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Spatial Assessment of Hospital Waste Generation and Associated Human Health Risks in Sargodha City

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1. Abstract

Healthcare waste is a significant environmental and public health issue because healthcare produces different categories of waste streams which are different in quantity and hazard properties. The present study aimed to evaluate the hospital waste generation in selected hospitals of Sargodha city, Punjab, Pakistan and its impact on environment and its impact on human health. This study was a descriptive, field study of the quantitative approach. Primary information was collected from 15 selected hospitals using available waste generation records from hospitals and some field observations to support the information. The variables included were average daily, weekly and monthly waste generation, patient admissions and bed capacity. Geographic Information System (GIS) technique was used to represent the spatial distribution of the selected hospitals. The findings indicate that all the selected hospitals reported a total of 42.6 kg of waste per day, which came up to 298.2 kg for a week and 1278 kg for a month. The average was 2.84 kg per day of waste per hospital. The highest average daily generation was at Sadiq Hospital with 7.2 kg/day while Kings Hospital, Bhatti Medical Complex Hospital and Al-Abbas Hospital had 1.2 kg/day each. The daily waste streams reported were red = 10.65 kg / day, and yellow = 31.95 kg / day, that is 25% and 75%, respectively. The results suggest that there were significant disparities between hospitals and data suggest waste generation is not solely determined by the number of beds. Inadequate segregation, containment, collection, treatment and disposal of hospital waste have the potential to create an occupational and environmental risk. The study does not however take place in the lab, nor does it sample the environment or make individual disease assessments; therefore, it also cannot determine any direct results of disease or environmental contamination. This study establishes baseline data on generation rates of waste in hospitals of Sargodha city and facilitation of a waste management plan with the consideration of real time data related to the quantity of waste level in the specific hospital.
Keywords: hospital waste; healthcare waste; waste generation; human health; GIS; Sargodha City; Pakistan.

2. Introduction

With the expansion of healthcare services, there is greater amount and diversity of waste from healthcare institutions, especially hospitals. Healthcare waste encompasses waste generated in the process of diagnosis, treatment, immunization, laboratory research, surgery and patient care. A significant portion is similar to common municipal waste, but a smaller quantity may contain infectious materials, sharps, chemicals or pharmaceutical residues and thus will need special treatment (Chartier et al., 2014). The difference between general and hazardous waste is significant due to the potential for cross connecting and thereby shifting risks from a relatively low-risk waste stream to the broader waste system if segregation is not optimal.

Hospital waste management consists of a series of interrelated activities that are involved in the process of segregation at the point of production, collection, temporary storage, internal transportation, external transportation, treatment and final disposal. If we fail to perform any of the steps, the whole system will be useless. Windfeld and Brooks (2015) highlight inappropriate classification/sorting that can result in more waste needing specialized treatment and staff education and consistent streams of waste that can streamline the management process. Safe segregation, handling, storage, transport, treatment and disposal are also recognized as key pillars of sustainably managed healthcare waste management by the World Health Organization (WHO) (Chartier et al., 2014).

Healthcare workers, sanitation and waste handlers who frequently come in contact with waste should be especially concerned with the human-health effects of hospital waste. The risk of exposure to blood borne pathogens is higher for contaminated sharps and the opportunity of exposure is greater with any infectious material and improperly managed waste. Another key reason for Environmental pathways is that if the disposal is not controlled, leakage/burning can impact soil, water and air quality. The risks are not only related to quantity of waste produced, but also to the nature of the waste and to the efficiency of the waste management system.

The regulation system for managing waste at hospitals is in place in Pakistan. The Hospital Waste Management Rules, 2005 were laid down by the Government of Pakistan with regards to segregation, collection, storage, transportation, treatment, disposal, training, record keeping and institutional responsibilities (Government of Pakistan, 2005). Despite this, there is evidence that implementation is not uniform, as is the case in Pakistan. In this regard, Zeeshan et al. (2018) found that there was a huge dearth of waste management planning, record keeping, segregation, color coding, training and transportation in tertiary hospitals in Peshawar. Findings such as this build the argument that there is a need to understand that having a regulation does not automatically equate to effective implementation. The same pertains to Pakistan's fast growing urban healthcare system. In a study of 44 hospitals in Faisalabad, Hameed et al. (2017) found that 7646 kg of waste per day; of this was 1117 kg infectious. From their findings, it is understood that a significant amount of healthcare waste is being generated within a large city of Punjab and the significance of training and appropriate handling of waste. International experience also indicates that there is variation in healthcare waste based on the quality of healthcare, in economic conditions and in institutional factors (Minoglou et al., 2017).

