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Research Article

Characterization of Hospital Wastewater, Risk Waste Generation and Management Practices in Lahore

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Abstract: Hospitals generate both, liquid and solid waste. High public health risks are involved in managing these wastes. Objectives of this study were: (i) to determine the characteristics of hospital wastewater; (ii) analysis of current risk waste management practices and compliance level with hospital waste management rules-2005 (HWMR-2005); and (iii) analyse the risk waste generation rates. Three main hospitals of Lahore, i.e., Services Hospital, General Hospital and Gulab Devi Chest Hospital, were selected for this study. Wastewater characteristics were determined by taking samples from each hospital. Results were compared with National Environmental Quality Standards (NEQS). Survey of hospitals was conducted, using a questionnaire, to determine the compliance status with HWMR-2005. Risk waste generation data for the year 2012 was collected and analysed. Wastewater analysis revealed that BOD, COD and Cadmium concentrations were more than the permissible limits prescribed in NEQS. Compliance with HWMR-2005 was found better. Mean risk waste generation rates in Services Hospital, General Hospital, and Gulab Devi Chest Hospital were 0.22, 0.2 and 0.02 kg/bed/day. No significant variations were observed in risk waste generation rates on daily, weekly, monthly and seasonal basis.

Keywords: Hospital, wastewater, risk waste, generation rates, Lahore

1. INTRODUCTION

Disinfectants, pharmaceuticals, radionuclides and solvents are widely used in hospitals for medical purposes and research. After application, these reach the municipal sewer network [1]. If left untreated, these could lead to outbreak of communicable diseases, water contamination, and radioactive pollution [2]. Study conducted on bacteriological and physiochemical qualities of hospital wastewater revealed that there was contamination of the receiving environment (water, soil and air) due to the discharge of hospital wastewater. It could also be hazardous to human health [3]. Hospitals generate significant volumes of wastewater on daily basis [4]. Average wastewater production from hospitals is estimated to be 362 to 745 litters per occupied bed per day [4, 5-7]. This huge volume of hazardous wastewater needs special attention.

Outside Pakistan, many studies have been conducted on hospital wastewater in different countries such as France, India, Nigeria, Ethiopia, Iran, Morocco, Indonesia and Korea. These studies showed that BOD values varied from 242 mg/L to 632 mg/L and COD values varied from 616 mg/L to 1388.75 mg/L. Heavy metals such as Cadmium, Chromium, Copper, Lead, Mercury, Nickel and Zinc were also found in hospital wastewater [1-17, 36]. However, there is no known study on hospital wastewater in Pakistan and little data exist on its characteristics.

In addition to wastewater, hospital also generate risk waste like infectious waste, pathological

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waste, sharps, pharmaceutical waste, genotoxic waste, chemical waste, and radioactive waste. Studies have been conducted in different countries like Iran, South Africa, China, Germany, Korea, Egypt, UK, Turkey, Bangladesh, India and Congo on the generation and management of risk waste [18-27, 39]. Rules and regulations relating to the definition and disposal of hospital waste vary widely in different countries. In European countries classification and disposal of hospital waste is regulated by ordinances [21].

In Pakistan, Ministry of environment issued hospital waste management rules (HWMR) in 2005 [11]. According to the rules, waste originating from healthcare facilities like clinic, laboratory, dispensary, pharmacy, nursing home, health unit, maternity centre, blood bank, autopsy centre, mortuary, research institute and veterinary institutions is termed as hospital waste. It includes both, risk waste and non-risk waste. Non-risk waste includes paper and cardboard, packaging, food waste and aerosols and the like. Risk waste is described in the above para. According to World Health Organization, normally, 15 to 20% of waste originating from a healthcare facility is risk waste; and it needs special handling and treatment. For different types of risk waste, HWMR-2005 specify colour coding for its proper segregation at source of generation. It suggests to use while colour bags for non-risk waste. While for risk waste yellow colour bag should be used. For sharps, yellow colour, leak proof and penetration resistant, container should be used [11].

In Pakistan, little attention is so far paid to risk waste management. Study conducted in eight hospitals of Faisalabad city shows that 90% of the hospital staff was not trained in hospital risk waste management. 80% of the hospitals did not ever received any notice from Pakistan Environmental Protection Agency. There was no segregation of risk and non-risk waste in 76.7 % of the hospitals. Sanitary workers transport the waste without any personal protective equipment (gloves, boots etc.). The research indicates that doctors and hospital management were totally unaware of basic methods of risk waste disposal [27].

Study conducted in ten large public and private hospitals of Rawalpindi and Islamabad shows that segregation practices (for risk and non-risk waste) at the point of generation were not followed. Waste segregation issues were due to lack of training of medical and other staff including sweepers and ward servants. There were no waste bins. Waste was collected without using standard operating procedures for final disposal and treatment. The study suggests that training of hospital staff can lead to improved hospital risk waste management practices [28].

