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CLINICAL LIQUID WASTE MANAGEMENT IN THREE GHANAIAN HEALTHCARE FACILITIES – A CASE STUDY OF SUNYANI MUNICIPALITY

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ABSTRACT: *Clinical Liquid Waste Management (CLWM) has become a huge task for the authorities of health care facilities in Ghana. It is therefore a necessity to ascertain the managerial strategies currently being used in managing this type of waste. The study objectives were to identify the clinical liquid waste management techniques presently being used by the hospitals, estimate their generation rate and to determine the efficiency of their clinical liquid waste treatment system(s). The study employed experimental research method as well as quantitative method involving structured interview and participatory observation triangulated with documentary analysis. The results found different levels of clinical liquid waste generation in sampled health care facilities. From the results, the study revealed that clinical liquid waste is managed using strategies such as segregation, collection, handling, transportation, treatment and disposal.. The Regional Hospital (RH) uses on-site conventional wastewater treatment system located in the hospital premises whilst the Municipal Hospital and S.D.A uses off-site Waste Stabilization Pond (WSP). The results found that different treatment methods employed by sampled hospitals affect the quality of treatment. The results show revealed inefficiency in both treatments facilities. These findings were revealed from results obtained from the microbial analysis of Total Coliform bacteria; Feacal coliform bacteria and heterotrophic bacteria of sampled hospitals; as the results do not meet both the EPA-Ghana and WHO standards. Factors such as unreliable power supply, lack of maintenance, lack of enforcement and effective monitoring from statutory bodies and apathy from health officials were identified as factors that affect proper treatment of liquid waste in the municipality. The findings results suggest an environment problem due to the contamination of treated effluent from the sampled hospitals which is used for agricultural irrigational purposes, drinking and cooking. The study recommend; an urgent remedial measure to prevent outbreak of communicable disease through creation of awareness to educate communities downstream on the need to apply local methods such as boiling.*

KEYWORDS: Clinical Liquid Waste management (CLWM), Microbial Analysis, Liquid Waste Strategy, Liquid Waste, Generation Rate

INTRODUCTION

Clinical Waste Management (CWM) has become an important concern for many healthcare facilities in the World (Abdulla et al., 2008; Hossain et al., 2013). The problems of managing safe disposal of clinical waste especially liquid waste is becoming more challenging in the 21st

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century as the number of infectious diseases treated in healthcare facilities escalates and the types of pathogens become more complex (WHO, 2007). Numerous literatures seem to suggest that the risks associated with clinical waste especially liquid waste are not given the needed attention it deserves (WHO, 2007). This is because the common practice of pouring untreated liquid waste down the sanitary sewer into our water bodies and on the bare soil especially in developing countries is viewed by many as a normal practice. However, WHO and Center for Disease Control (CDC), U.S.A have empirically shown that clinical liquid waste contains large numbers of microorganisms that can be detrimental to humans who come into contact with it (Agarwal, 1998; Nema et al., 2011; WHO, 2007). Hence, the need for healthcare facilities and its personnel to ensure that appropriate technologies are utilised and that personnel are well trained on safely managing liquid clinical waste in health facilities.

Many studies have empirically found and reported that poor management of clinical waste generally at healthcare facilities are highest in developing countries (Abd El-Salam, 2010; Udofia & Nriagu, 2013; Wiafe et al., 2015). WHO, (2007) and Udofia & Nriagu, (2013) estimated that the African continent alone has over 67,000 healthcare facilities that generates over 283, 000 tonnes of clinical wastes annually. A WHO survey in 22 developing nations found that about 18% to 64% of healthcare centres' use inappropriate clinical waste treatment and disposal technologies (WHO, 2005a as cited in Wiafe et al 2015). Some factors such as financial sustainability (Lohri et al., 2014) and lack of skill expertise to manage and reliance on obsolete technology (Coker et al., 2003; Guerrero et al., 2013) are blamed as the cause.