Sargodha City is a significant milieu in which the waste generated through hospitals in this city can be studied as it serves as a healthcare center for the region and there is limited available data on waste

generation in hospitals from Sargodha city (Hameed et al, 2017). The present study thus evaluates the reported waste generation from 15 selected hospitals, investigates the difference between generation of waste quantity at different hospitals, tries to develop an idea regarding the potential health and environmental impact of the generated waste and makes an idea about the geographic representation of the selected 15 hospitals as part of the study unit. The analysis is confined to the evidence for which there are hospital records, field observations and established literature.

3. Study Area

This study was done in Sargodha City of Punjab, Pakistan. Sargodha is also a vital urban center of central Punjab and is administrative capital of Sargodha Division and District. The city has grown up as a farming, commercial, education, administration and medical hub and also provides medical facilities for people residing outside its boundaries as well as for patients from other districts (Riaz et al, 2017; Riaz et al, 2024). As health care infrastructure grows, systematic systems in hospitals for waste management become important.

The geographical location of Sargodha City is 32.0825° N latitude and 72.6691° E longitude. Its location is in relatively level alluvial plains of central Punjab at around 190 m above sea level. Groundwater, the resource, is important for domestic and other uses, and the city has residential, commercial, institutional and agricultural land uses. This relates to the physical characteristics and land use since inappropriate containment of healthcare waste can offer potential contamination for nearby waters and land (Riaz et al, 2017). However, study was conducted for the study does not measure actual contamination as no environmental sampling was done.

This investigation was conducted in the following hospitals namely Mubarak Medical Complex Old Block, Mubarak Medical Complex New Block, Kings Hospital, Rai Medical Complex, Sadiq Hospital, Niazi Medical Complex, Niazi Medical Complex VIP Block, Faiz Memorial Hospital, Bhatti Medical Complex Hospital, Ibn e Sina Hospital, Al Haram Hospital, Khawaja Arshad Family Hospital, Central Hospital, Al-Abbas Hospital and Shifa Hospital. Each such facility has a different number of beds for receiving patients and uses a different number of patients so it can be used for comparison of waste generation levels in the same urban facility.

The geographical dimension of the research was supported with the help of geographical information system (GIS) based identification of selected hospitals. The final spatial model provides a spatial representation to fix the study units location within Sargodha City and link the quantitative waste generation findings with the urban context. The spatial analysis is descriptive as it is not making an indication of contamination areas or waste transport routes where no samples were collected.

4. Methodology

The study used quantitative study with descriptive type of field study. The hospital was assumed as the main unit of analysis as the research concentrated on the amount of waste in the hospital and not on individual perceptions or clinical health outcomes. Geographical range was limited to Sargodha City and 15 hospitals were selected purposively based on their location in the study area, availability of relevant information at the hospitals level.

The primary research was the primary reason for conducting research. Bed capacity, daily, weekly and monthly waste generated in selected hospitals were obtained during the field visit. Separate amounts of

red and yellow waste were also provided on the records. Hospital furnished statistics were not changed by substituting them with estimations. The amounts of waste collected were standardized by presentation in kilograms and the original temporal categories were kept.

Additional data was gathered through field observations. In visits general waste handling arrangements, containers, areas of storage and the presence of segregation in sight were discussed. These observations, however, were not gathered from a systematic set of scoring items and as such were not scaled into performance measures. They were in use only as a way of giving context to the interpretation of the quantitative records.

Secondary data was derived from scientific literature and official regulatory documents and international guidance. The findings of the literature search were used to define the conceptual and regulatory context and for comparison with the findings from earlier studies. Analytical difference between primary evidence and secondary evidence was maintained throughout the study.