Another study was conducted in eight teaching hospitals of Karachi. It revealed that out of eight hospitals visited, 2 (25%) were segregating the risk waste at source. Only one (12.5%) hospital arranged training sessions for its waste handling staff regularly. Five (62.5%) hospitals had storage area for risk waste but mostly it was not protected from access of scavengers. Five (62.5%) hospitals disposed their risk waste by burning in incinerators, two (25%) disposed it in municipal landfills and one (12.5%) was burning waste in open air without any specific treatment. No record of risk waste was generally maintained. Only two (25%) hospitals had well documented guidelines for risk waste management and a proper waste management team. Study concluded that HWMR-2005 should be followed and implemented by law enforcement agencies [29]. In order to improve risk waste management and develop a management strategy, it is important to understand and evaluate current practices [20]. Information about hospital waste management in Pakistan is currently inadequate. Compliance rating of hospitals with HWMR-2005 is non-existent.

Different factors affect the hospital risk waste generation rates. Tabasi and Marthandan [30] reviewed 20 research papers that reported relevant associated factors in hospital risk waste production. Out of 20 studies, 13 studies (65%) reported that the type of healthcare establishment has significant

effect on risk waste generation. Other factors include the number of patients, number of beds and the percentage of bed occupancy. Hospital risk waste generation rate were determined in some of the developing countries like India, Bangladesh, China, Taiwan lie in a range of 0.14 to 0.88 kg/bed/day [20, 22, 32, 34, 35, 40]. In 2010, study conducted on quantification, classification and management of hospital waste in Lahore city showed that 785 million ton of risk waste was produced and incinerated in Lahore per annum [33].

Evaluation of waste generation rates and quantities is essential for the establishment of a waste management system for hospitals [31]. The objectives of the present study were to; (1) characterize hospital wastewater; (2) evaluate compliance with HWMR-2005 and (3) evaluate the risk waste generation rates and its variations. In Pakistan, previous studies on hospital risk waste generation rates are not rigorous, since these were based on the data of only one to three weeks [38, 39]. However, this study is based on risk waste data of 52 weeks (one year). Thus all possible variations like weekly, monthly and seasonal were accounted for. In addition, no previous work exists on hospital wastewater characteristics which is pre-requisite for the selection of an appropriate treatment technology.

2. MATERIALS AND METHODS

2.1 Hospitals Selected for the Study

In Lahore, there are 232 hospitals. Out of these 47 are public and the rest are private. To study wastewater characteristics and risk waste generation, it was necessary to select major hospitals with plenty of instrumentation, a range of medical services and large outrun of patients. For this study, hospitals having 200 or more beds were considered as major. Thirteen public hospitals in Lahore meet this criteria. Out of these, 3 hospitals were selected randomly making a sample size of 23%. Ten percent or more sample is considered to be a good sample size for small populations [41]. The selected hospitals included: Services hospital (SH) having 1196 beds, General hospital (GH) with 1048 beds and Gulab Devi (GD) chest hospital (1500 beds).

2.2 Sampling and Analysis of Wastewater

There were several wards in the selected hospitals. Each ward generated wastewater having different characteristics. All these wastewaters join at the tank of disposal station and are homogenized. To take a representative sample, it was decided to collect wastewater from the disposal tank. The parameters tested and the testing procedures are mentioned in Table 1. The heavy metals in the wastewater were analysed by using atomic absorption spectrophotometer (PerkinElmer Analyst 800).

Table 1. Parameters tested and the testing procedures.*

Parameter	Testing Method
pH	pH paper
Five-day biochemical oxygen demand (BOD)	5210 (B)
Chemical oxygen demand (COD)	5220 (B)
Total dissolved solids (TDS)	2540 (C)
Chlorides	4500 Cl^- (C)
Alkalinity	2320 (B)
Total nitrogen	4500 N_{org} (B)
Ammonia nitrogen	4500 NH_3 (B&C)
Iron	3111 Fe
Manganese	3111 Mn
Cadmium	3111 Cd
Copper	3111 Cu
Nickel	3111 Ni
Lead	3111 Pb
Zinc	3111 Zn
Chromium	3111 Cr

*All the testing methods are based on Standard Methods for the Examination of Water and Wastewater, 20th edition (1998), www.standardmethods.org.

2.3 Methodology for Analysis of Hospital Waste Management Practices

For analysis of current hospital waste management practices, a survey questionnaire based on HWMR-2005 was developed. Questionnaire was filled through visits of the selected hospitals. It contained 25 questions about different aspects of hospital waste management.

2.4 Methodology for Determination of Generation Rates

Proper record of risk waste generated, in the selected hospitals, was maintained on daily basis. For this study risk waste generation data from 1st January to 31st December 2012 (365 days) were collected from the available record of selected hospitals. Statistical analysis was performed on the yearly data including mean, minimum, maximum, standard deviation and coefficient of variation.

Separate analysis was performed to find out weekly, monthly and seasonal variations in risk waste generation. There are 52 weeks in a year, therefore each day approximately occurs 52 times in a year. For weekly variation, data for a specific day of the week, for the entire year, was added and mean and standard deviation (SD) was calculated. Mean of different days were compared by calculating standard error of mean (SEM) and lastly values for 95% confidence interval were found out.

