigation as a case study. Data collection was carried out during TTH visits and by questionnaires. Sampling was performed during a 10-month period, one week each sampling month. The medical waste analyzed was comprised of 63.04% general waste (non-risk) and 36.96% hazardous waste. The results indicated that the medical waste generation rate is 0.9 kg/bed.day and 0.75 kg/patient.day. Statistically significant linear correlations were established between the daily production of medical solid waste and the respective number of patients and the occupied beds in TTH as whole. Based on the average daily production of medical solid waste produced by the departments of TTH (kg/d), the larger producer of general medical solid waste was obstetric department with average daily production of 25 kg/d, while the larger producer of hazardous medical solid waste was obstetric department with average daily production of 11 kg/d. The average specific weight of total medical waste, general waste, and hazardous waste were determined to be 218.6, 206.5 and 225.54 kg/m³, respectively. The average moisture content of total medical waste, general waste, and hazardous waste were determined to be 21, 20.4 and 23.4 %, respectively. The average general medical waste composition was: 40% organics, 21% plastics, 19% paper, 11% glass and 9% metals. Pathological wastes and sharp objects comprised 43% and 25% of the hazardous medical waste components.
Introduction

The municipal solid waste (MSW) generation rate per capita is considered a core indicator of environmental pressure and a useful measure for evaluating the intensity of waste generation over time and comparing the intensities among cities [1]. To develop the waste system and improve technologies, detailed data for the material characteristics of the waste involved are needed [2]. Although medical wastes represent a relatively small portion of the total waste generated in a community, medical waste management is considered an important issue worldwide [3]. Medical waste management is one of the many complex and demanding challenges facing humanity as the global population swells and the demand for medical services increase. Medical waste is classified by the World Health Organization (WHO) as: “waste that is generated in the diagnosis, treatment or immunization of human beings or animals [4]. Medical waste can be classified into two major groups: general and hazardous waste. Between 75% and 90% of the waste produced by health-care is non-risk or general health-care waste that is comparable to domestic waste [5]. Approximately 10-25 % (by weight) of medical waste is considered special or hazardous [6]. The hazardous or special wastes include infectious waste, pathological waste, pharmaceutical waste, chemical waste, waste with high heavy metal content, pressurized containers, and radioactive waste, most of which are toxic, harmful, carcinogenic, and infectious materials [5, 6, 7]. Although the portion of infectious and hazardous waste is relatively small, improper waste management can cause environmental pollution, unpleasant odors, and growth of insects, rodents and worms; it may lead to transmission of diseases like typhoid, cholera, human immunodeficiency virus (HIV), and hepatitis (B and C) through injuries from sharps contaminated with human blood [8,9]. The World Health Organization estimated in 2000 that injection with contaminated syringes caused 21 million hepatitis B infections, 2 million hepatitis C infections and 260,000 HIV infections [5]. Information about generation rates and composition of medical solid waste is important to design and cost management systems for medical solid waste, for safety and health considerations and for assessing environmental impact [10]. The obtained results from this study were compared with the generation rates determined in the other studies from other countries. In the study that performed by Al-Mendalawi[11], the most of the official hospitals located in Al-Weheda District in Baghdad City were covered and the study estimated the average generation rate of medical waste was between 0.32 to 1.6 kg/bed.day. The higher generation rates at Baghdad city were due to the medical centers in the capital of Iraq being more developed general public facilities, and thus serving a larger number of patients in comparison with other hospitals. Throughout the study conducted by Al-Hamdani [12] which selected Al-Khansa’a Hospital in Mosul City, the average generation rate of medical waste was 1.51 kg/bed/day and this is attributable to the fact that it covers most of the treatment specializations. Some Arabic countries such as Saudi Arabia and Kuwait had higher medical waste generation rates than those reported in the present study and ranged from 0.03 to 3.78 and from 3.65 to 5.4 kg/bed/day respectively [13]. A study conducted by Abdulla et al. [8] indicated that the average generation rate was 0.83 kg/bed.day in the northern Jordan. Birpinar et al. [14] investigated 192 hospitals in Turkey and reported an average generation rate was 0.83 kg/bed.day. Finally, Tsakona et al. [15] reported an average generation rate in Greece of about 1.9 kg/bed.day. The results of the study indicated that the percentage of hazardous waste in the total medical solid waste stream in TTH is about 36.96 % and the general solid waste comprised 63.04 % in the total medical solid waste stream in TTH. According to summary by Diaz et al. [16], the total amount of
healthcare waste generated in selected hospitals in developing countries varied from 0.016 to 3.23 kg/bed.day.