The data was mostly analyzed descriptively. The numbers of total, mean, minimum and maximum wastes produced per day, per week and per month were studied. Each hospital was compared based on the reported waste and the streams of red and yellow waste that arising from each hospital were analyzed separately. This study also included the variable of bed capacity as a contextual variable. The relationship between the bed capacity of these facilities and the generation of the waste was not interpreted as causal relationship, as the database was not sufficiently complete to isolate all the factors that affect the quantity of waste generated.

The spatial distribution of selected hospitals was presented using GIS approach. This gave a geographical context to the quantitative results and helped the interpretation from health geographical aspect. No analysis of the waste composition was carried out in the laboratory and no structured health survey was performed among patients or nearby residents and among workers and waste handlers. The implications on health are therefore not given as outcomes that are measured but instead as risks that are backed up by sound scientific evidence.

5. Results and Discussion

5.1 Overall Waste Generation

The data showed great differences in generation of waste among the 15 selected hospitals. The average combined daily waste generated was 42.6 kg per day, which equates to 298.2 kg/week and 1278 kg/month according to the Hospital records. The mean daily production of generation was found to be 2.84 kg per hospital, the mean weekly and mean monthly productions were found to be 19.88 kg and 85.2 kg respectively, in each hospital. The data suggest that these amounts can rapidly add up to an appreciable management problem over time, even if it is a relatively low management amount in the first place. Sadiq Hospital recorded highest average of waste generation at 7.2 kg per day, Ibn e Sina Hospital and Mubarak Hospital New Block had 4.2 kg and 3.6 kg of average daily generation respectively while Niazi Medical Complex had also 3.6 kg. Three Hospitals (Mubarak Medical Complex Old Block, Niazi Medical Complex VIP Block, Khawaja Arshad Family Hospital) reported 3.0 kg per day. The other hospitals individually reported, Rai Medical Complex 2.4 kg, Faiz Memorial hospital 1.8kg, Al Haram hospital 1.2kg, Central hospital 1.2kg, Kings hospital 1.2kg and Bhatti Medical Complex hospital 1.2kg per day.

Table 1. Reported waste generation in the selected hospitals.

Hospital	**Daily (kg)**	**Weekly (kg)**	**Monthly (kg)**
Sadiq Hospital	7.2	50.4	216
Ibn e Sina Hospital	4.2	29.4	126
Mubarak Hospital New Block	3.6	25.2	108
Niazi Medical Complex	3.6	25.2	108
Mubarak Medical Complex Old Block	3.0	21.0	90
Niazi Medical Complex VIP Block	3.0	21.0	90
Khawaja Arshad Family Hospital	3.0	21.0	90
Rai Medical Complex	2.4	16.8	72
Faiz Memorial Hospital	2.4	16.8	72
Al Haram Hospital	2.4	16.8	72
Central Hospital	2.4	16.8	72
Shifa Hospital	1.8	12.6	54
Kings Hospital	1.2	8.4	36
Bhatti Medical Complex Hospital	1.2	8.4	36
Al-Abbas Hospital	1.2	8.4	36

Reported daily maximum and minimums vary considerably. Sadiq Hospital's 7.2 kg/day is 6 times higher than the reported values of the 3 hospitals generating the lowest amounts (1.2 kg/day). The same correlation is observed at weekly and monthly time scales due to the following reported daily pattern at longer time scales. The Sadiq Hospital made 216 kg monthly contributions while Bhatti Medical Complex Hospital, King Hospital and Al-Abbas Hospital each reported 36 kg monthly.

5.2 Red and Yellow Waste Streams

There are two waste streams in the hospital records red and yellow. The average amounts of red and yellow waste at all 15 hospitals were 10.65 kg and 31.95 kg per day, respectively. Their total is 42.6 kg which means that 25%, or 10.6 kg, of the reported daily waste was red waste and 75% or 32.0 kg was yellow waste. The red waste at weekly level was 74.55 kg and the yellow waste was 223.65 kg while the red waste at the monthly level was 319.5 kg and the yellow waste was 958.5 kg.