Similarly, for monthly variations, the mean of each month was calculated from the daily risk waste generation data, along with SD for each month. Mean of different days were compared by calculating standard error of mean (SEM) and lastly values for 95% confidence interval were found out. For seasonal variations, period from May to September was taken as summer, from October to November as autumn, from December to February as winter and March to April as spring. Mean of each season was calculated from the daily data for that season with SD for each season. SD for weekly, monthly and seasonal variations are shown as error bar on the relevant figures in section 3.4. Standard error of mean could not be calculated for seasonal variation due to difference is sample size.

In order to compare the amount of risk waste generated from each unit of a hospital, one week risk waste generation data was taken for two hospitals i.e. GH and GD. The week was randomly selected. However, the same week for the two hospitals was taken. Mean of the entire week, for each unit, was then plotted for the sake of comparison.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Hospital Wastewater

Hospitals investigated had no wastewater treatment plant. The results of physico- chemical parameters are presented and compared with NEQS in Table 2. Values of pH varied from 6.8 to 7.5. These values were within the permissible limits of NEQS. Similar results were obtained in other studies. Beyene and Redaie [7] determined pH value in hospital wastewater to be 7.4. Study on hospital wastewater in India showed pH value of 7.36 [2].

BOD and COD values varied from 112 mg/L to 750 mg/L and 251 mg/L to 1400 mg/L respectively. These concentrations were more than the permissible limits of NEQS. Highest concentrations of BOD and COD were in General hospital and Services hospital. TDS and Chlorides concentrations were in a range of 620 mg/L to 1400 mg/L and 70 mg/L to 200 mg/L, respectively. These values were within

Table 2. Physicochemical charcterisation of hospital wastewater.

Parameters	NEQs	General Hospital	Services Hospital	GulabDevi Chest Hospital
pH	6 – 9	6.8	7.2	7.5
BOD	80 mg/L	120	750	300
COD	150 mg/L	280	1480	680
TDS	3500 mg/L	900	800	1400
Chlorides (Cl^-)	1000 mg/L	110	110	70
Alkalinity	*	480	600	670
Total Nitrogen	*	27.6	45.2	18.6
Ammonia Nitrogen	40 mg/L	16.7	24.2	17.6

* No NEQs for this parameter.

Table 3. Concentrations of heavy metals in hospital wastewater.

Heavy metals	NEQS	General Hospital	Services Hospital	Gulab Devi Chest Hospital
Cadmium (mg/L)	0.1	0.032	0.045	0.676
Chromium (mg/L)	1.0	0.042	0.107	0.088
Lead (mg/L)	0.5	0.012	0.104	0.229
Nickel (mg/L)	1.0	0.593	0.631	0.634
Zinc (mg/L)	5.0	0.077	0.174	0.150
Copper (mg/L)	1.0	BDL*	BDL*	BDL*
Manganese (mg/L)	1.5	0.027	0.057	0.027
Iron (mg/L)	8.0	0.339	0.447	0.445

*BDL=Below Detection Limit

the permissible limits of NEQS. Alkalinity was in a range of 480 mg/L to 670 mg/L as $CaCO_3$. Total nitrogen and ammonia nitrogen were in a range of 18.6 mg/L to 45.2 mg/L and 16.7 mg/L to 24.2 mg/L respectively. These values were within the permissible limits of NEQS.

The results of heavy metal concentrations in hospital wastewater samples are presented and compared with NEQS in Table 3. It can be seen that concentration of all heavy metals were within permissible range except Cadmium in Gulab Devi hospital. Possible reasons of high Cadmuim contents are old and discarded nickel-cadmium batteries, pigments, coatings and plating, used in the hospitals. High concentration of cadmium may cause kidneys, lungs, and bones effects.

3.2 Analysis of Hospital Waste Management Practices

The findings of the questionnaire filled, during field visits, are discussed below.

3.2.1 Waste Management Team

HWMR-2005 specify that each hospital must have a notified waste management team; duties of team must be defined and hospital administration must make waste management plans. It was observed that waste management teams were notified under rule (u/r) 4(1). Waste management officer was nominated u/r 4(4). Duties and responsibilities of waste management team were notified u/r 4 (3) & 5. Meetings of waste management team u/r 6 were conducted twice a month.

3.2.2 Segregation of Waste

HWMR-2005 prescribe that risk waste should be segregated, on site, inside the hospital. After segregation, it should be weighed and packed in color coded bags as described in Section 1. It was observed that risk waste was separated from non-risk waste at source u/r 16(1). Syringe needle cutting u/r 16(2) was practiced. Plastic bags, infusion bags, drip bags were being cut down u/r 16(2). Broken syringes and needles were placed in yellow boxes u/r 16(4). Sharp containers were yellow in color u/r 16(4). Sharp containers were marked “Danger! Contaminated Sharps” u/r 16(4). The sharp container was closed and sealed when 03 quarters u/r 16(4). Non risk waste containers were

Table 4. Results of statistical analysis of risk waste generation data for year 2012.