The aims of this study are to determine the daily production (kg/d) and unit production rates (kg/bed.d and kg/patient.d) of the medical solid waste produced by TTH, the composition of medical solid waste produced by TTH, and regression equation that correlates the number of both patients and beds in TTH with the amount of generated medical solid wastes. In this study, which was a data-collected method field, sampling each month in the 1st and 4th –week of every sampling month over 7 days a selected week was done.

**Brief Description of TTH**

Tikrit Teaching Hospital (TTH) is (35) years old hospital. TTH is considered a general hospital that provides medical services and is typically the first patient contact. The following wards/departments of TTH (with the number of beds in parenthesis) participated in this study: surgery (48 beds), obstetric (80 beds), neonatal care unit (18 beds), pediatrics (83 beds), medicine (74 beds), cardiology (7 beds), cardiac catheterization (12 beds), hemodialysis (artificial kidney) unit (20 beds), emergency (18 beds) and special ward (24 beds). TTH has (384 beds) for patient care.

**Materials and Methods**

Along with the amount of medical waste collected, the number of beds in the hospital as a whole and the number of patients entering the hospital conducted on the particular sampling days was recorded. The number of beds was used to compute unit production rates, as kg/bed.d. It was not possible to distinguish between people visiting the outpatient department and hospitalized and those examined and leaving the hospital on the same day. There for the term "patient" refers to everybody entering the hospital for medical examination, regardless if he was hospitalized or not. The number of patients was used in order to compute the medical waste production rates, as kg/patient.d. Correlations between daily production and the respective number of patients and the respective number of beds were conducted.

The medical solid waste was collected, manually separated and weighed over a period of 10-working months, a week per month randomly selected during the sampling month. Sampling was analyzed for a week per month to capture the daily variations of quantity and quality. According to walk-through survey of all medical departments in TTH, the survey process was completed. The data forms were completed for further analysis. A special container with a 200 L (0.2 m³) volume was used to determine the waste volume, which allowed calculating the uncompact specific weight of the waste, where this result was reported in kg/m³. The moisture content of the medical solid waste was expressed as a percentage of wet-weight of the material. The wet-weight method is used most commonly in the field of solid waste management. To measure the moisture content; a sample was weighed as collected, dried at 105°C and then weighing the sample after drying.

**Results and Discussion**

1. **Daily Production of Medical Solid Waste**

Based on the average daily production of medical solid waste produced by the departments of TTH (kg./d), the larger producer of general medical solid waste was obstetric department with average daily production of 25 kg/d, followed by pediatrics department with 20 kg/d and followed by medicine with 18 kg/d. While the larger producer of hazardous medical solid waste was obstetric department with average daily production of 11 kg/d, followed by emergency department with 10 kg/d and followed by surgery with 9 kg/d. The average daily production of total medical solid waste, general waste and hazardous waste is shown in Figures (1, 2, and 3), respectively.
According to the survey process, the average generation rate of medical solid waste produced at TTH is 0.9 kg/bed.day and 0.75 kg/patient.day. Medical solid waste generation rate in different countries is given in Table (1).