The dominance of the yellow stream is consistent with each of the facilities chosen, as the proportion of each stream remains the same in the records reported for the two streams. A sample of the hospital Sadiq reported had a red waste of 1.8 kg, and a yellow waste of 5.4 kg per day. Ibn e Sina Hospital reported 1.05 kg and 3.15 kg respectively.

The cumulative quantities are of greater importance than the daily amounts from a management standpoint. A total of 1,278 kg is needed each month and needs to be continuously segregated, contained, collected and subsequently managed appropriately. The larger yellow stream is therefore very significant as an operational requirement but the smaller red stream is also important as it does not only require management based on volume but on the contents and attendant hazards.

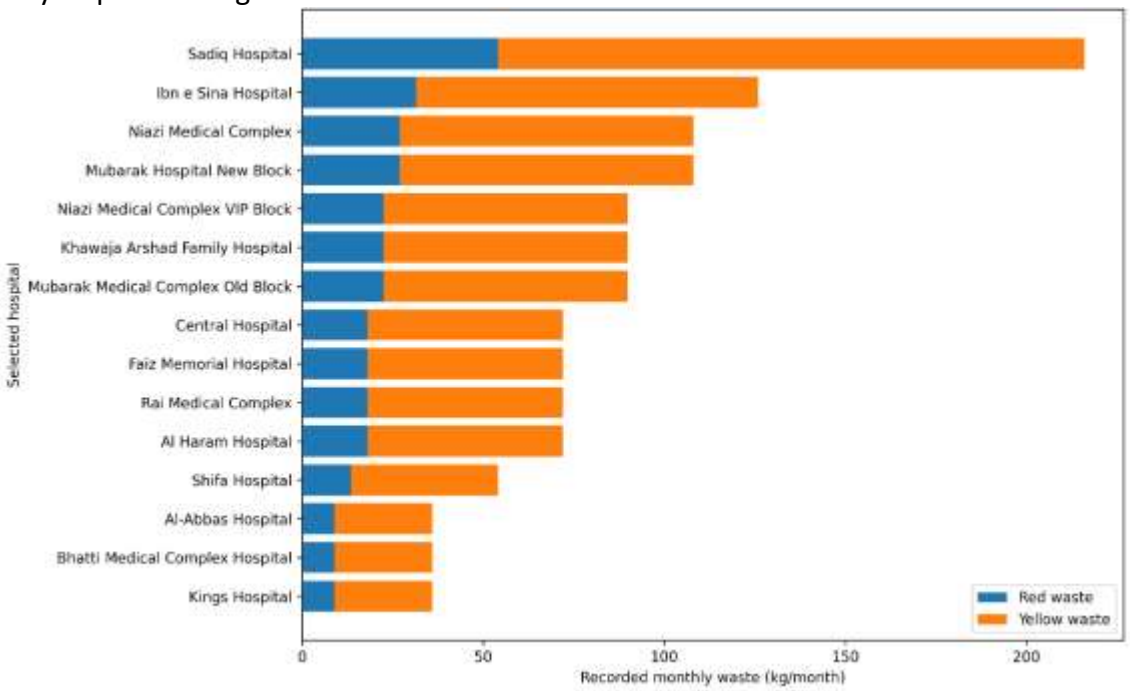


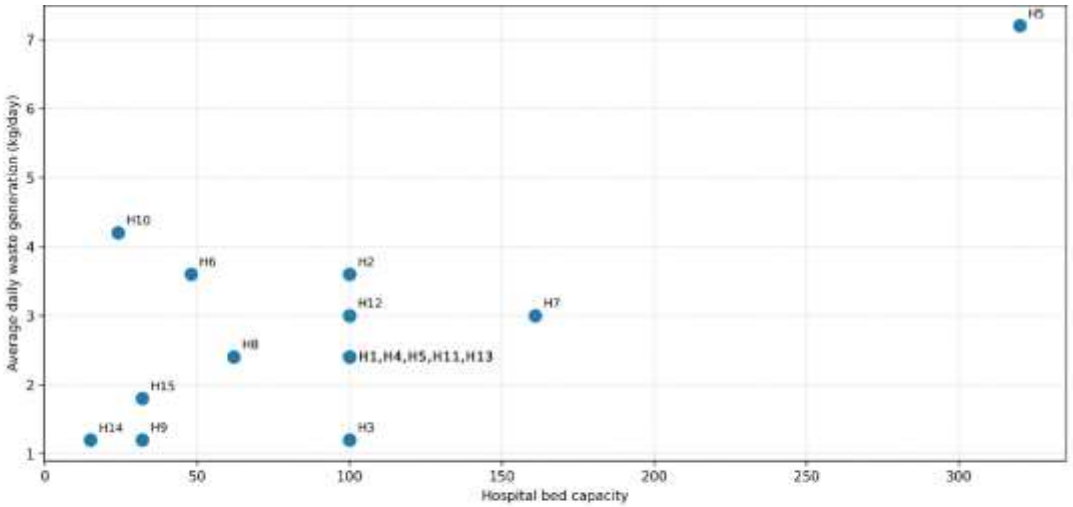
Figure: 5.1. Recorded Red and Yellow Streams

5.3 Relationship with Hospital Capacity

By comparison of bed capacity to waste generation, we see that hospital size helps to provide context but is by itself insufficient to explain what we see. Sadiq hospital had the largest recorded capacity (320 beds) and the highest amount of waste generated (7.2 kg/day). This can be understood given the accepted idea that bigger health centers produce larger volumes of waste due to a larger service coverage and its activity level.

The relationship is not consistent, however. Ibn e Sina Hospital's waste was measured as 4.2 kg of waste per day, though it had only 24 beds, more than 2 other hospitals with bed capacity of more than 3000 were having more. In a similar manner, hospitals with 100 beds had varying amounts of kg/day: Mubarak Hospital New Block had 3.6 kg/day, Mubarak Medical Complex, Old Block, 3.0 kg/day, Rai Medical Complex, 2.4 kg/day, Al Haram Hospital, 2.4 kg/day, Central Hospital, 2.4 kg/day, and Kings Hospital, 1.2 kg/day. Clearly, these disparities indicate that simply looking at bed capacity is not a good indicator of waste generation.