Although the risks from clinical liquid and its related wastes are dependent on exposure, liquid waste disposal problems place patients, healthcare staff, visitors at risk, while adding enormous costs to health care (Nemathaga et al., 2008; Udofia & Nriagu, 2013). Recently, healthcare workers' agitation over waste related infections in hospital are putting increasing international pressures on governments to maintain stringent handling practices and safe disposal of clinical waste (Manyele & Lyasenga, 2010; Lultrell et al., 2003; Hossain et al., 2013; Nema et al., 2011). Realising this potential gap in the healthcare system coupled with recent growth in hospital attendance, healthcare professionals through seminars and forums has urged and called for the introduction of new legislation by Government to propose strategies for waste management policies. The Ministry of Health and its allied agencies in Ghana over the years have implemented significant changes to their health care practices. However, these changes within the hospital waste management have placed requirements on the health care sector to develop and implement new protocols for the management of wastes generated across the sector specifically with the recent Ebola epidemic across some West African nations. The Ghanaian Ministry of Health and Ghana Health Service has embarked on processes to consider the implications of these changed policy directions to establish an overarching policy which addresses all aspects of clinical and its related waste management. The policy intends to harmonise the minimum requirements for all public and private health related services that generate relevant waste: the General Hospitals, Metropolitan/Municipal/Districts Hospitals, University hospitals, Polyclinics, Private hospitals and Clinics). The waste streams comprising clinical and related wastes have defined management processes for their segregation, storage, transport and disposal in or from health care settings (Wiafe et al., 2015).

However, in Ghana, there is growing concern over poor management practices and improper precautions taken by most clinical waste workers during the waste management process. Reasons such as delay in passing occupational health and safety legislation, non-existence of comprehensive waste management strategies coupled with lack of awareness of the healthcare workers regarding the infectious risk of clinical waste are attributed to the mismanagement of clinical waste in many healthcare facilities (Wiafe et al., 2015) in many health facilities of developing countries (Nema et al., 2011). In Ghana, collection, transportation, treatment and disposal of clinical liquid wastes are major challenges for the healthcare facilities. These challenges are much aggravated when state institution whose mandate are to ensure safe disposal of clinical waste cannot monitor and evaluate the conditions of clinical waste before discharging them into the environment due to genuine logistical constraints. As a result some healthcare official's compromise on work ethics by breaching the CLWM standards and best practices to discharge untreated liquid waste into natural water bodies thus poses a public health risk. Semenza et. al., (1998) demonstrated in Uzbekistan with epidemiological data and found that diarrhea diseases is closely linked to cross-connection between the municipal water supply and sewer due to leaky joints. Craun & Calderon, (1999) found in the USA that reported outbreaks of waterborne disease were attributed to contamination of water system (Craun & Calderon, 1999). There are unconfirmed reports from hospitals and clinics within the Sunyani Municipal Assembly of high cases of cholera, diarrhea, and typhoid who are water borne related diseases. This means that the quality of water consumption in some parts of Sunyani Municipality is at high risk. This is collaborated by a nationwide incidents of reported water related diseases such as Cholera, diarrhea, Typhoid and Fever in some regions in Ghana in 2015. So, if the current hospital admission rate of 49.19 in the region is higher than the national average of 43.79 and an outpatient attendance per capita of 1.15 higher compared to national average of 0.81 (Ministry of Health, 2015), the need for adequate monitoring of water sources is important to avert epidemic. In Sunyani Municipality treatment of clinical liquid waste are discharged into water bodies that serve as source of water for many inhabitants. Thus, monitoring liquid treatment and its quality is necessary especially in the wake of incessant power outage in 2015 that disrupt the operations of the conventional liquid treatment plant in the municipality. This study aims to fill the gap by investigating the challenges and opportunities in Ghana's healthcare facilities in managing clinical liquid waste and pointing out options on possible remedial measures to be implemented. The study explored within the Sunyani Municipality especially in three selected hospitals namely, Municipal Hospital, Regional Hospital and S.D.A Hospital. Thus the study specifically sought to:

- To identify the various sewerage management techniques currently used by the three hospitals within the municipality
- To determine the clinical liquid waste generation in the sampled hospitals within the municipality
- To assess the efficiency of sewerage management facilities used in the sampled hospitals within the municipality
- To recommend possible remedial measures to be implemented in Sunyani Municipality, Ghana.