**Table 1: Average medical waste generation rate in different countries/cities hospitals**

<table>
<thead>
<tr>
<th>Country</th>
<th>Waste generation rate</th>
<th>General waste %</th>
<th>Hazardous waste %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iraq/Tikrit</td>
<td>0.75 Kg/patient/d</td>
<td>63.04</td>
<td>36.96</td>
</tr>
<tr>
<td>Taiwan</td>
<td>0.88 Kg/bed/day</td>
<td>64</td>
<td>92</td>
</tr>
<tr>
<td>Greece</td>
<td>8.4 kg/bed/day</td>
<td>83.33</td>
<td>16.67</td>
</tr>
<tr>
<td>South Africa</td>
<td>0.6 Kg/patient/day</td>
<td>60.74</td>
<td>39.26</td>
</tr>
<tr>
<td>Algeria</td>
<td>0.7-1.22 kg/bed/day</td>
<td>75-90</td>
<td>10-25</td>
</tr>
<tr>
<td>Libya</td>
<td>1.3 kg/patient/day</td>
<td>72</td>
<td>28</td>
</tr>
<tr>
<td>El-Beheria, Egypt</td>
<td>2.07 Kg/bed/day</td>
<td>60.10</td>
<td>38.90</td>
</tr>
<tr>
<td>Public hospital, Iran</td>
<td>3.16 Kg/bed/day</td>
<td>56</td>
<td>42</td>
</tr>
</tbody>
</table>

From the available data it is evident that amount of medical waste generation rate depends on the level of economic development of the region. Data from World Health Organization (WHO) reveal that North America produces 7-10 kg of medical solid waste per bed/day [4]. This is may be due to the developed nation’s lifestyle demands consumption of high amounts of goods and services which tend to generate a higher amount of waste [6]. Furthermore, the use of disposable instruments and packing materials rather than the
use of reusable items in hospitals and healthcare centers has increased the amount waste generation [22]. In addition to the use of more disposable items on the patient’s expenses and meals brought to patient by his relatives which were added to the wastes [20]. Statistically significant linear correlations were established between the daily production of medical solid waste and the respective number of patients and the occupied beds in TTH as whole by the following regression equation ($R^2 = 0.997$),

\[ Y = -2.334 + 0.867X_1 + 0.035X_2 \]

where

- $Y$: daily production of medical solid waste produced by the departments of TTH as whole, (kg/day).
- $X_1$: number of patients entering TTH per day.
- $X_2$: number of total occupied beds in TTH as whole per day.

### 3. Classification of Medical Solid Waste

#### 3.1. Physical Components of Medical Solid Waste

In an attempt to gain a general appreciation of the type of wastes generated in a hospital, the waste stream of TTH was observed. Waste is produced from the various activities performed in the hospitals. The medical solid waste analyzed was comprised of 63.04% general waste (non-risk) and 36.96% hazardous waste. The composition of the whole generated medical waste was found to be 38% organics, 21% plastics, 20% paper, 11% glass, 6% textiles and 4% metals as presented in Figure 4.

#### 3.2. Components of General Medical Waste

General waste is the product of food preparation, administrative departments, housekeeping and so on. According to the nature of these jobs, general waste has the same composition as municipal solid waste and should be segregated correctly and dealt with by the municipal waste disposal system. The qualitative analysis of general waste as shown in Figure (5), determined food residues as the primary component 40%, followed by plastics 21%. The high organic residue content is due to the meals brought to patient by his relatives who were added to the wastes and the high plastic content is due to the widespread use of disposables rather than reusable for various purposes (e.g. bottles, packaging materials and bags used for food). Paper had the third highest percentage 19%, while the glass and metals comprised 11% and 9%, respectively.

#### 3.3. Hazardous Waste Categories According to WHO Classification

Hazardous waste is a byproduct of diagnostic and experimental activities and therapeutic methods such as surgery, dialysis, labor and delivery and injections [23,25]. According to WHO, hazardous waste produced by the departments in TTH was classified to: pathological, sharp objects and other hazardous waste as shown in Figure (6). The highest percentage 43% of hazardous waste was pathological waste while 25% were sharp objects.
and 32 % was other hazardous waste which includes chemical waste, pharmaceuticals waste and expired medicines. Komilis et al. found that the hazardous wastes fraction constituted 35% of the total medical wastes MW [24].