This trend is parallel to the international literature that indicates that the amount of healthcare waste generated is dependent on a number of institutional and socio-economic factors, as opposed to a single factor (Minoglou et al., 2017). A range of activities might contribute to the differences between hospitals including patient activity, type of clinical services, lab work, surgery and emergency care and the use of disposable materials. The observed association in the current study was not measured systematically and should not be considered as causal.



H1 = Mubarak Medical Complex Old Block H2 = Mubarak Hospital New Block H3 = Kings Hospital H6 = Rai Medical Complex H5 = Sadiq Hospital H6 = Niazi Medical Complex H7 = Niazi Medical Complex VIP Block H8 = Faiz Memorial Hospital H9 = Bhatti Medical Complex Hospital H10 = Ibn e Sina Hospital H11 = Al Haram Hospital H12 = Khawaja Arshad Family Hospital H13 = Central Hospital H14 = Al-Abbas Hospital H15 = Sirfa Hospital

Figure: 5.2. Relationship between Hospital Capacity and Daily Waste Generation

5.4 Comparison with Previous Research

The magnitude and distribution of waste observed in case of Sargodha needs to be evaluated in context of other studies conducted through different methods. In Faisalabad, Hameed et al. (2017) were able to report the daily waste produced by 44 hospitals, which was 7,646 kg of waste in total with 1,117 kg of infectious waste. They generated waste as a whole at the rate of 1.28 kg value/bed/day. The Faisalabad study had much higher number of hospitals and employed a different method for data collection including both questionnaires and interviews and observations. This is not an appropriate comparison of the present study with other research because of differences in sample sizes, hospital type, size of beds, and in the procedure of measurements and classification.

There is a general trend, however, similar here; the amount of waste produced in hospitals can fluctuate markedly from facility to facility. Better sort and education is crucial for waste control in its infectious treatment streams, as foreseen by Windfeld & Brooks (2015). This is significant with respect to Sargodha as these quantities will have to be segregated effectively before collection, treatment and disposal. The results also lend themselves to support the notion that the hospital waste management system should be designed based on the specific situation of every waste generator instead of an average assumption for all hospitals.