Hospital Name	Average (kg/day)	Minimum (kg/day)	Maximum (kg/day)	Standard Deviation	Coefficient of variation	Total Annual (kg/day)	Average (kg/bed/day)
Services Hospital	234	127	326	40	17	73,118	0.22
General Hospital	204	115	324	46	22	63,863	0.20
Gulab Devi Hospital	28	12	64	11	39	8,906	0.02

lined with white waste bags u/r 16(8).

3.2.3 On-Site Collection and Transportation of Waste

Directions of on-site collection and transportation of waste were followed as per HWMR-2005. Waste was collected once daily u/r 17(3) a. All waste bags were labelled indicating point of production and contents u/r 17(3) b. The transportation of waste was properly documented u/r 18(5) g. Risk waste was transported by trollies to the central storage facility. Before transferring the waste was again weighed and proper record of waste generation was maintained. There was violation of rule 17(2) in all the studied hospitals as sanitary staff and sweeper did not wear personal protective equipment (gloves, boots, and clothes).

3.2.4 Waste Storage

HWMR-2005 direct to store risk waste in a separate room inside hospital for temporary storage, at suitable temperature. It was observed that the above facility u/r 19(1) was provided in all the studied hospitals. These storage facilities were away from the public approach. Proper cooling was provided in the storage rooms to maintain temperature between 3^0C to 8^0C.

3.2.5 Treatment/Disposal of Risk Waste

It was told by the concerned persons in the hospitals that risk waste is sent to the incinerator installed in the Children hospital Lahore. Before transportation, it is again weighed and proper record was maintained by both the authorities operating incinerator and the hospital. There was a small scale incinerator available in the Services hospital Lahore. It is based on old technology and thus causes air pollution. Concerned staff at incineration plant told that it is utilized only in case of emergency such as shutdown of the incinerator at Children hospital.

3.3 Generation Rates of Risk Waste

Statistical analysis of the risk waste data is presented in Table 4. It shows that average daily risk waste generation rates were high in SH (234 kg/day; 0.22 kg/bed/day) and GH (204 kg/day; 0.20 Kg/bed/day) as compared to GD (28 kg/day; 0.02 kg/bed/day). Risk waste generation in GD is much less than other hospitals. The major reason is that type of healthcare facilities provided in GD hospital are different from other two hospitals. It is discussed in more detail in section 3.5.

The range in which risk waste generation per day varied in SH, GH and GD were 127 to 326, 115 to 325 and 12 to 64 kg/day, respectively. The respective standard deviation for the yearly data, for the above hospitals, was 40, 46 and 11, whereas the coefficient of variation were 17, 22 and 39. This shows that variations/scatter in the risk waste generation in GD is more than the other two.

An important parameter, for reporting and designing systems for risk waste management, is risk waste generated per bed per day. These figures for SH, GH and GD hospital were evaluated to be 0.22, 0.2 and 0.02, respectively. The figure for GD does not lie in the reported range for other developing countries (0.14 to 0.88 kg/bed/day). The reason are discussed in detail at the end of this section.

3.4 Variations in Risk Waste Generation

In addition to daily variation of risk waste discussed in section 3.3, seasonal, monthly and weekly variation are also important to study. As these are taken into account while designing waste management system. The results for weekly variation are presented in Fig. 1, which shows average value for each day of the week and standard deviation as error bar. It can be seen that there is no significant variation between different days of the week for all the hospitals. Table 5 shows the confidence interval for 95% confidence level, for all the hospitals, for weekly variation. The margins of error shows the standard error of the mean. It can be seen that margin of error for GH and SH are very close to each other. This may be due to the similar nature of treatment facilities provided. For 95% of the time, the risk waste on a specific day of the week lied in a range of 190 to 218, 25 to 32 and 220