![Pie chart showing composition of total medical solid waste](image)

**Figure 6:** The composition of the total medical solid waste

### 4. Specific Weight of Medical Solid Waste

For the purposes of medical waste management, it is important to know the specific weight of the waste for the following reasons: determination of storage space, evaluation of capacity and size of the collection devices and vehicles, estimation of the requirements for processing equipment (compaction, size reduction, treating and so on) [10,11]. The specific weight was measured by filling an empty container of known volume and mass by a solid waste sample and then weighing the filled container. Then, the density could be calculated by dividing the net weight of solid sample by the volume of container [26]. Figure (7) shows the specific weight of generated medical waste in TTH.

![Bar chart showing specific weight of generated medical waste in kg/m^3](image)

**Figure 7:** The specific weight of generated medical waste in TTH (kg/m^3)

A comparison of this result with other reports Table (2) shows some differences in measured specific weight and this is due to differences in the percentages of the components found in the medical solid waste as whole. The reason for such high specific weight in the present study could be the high percentages of high-density materials such as organic residue, human tissues in the composition of generated medical waste, (e.g. the weight of a placenta alone equals 1 kg).

<table>
<thead>
<tr>
<th>Country/City</th>
<th>Average specific weight (kg/m^3)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total waste</td>
<td>General waste</td>
</tr>
<tr>
<td>Iraq/Tikrit</td>
<td>218.6</td>
<td>206.5</td>
</tr>
<tr>
<td>Iraq/Mosul</td>
<td>-</td>
<td>175.82</td>
</tr>
<tr>
<td>Philippines/Manila</td>
<td>-</td>
<td>151</td>
</tr>
<tr>
<td>Peru</td>
<td>218</td>
<td>211</td>
</tr>
<tr>
<td>Tabriz/ Iran</td>
<td>99.58</td>
<td>101.26</td>
</tr>
</tbody>
</table>

### 5. Moisture Content of Medical Solid Waste

The moisture content of MW was estimated by weighing a sample of discarded solid waste which represented its wet weight, and then it was dried at 105 °C temperature. The difference in the sample's weight represented the moisture content which was expressed as percentage [26]. It was evident from figure (8) that the moisture percentage of the total waste, general and hazardous waste found to be 21, 20.4 and 23.4%, on the wet-weight basis, respectively.
Conclusions

The following conclusions were drawn about the composition and production rate of medical solid waste produced in TTH for the study period:

1. Inappropriate segregation practices are the dominant problem in most of developing countries, which led to increase quantities of generated medical waste and hence higher costs for their disposal.

2. Based on the average daily production of medical solid waste produced by the departments of TTH (kg /d), the larger producer of general medical solid waste was obstetric department with average daily production of 25 kg/d, followed by pediatrics department with 20 kg/d and followed by medicine with 18 kg/d. While the larger producer of hazardous medical solid waste was obstetric department with average daily production of 11 kg/d. Followed by emergency department with 10 kg/d and finally surgery department with 9 kg/d.

3. The unit production rates for total medical solid waste for TTH were 0.75 kg/patient/d and 0.9 kg/bed/d.

4. Statistically significant linear correlations were established between the daily production of medical solid waste and the respective number of patients and the occupied beds in TTH.

5. The total production of general and hazardous waste comprised 63.04% and 36.96% of the overall medical solid waste wet weight produced at TTH, respectively.

6. The composition of the whole generated medical waste was found to be 38% organics, 21% plastics, 20% paper, 11% glass, 6% textiles and 4% metals.

7. Total medical solid waste was classified in the following categories:

Organics comprising 38%, plastics with 21%, paper with 20%, textiles with 6% and metals with 4% by mass of the total medical solid waste.

8. General waste has the same composition as municipal solid waste.

9. The qualitative analysis of general waste determined food residues as the primary component 40%, followed by plastics 21%, paper had the third highest percentage 19%, while the glass and metals comprised 11% and 9%, respectively.

10. The highest percentage 43% of hazardous waste was pathological waste while 25% were sharp objects, and 32 % was other hazardous wastes which include chemical waste, pharmaceuticals waste and expired medicines.

11. The specific weights of total medical waste, general waste, and hazardous waste were determined to be 218.6, 206.5 and 225.54 kg/m³, respectively.

12. The moisture content of total medical waste, general waste, and hazardous waste were determined to 21, 20.4 and 23.4 %, respectively.

References