An additional basis for Pakistan is the regulatory landscape. The Hospital Waste Management Rules, 2005 lay down the norms for the segregation, collection and storage, transport, processing and disposal of hospital waste. Based on evidence created from Peshawar, Zeeshan et al. (2018) still found issues of formal planning, inadequate record keeping, fragile segregation and colour coding, as well as lack in transportation and disposal. Due to the lack of structured assessment checklist in the field observations, the present study does not determine a specific 'compliance score' for the hospitals in Sargodha. However, the level of recording and appropriate segregation is a clear example of why these are key aspects of institutional waste management.

The COVID-19 pandemic again illustrated how quickly amounts of healthcare waste can grow when medical services and the use of disposable protective materials have risen. During such circumstances, Das et al (2021) highlighted the need to have sufficient treatment facilities, preparedness for emergencies and proper disposal of healthcare waste. The prime lesson of the present study is that waste-management systems should have enough capacity and be flexible enough to cope with the changes in the health care activities, though not a pandemic assessment.

5.5 Human-Health and Environmental Implications

The quantities reported may have implications for workers' health, since health care waste continuously comes into existence and needs to be treated on multiple occasions before disposal. Failure to segregate and/or contain infectious material or contaminated sharps can cause exposure of workers engaged in collection, internal transport, storage and treatment. The World Health Organization has included contaminated sharps and infectious waste as key sources of risk for injury and exposure (Chartier et al., 2014). Likely, then, the risk is also related to the quality of separation, containment and handling of waste.

Potential environmental impacts can occur if waste is not adequately stored, transported or disposed. Pollutants or hazardous materials can leak into surrounding environment through uncontrolled disposal and applications of inappropriate burn activities. Some inappropriate treatment and overclassifying waste as infectious, can also result in unnecessary burdens to the environment, Windfeld and Brooks (2015) point out. The geographical context of Sargodha is Ground Water in its alluvial context and its importance makes the topic of environmentally sound waste management more relevant for the area. However, the present study does not have laboratory evidence for soil, water or air contamination.

Consideration must thus be given to the findings, which are presented rather cautiously in the light of the uncertainties mentioned above. Study findings indicate an ongoing need for waste management and potential route of exposure, but don't prove that any specific hospital is responsible for a specific disease, injury, or contamination of the environment. No environmental sample testing was performed, and no

individual health survey undertaken. This separation is crucial in order to keep the results interpreted in an evidence-based way.

5.6 Geographical Interpretation

The GIS aspect provides a spatial perspective of quantitative assessment. Selected hospitals are not a single waste generating point, but rather a number of points of waste production throughout Sargodha City. The various reported amounts show that the level of waste management varies spatially between facilities. Retail facilities which generate larger amounts of waste may need additional storage and collection points while lower generating facilities still need to maintain stock separation of waste products and collection procedures for safe waste disposal.

Equally the spatial portrayal should not be taken to indicate an environmental impact map. The hospital location and values of waste generated are identified in the study, but no data is available on where waste is transported, where it is disposed, groundwater quality, soil contamination, exposure of population. Future research using hospital waste data linked to land use, population and environmental, sampling and transportation maps will be able to give in great detail a spatial risk assessment.