Research Questions

1. What are the various types of liquid waste management techniques currently used by the three hospitals within the municipality?
2. What is the clinical liquid waste generation in the three hospitals within the municipality Ghana?

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3. What is the level of treatment of clinical liquid waste generated prior to disposal in the Sunyani Municipality?

4. What possible remedial measures can be implemented to improve CWM practices in the municipality?

LITERATURE REVIEW

Concept of clinical liquid waste management (CLWM)

Definition of clinical liquid waste

Clinical liquid Waste for the purposes of this paper is defined as hazardous and non-hazardous liquid waste with sufficient free liquid (Biswal, 2013; WHO, 2007) "arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation, treatment, care, teaching or research" (Collins, 1991as cited in Wiafe et al., 2015) that requires additional safety packaging to ensure safe storage, transportation and treatment (WHO, 2007).

Source classification of clinical liquid waste

Clinical waste can be classified as major or minor sources according to quantities generated. The major source of clinical waste are generated at major hospitals (e.g. university teaching hospital, general and districts hospitals) and other health centers (i.e. emergency medical care services, health care centre and dispensaries etc.) (Cheng et al., 2009) The minor sources of clinical waste are generated at small health care (Katoch & Kumar, 2008 cited in Wiafe et al., 2015: 35).

Clinical liquid Waste classification

Liquid waste generated in health care facilities can be classified as hazardous (i.e. infectious, pathological liquid waste, chemically hazardous liquid waste, pharmaceutical liquid waste, photographic chemicals) and non-hazardous (i.e general (grey) liquid waste, certain pharmaceutical liquid waste). The WHO has stated that 85% of such hospital wastes are actually nonhazardous, around 10% are infectious, and around 5% are non infectious but hazardous (Figure 1).

1. ***Non-hazardous liquid waste*****:** Non-hazardous liquid waste in the context of clinical liquid waste are generated from hospitals kitchen and laundry facilities. This liquid waste may be termed as grey water and are generally not infectious or contain any pathogens. In developing countries, such liquid wastes are directly channelled into storm drains or sent to natural wetlands for removal of nitrogen and phosphorus present (WHO, 2007) poses no infectious risk to persons who handle it (Franceys et al., 1992; Feachem et al., 1983).

2. ***Hazardous liquid waste*****:** Hazardous clinical liquid waste comprises both infectious, pathological, chemically hazardous, pharmaceutical, photographic chemicals liquid waste arising from medical, nursing, dental, veterinary, pharmaceutical or similar practice, investigation, treatment, care, teaching or research (Biswal, 2013; Collins, 1991) that requires various treatments level before discharging into water bodies. Infectious and pathological waste consists of blood and body fluids from cultures of infectious agents, cultures from laboratories, biological, discarded vaccines, culture dishes and devices.

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Chemically hazardous (i.e. Formaldehyde (obtained from pathology labs, autopsy, dialysis, embalming); Mercury (broken thermometers, sphygmomanometer, dental amalgams); Solvents (pathology and embalming); Radioactive isotopes. Some pharmaceutical liquid waste such as discarded/unused/expiry date medicines are non-infectious but hazardous (Biswal, 2013).