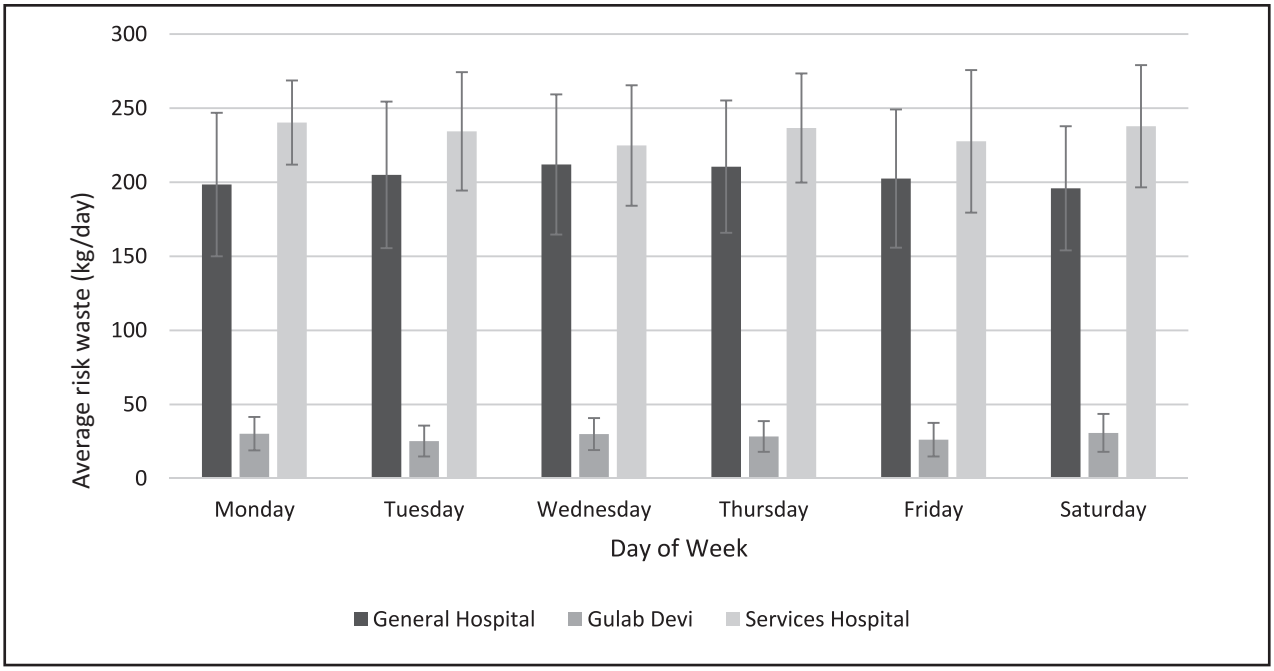

Fig. 1. Average week days risk waste generation rates.

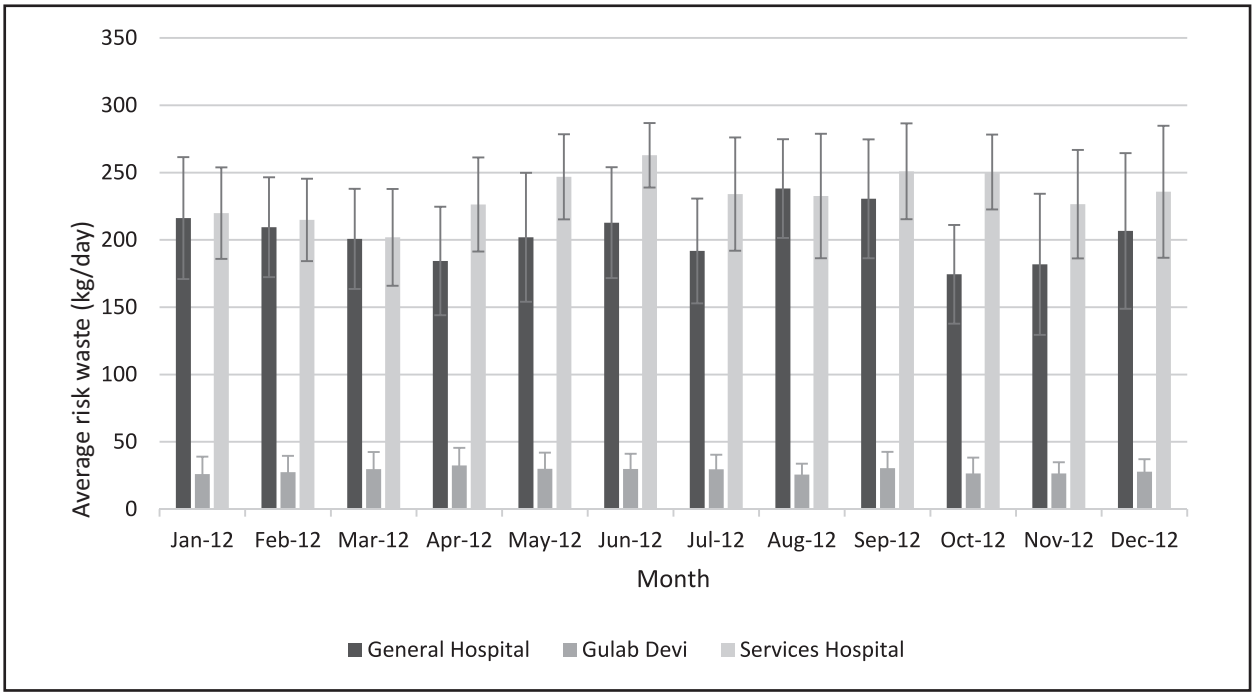

Fig. 2. Average monthly risk waste generation rates.

Table 5. Standard error and confidence intervals for weekly variation.

Hospital Name	Confidence level	Confidence coefficient	Margin of error	Confidence interval	
				Upper bound (kg/day)	Lower bound (kg/day)
General Hospital	95%	1.96	14	218	190
Gulab Devi Hospital			3	32	25
Services Hospital			13	247	220

Table 6. Standard error and confidence intervals for monthly variation.