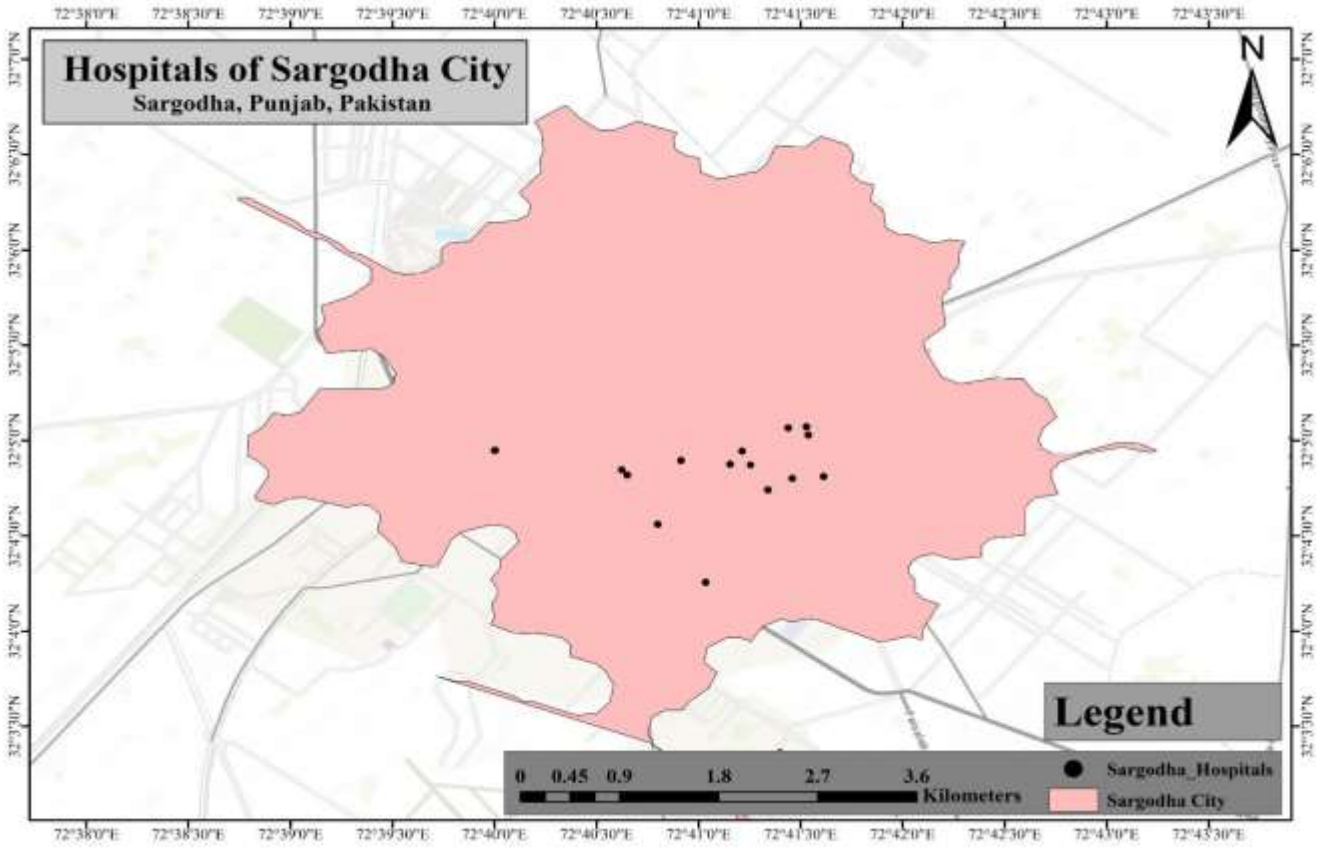


Figure: 5.3. Spatial Distribution of Selected Hospitals in Sargodha City

5.7 Implications for Waste-Management Planning

The findings indicate that the planning of the waste management system in Sargodha must depend on the amount of waste produced by each of these waste generators. Hospitals with greater reported amounts should be able to provide adequate temporary storage facilities and have an ongoing collection and treatment plan. Daily generation can be aggregated to the longer term and the result is visualized on the graph starting from 42.6 kg/day up to 1,278 kg/month.

Increased systematics in record keeping throughout hospitals with consistent units, times and waste categories for collection of quantities of health care hazard waste. Source separation should continue to be seen as a priority and the use of appropriate containers and clear labelling coupled with training for staff. Sharps must be disposed of in an appropriate puncture resistant container and collection and transport within the premises must reduce unnecessary exposures. All measures are in line with overall principles of safe healthcare waste management as stated by Chartier et al. (2014), and with Pakistan's regulatory framework.

The study also suggests that the assumption that smaller hospitals do not have any waste management needs is false. Even the lowest reported figure of 1.2 kg per day, equals 36 kg per month. Based on this, there are suitable management systems to be maintained in facilities of various sizes, and operational capacities adjusted based on the quantity and characteristics of the waste.

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