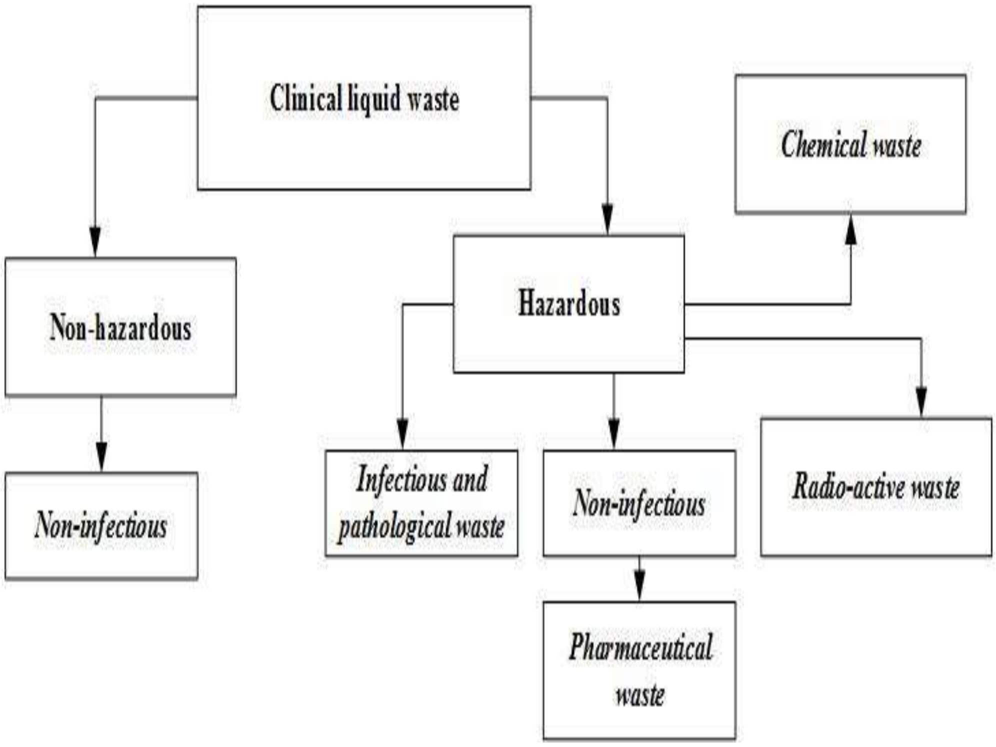

Figure 1: Classification of clinical liquid waste

Composition of clinical liquid wastewater

Normally most water bodies such as rivers or streams receive pollution from many different sources, which differ in volume. Typically, the composition of clinical wastewater is a reflection of the healthcare facility's functions that are practiced (Gray, 1989). The composition of liquid waste from healthcare facilities are a complex mixture of infected and non-infected blood, body fluids (urine, faeces (stool) from laboratory), organic and inorganic materials (Lim et al., 2010).

Microbiological composition of clinical liquid waste

Clinical liquid waste contains a wide range of micro-organisms specially bacteria, viruses and protozoa. The majority is harmless and can be used in biological sewage treatment, but sewage also contains pathogenic microorganisms. Bacteria which cause cholera, typhoid and tuberculosis; viruses which cause infectious hepatitis; protozoa which cause dysentery and the eggs of parasitic worms are all found in sewage (Shaaban et al., 2004).

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Clinical waste management process

WHO (2014) stipulate that the objective of any effective CWM program should be able to provide protection to human health and the environment from hazards posed by the waste. Thus proper management ensures that infectious waste is handled in accordance with established procedures from the point of generation through to treatment of the waste and its final disposal stage (cited in Wiafe et al., 2015). In developing countries such as Ghana, most clinical liquid waste management process is outlined as below in healthcare facilities.

1. Identification and Segregation

2. Collection, Packing and Handling

3. Internal and external transportation

4. Temporary storage

5. Treatment technique

6. Disposal of treated clinical waste

Identification of Waste: Waste is identified in hospital depending on its sources and level of hazards. Many health care waste management and operational procedure stipulate that medical waste either solid or liquid must be identified and separated at source to avoid being mixing (Berger et al., 2000)

Segregation: Waste segregation is separating wastes at source of generation (Sagoe-Moses et al, 2001). One major advantage of segregation is to minimised wastes at source and ease of collection, packing and handling.

Collection, packing and handling: Clinical liquid waste depending on its nature (i.e dangerous, toxic and flammable liquid) may be collected and placed into approved water-tight containers and packaged in order to protect waste handlers and the public from exposure or drained through secured pipelines for treatment and disposal (Franceys et al., 1992; Feachem et al., 1983).

Temporal holding area: Temporary holding areas comprises of an area designated for storing dangerous, toxic or flammable clinical liquid for a short period of time before transportation. Depending on the nature of waste generated, the temporary holding area may be a building where liquid waste sealed in containers are kept or a septic tank to hold the liquid waste (Marinkovic et al., 2008). Past studies have not shown yet a universally accepted standard period of time that the waste can be stored prior to treatment and disposal, however, WHO recommends that time for holding clinical waste be kept as short as possible (cited in Wiafe et al., 2015).