Hospital Name	Confidence level	Confidence coefficient	Margin of error	Confidence interval	
				Upper bound (kg/day)	Lower bound (kg/day)
General Hospital	95%	1.96	19	223	185
Gulab Devi Hospital			5	33	24
Services Hospital			18	251	216

to 247 kg/day for GH, GD and SH, respectively.

The monthly variation of risk waste is shown in Fig. 2. It can be seen that risk waste generation is maximum in the month of August and June for GH and SH, respectively; probably it may be due to Dengue fever. While it is minimum during the month of October and March for GH and SH, respectively. This finding is helpful while finding storage capacity for risk waste. More storage is required in the month of August and June. It can be observed that for GD, there is no significant monthly variations; it may due to the fact that GD is only for tuberculosis patients. No other patients are entertained here. Table 6 shows the confidence interval for 95% confidence level, for all the hospitals, for monthly variation. Again the margin of error for GH and SH are very close; the reason being the same as stated for weekly data. For 95% of the time, the risk waste in a month lied in a range of 185 to 223, 24 to 33 and 216 to 251 kg/day for GH, GD and SH, respectively.

The seasonal variation is shown in Fig. 3. This figure shows mean risk waste generated during each season and standard deviation as error bars. It can be concluded from this figure that there is no significant seasonal variation in GH and GD. However, in the case of SH slight seasonal variation has been observed. More risk waste is generated during autumn and summer. This finding may help to design waste management system. More storage is required during the season when more risk waste is generated.

3.5 Type of Healthcare Facility and Risk Waste

The risk waste generation from each unit of GH and GD are shown in Fig. 4 and 5. It is evident from a comparison of risk waste generated in a unit, within the same hospital, that type of unit has a significant impact on the amount of risk waste generation. For example, in the case of GH (Fig. 4), Homio Dialysis unit generates the maximum amount of risk waste (48 kg/day) and is followed by Surgical Operation Theatre (17 kg/day) and Medical Emergency (17 kg/day). It can also be observed that minimum risk waste is generated from eye wards (< 1 kg/day) while no risk waste is generated from Angiography unit.

From Fig. 5, it is evident that in GD maximum amount of risk waste is generated in Micro Lab (4.7 kg/day), which is followed by Cardiac OT (4.5 kg/day). Earlier studies conducted on this hospital did not collect the risk waste generation data from all the wards/ units. e.g. the data for GD did not include Micro Lab and Cardiac OT which produces highest risk waste in this hospital [38].

It is also evident from Fig. 4 and 5 that the type of healthcare facility has a significant impact on the

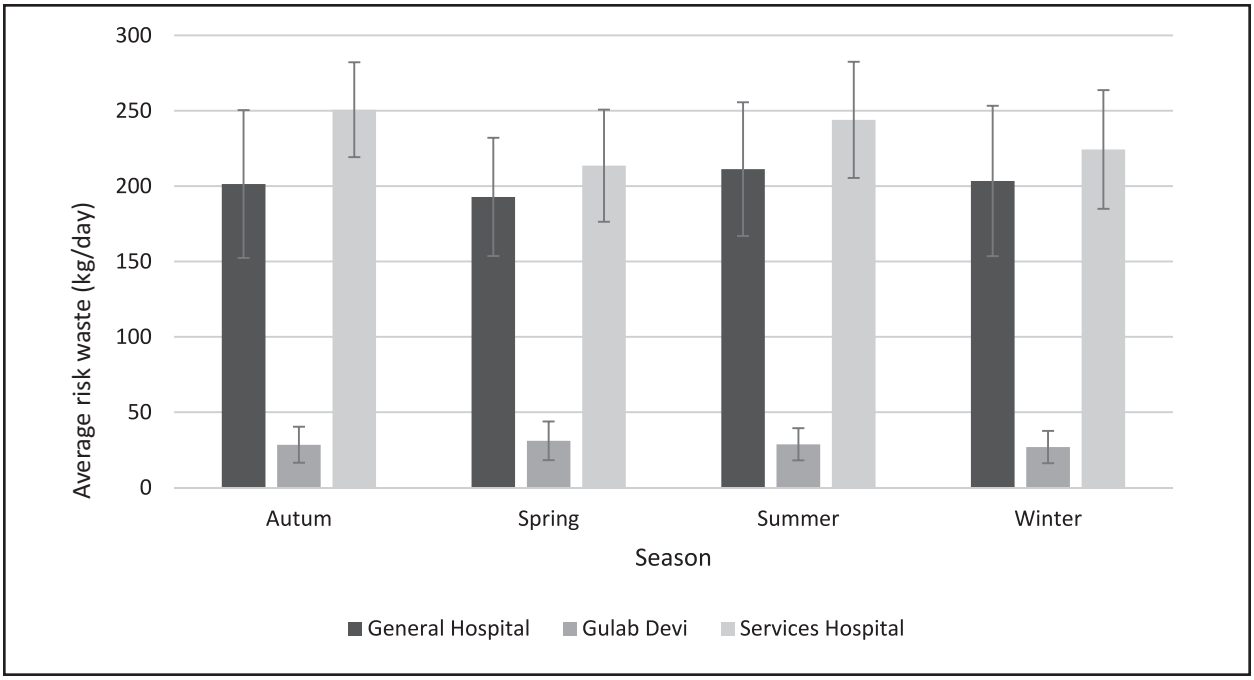

Fig. 3. Average seasonal risk waste generation rates.

amount of risk waste. GD is solely for chest while GH deals with all types of patients. This can also be seen from Table 4 that mean (yearly mean) daily risk waste from GD is 28 kg/day while the same for GH is 204 kg/day. This finding is endorsed by other studies in Lahore [39].