Transportation: Depending on the hospital size and functions, transportation of clinical liquid waste in healthcare centers may fall under two stages; the first is from the source of generation to an on-site temporary holding areas for pre-treatment (internal transportation) while the second involves removal from on-site temporal storage facility to a conventional treatment facility or an off-site treatment and disposal facility (external transportation) Coker et al, (2009).

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Treatment Technique: Treatment technique is any method, technique, or process designed to change the physical, chemical or biological composition of liquid waste (Marinkovic et al (2008). Table 1 presents advanced method of some liquid waste treatment. However, in developing countries many teaching or research hospitals may only have a conventional treatment facility or waste stabilization ponds (WSP) for treatment.

Conventional sewerage treatment plant

The conventional treatment facility is grouped into three categories i.e. primary treatment, secondary or biological treatment and tertiary or advanced treatment and based on the size of the health facility as well as the level of healthcare services; a selection of category is used. The main advantages of a conventional sewerage treatment plant are that treatment of large of amounts of sewerage quickly and needs relatively small land. One of the main drawbacks of this facility apart from cost of construction or installation of the plant is that sewage effluent may still contain large number of pathogens when it leaves the treatment plant (Abdul-Raoul et al., 2012).

Waste stabilization ponds

Waste Stabilization Ponds (WSPs) are large, shallow basins in which raw sewage is treated entirely by natural processes involving both algae and bacteria. In simple terms, waste stabilization ponds are impoundments into which wastewater flows in and out after a defined retention period. Treatment relies solely on the natural processes of biological purification that would occur in any natural water body. The WSP only uses sun energy for its operation and treatment is optimized by selecting appropriate organic loadings, retention periods and ponds depths, to promote the maximum growth of organic beneficial to the treatment process. This means that WSP works efficiently in wastewater treatment in tropical climates than temperate climates (Abdul-Raoul, 20012). Typically, there are three different types of WSP; anaerobic, facultative and maturation, each of which has different functions and design procedures (Mara et al., 2007). WSP is considered as the cheapest and most efficient way of treating wastewater. The wastewater flows in a series of large ponds to allow the solid part of the waste to settle and break down. The liquid part of the waste flows into other ponds where air and sunlight kill many of the harmful germs in the wastewater and makes it less harmful to living organisms. This means that waste stabilization ponds are very effective in the removal of faecal coliform bacteria.

Removal of coliform bacteria

Moawad (1968) observed that the environmental factors which were favourable for algal growth were unfavourable for the survival of coliforms. Pathogenic organisms of concern in wastewater include bacteria such as *Salmonella* and *Shigella*, viruses and protozoa. Bacteria provide the largest component of the microbial community in all biological wastewater treatment processes and numbers in the range of 10^6 bacteria/ml of wastewater are frequently encountered (Horan, 1990). Experimental evidence indicates that, the pathogenic bacteria generally have shorter survival times in the environment than coliforms, whereas viruses tend to survive longer. The efficiency of disinfection of sewage is generally estimated by the extent of removal of total coliform organisms (Sebastian & Nair, 1984). In terms of treatment efficiency relating the removal of total coliform organism, Pharhad & Rao (1976) and Shelef et al., (1977) found that the sewage stabilization ponds have generally more effective than conventional sewage treatment systems. Some empirical studies have revealed improvement

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in coliform removal in stabilization ponds (Malina & Yousef, 1964; Meron et al., 1965; Oswald et al., 1967).

Table 1: Overview of disposal and treatment methods suitable for different

Technology or method	Infectious liquid waste	Pathological liquid waste	Chemical liquid waste	Radioactive liquid waste	Kitchen and Laundry liquid waste
Chemical disinfection	Yes	Yes	No	No	No
Wet thermal treatment	Yes	Yes	No	No	No
Microwave irradiation	Yes	Yes	No	No	No
Discharge to a sewer	No	No	No	No	Yes
Approved containers for storing waste	No	No	Yes	Yes	No

Disposal of Treated liquid Waste: Disposal refers to the final placement of treated liquid waste on the land or into water bodies based on local conditions. Clinical liquid waste disposal are discharged into water bodies mainly developing countries (Franceys et al., 1992; Feachem et al., 1983).