4. CONCLUSIONS AND RECOMMENDATIONS

Following conclusions can be drawn from the current study with a few recommendations:

Wastewater treatment is not on the priority list of the management of selected hospitals. Since none of the hospitals have wastewater treatment plant. BOD and COD of hospital wastewater are above the limits prescribed in NEQS, while rests of the parameters tested were within the limits. Except Cadmium, all heavy metals analysed were within the permisible limit of NEQS. Cadmium was high in the wastewater of Gulab Devi Chest hospital due to its specialzied nature. The high amounts of BOD, COD and Cadmium may harm the aquatic life and even human health, since the wastewater in Lahore is finally disposed in river Ravi and agriculturel fields. This situation calls for immediate attention.

Compliance level of HWMR-2005 in the selected hospitals was better. Risk waste was disposed through incineration. Average daily risk waste generation rates in the hospitals varied from 28 to 234 kg/day (yearly mean). When related to number of beds, it varied from 0.02 to 0.2 kg/bed/day. The unit producing maximum amount of risk waste is Homio-dialysis. Thus, it can safely be concluded that the type of healthcare facilities significantly affect the amount of risk waste generation. There was no significant variations in mean weekly and monthly risk waste generation. However, season may affect the generation.

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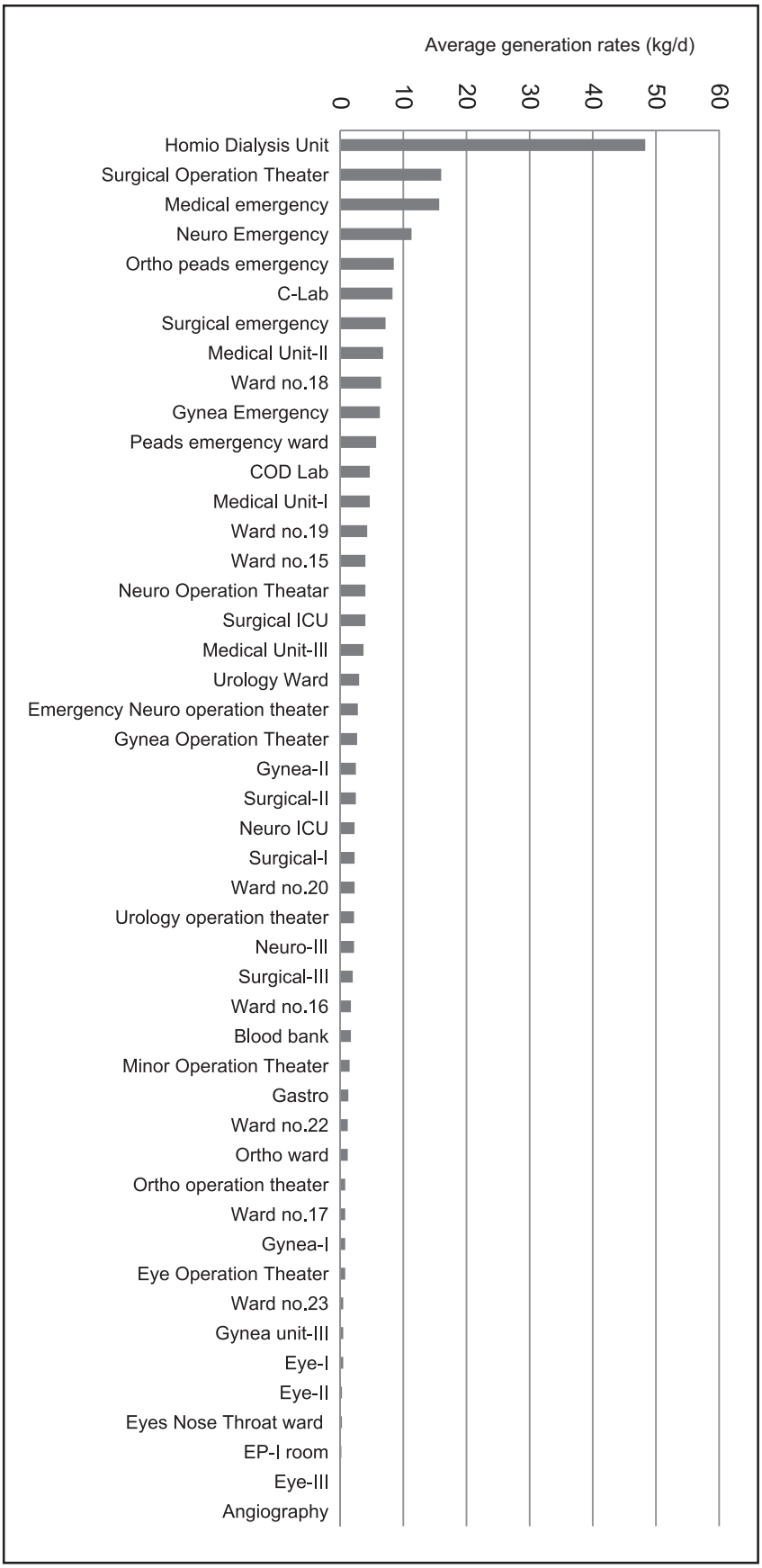

Fig. 4. Average risk waste of different wards/units of General Hospital (weekly average).

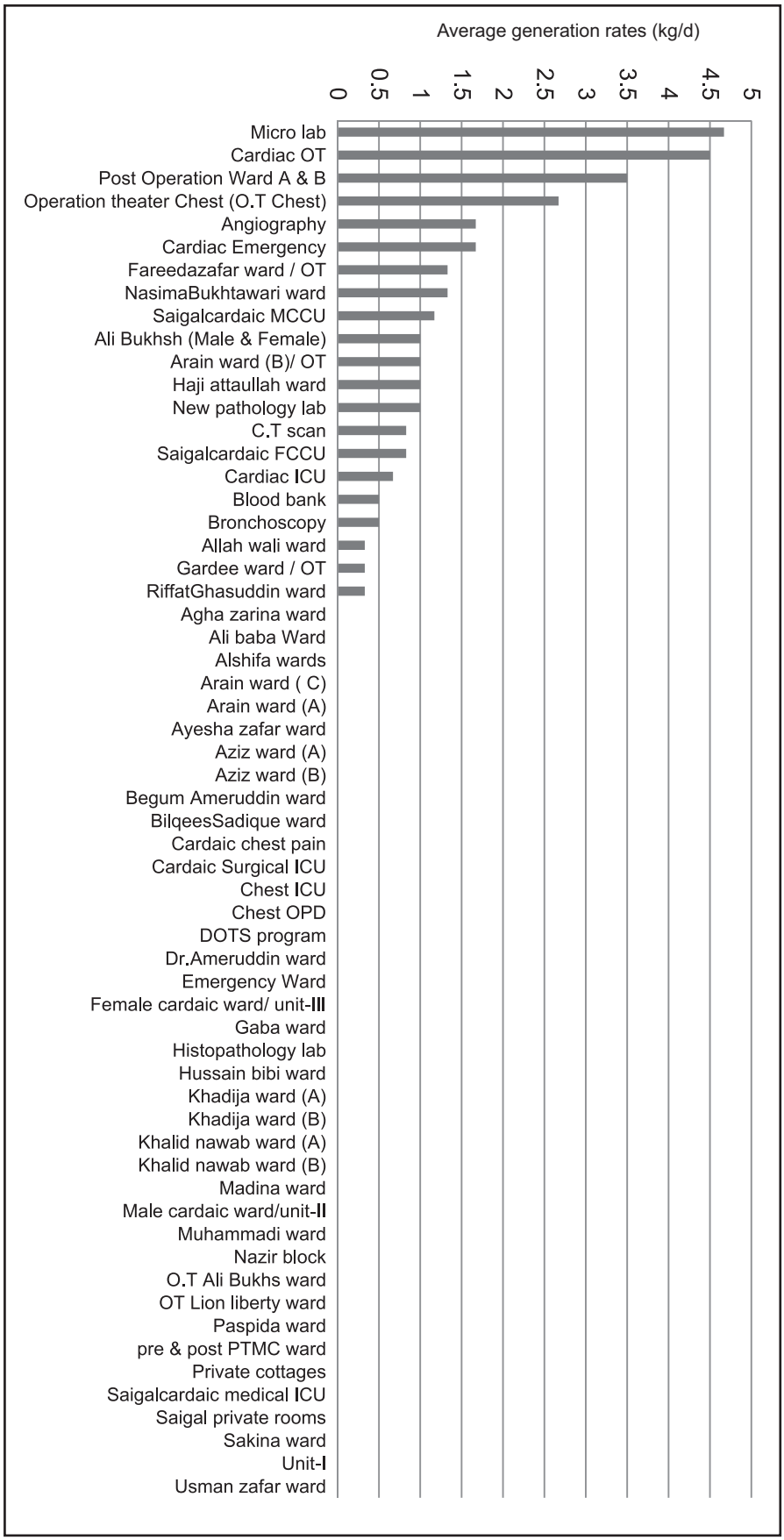

Fig. 5. Average risk waste of different wards/units of Gulab Devi Chest Hospital (weekly average).

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