RESEARCH METHODOLOGY

The study utilized experimental method to assess the physical, chemical and bacteriological condition of treated liquid waste in our hospitals on one hand. And mixed methods of quantitative, and observation triangulated with documentary analysis concerning liquid waste management situation in Sunyani Municipality on the other hand.

Mixed methods used for this research involving documentary analysis, quantitative approaches, and observations are briefly summarized as follows:

Document and literature analysis on clinical liquid waste directly or indirectly related to the topic was reviewed. The three hospitals, namely and geographically located on Regional hospital (RH) (2^{o}18'51.60''W and 7^{o}20'39.20''N), Municipal Hospital (MH) (2^{o}19'43.42''W and 7^{o}20'19.43) and a privately owned hospital called the Seventh Day Adventist (S.D.A) hospital (2^{o}20'33.92''W and latitude 7^{o}20'44.19''N) were sampled for the study using purposive sampling based on the following factors; hospital size, hospital location, type of health services and distance between them (Figure 2 and 3). The study undertook preliminary structured interview concerning the clinical liquid waste situation in the selected health facilities to understand the clinical waste management system setup in the municipality. The structured interview was prepared and administered by the researchers on a face-to-face interview method. Afterwards, material flow analysis with secondary data sources obtained from preliminary interviews of key informants involving a system description for liquid waste flows in the three sampled hospitals was conducted (Rodic et al., 2010). This enabled the researchers to design the structured questionnaire for management of health facilities (doctors, nurses, and health personnel) to obtain information on liquid waste generation, collection, treatment and disposal were obtained. The information on the number of beds and its occupancy, number of surgeries, amount of liquid wastes generated, and pretreatment, segregation, storage, treatment, and disposal of the wastes was collected from each of the hospitals through structured questionnaire administration during field work, liquid waste treatment log books, and observation. Information obtained from the structured questionnaire was cross checked with the set objectives to reassess information gaps. Reassessment questions were sent only to some health facilities personnel (i.e. doctors, nurses) and managers of liquid waste treatment facilities. Unobtrusive field observation of clinical liquid waste treatment facilities was done.

Ethical clearance was obtained from selected hospitals and Ghana Ministry of Health. For the purpose of facilitating field work, the study through a written consent, requested participants for their willingness to participate to this study. They were also informed that they have a right to withdraw at any time during the data collection and at the same time assured that their responses will be kept confidential and be used only for this study purpose (Wiafe et al., 2015).

The experimental method involved sample collection and laboratory analysis of some microbial parameters. Field measurement was done and sampling of liquid was carried out between 08:00 and 10:00 hours in the morning at the time when hospitals were operating (APHA, 2001). The liquid source was agitated during this period. Sterilized 200 ml glass bottles were used to collect samples from three different points in the sedimentation tanks and at 20-m intervals along the tanks. The sampling was performed on at least 3 different dates. Two samples each were collected from the sedimentation tanks of each sampled hospitals. The sampling and processing of the samples were done by the standard methods. The controls were always used with each sample, and if there was any contamination in any of the controls the whole sampling was repeated on another sampling date. The samples were stored in cold icebox and transported to the laboratory for analyses. Any samples collected were analysed within 24 hours without loss of cool storage (APHA, 2001).

The sampled liquid collected were analysed for quantification, isolation and identification of the bacteria present. A total of 4 growth media were used to quantify and isolate bacteria from the samples. These were MacConkey agar (Meduim for total coliform), Brilliant Green bile 2% Broth (medium for feacal coliform), Nutrient agar (NAM) (medium for heterotrophic Bacteria, Peptone H_2O (medium for E-coli). To determine the total coliform, 35g of sample was suspended in 1 litre of distilled water. The substance was heated until completely dissolved, distributed into container filled with Durham's tubes and sterilized by autoclave at 121^{o}C for 15 minutes. To determine feacal coliform, 40g of powder was weighed and dispensed into 1 liter of de-ionized water. The substance was allowed to soak for about 10 minutes, and then swirled to mix by gently warming to dissolve. The substance was dispensed into tubes with inverted Durham tubes and sterilized by autoclaving for 115^{o}C for 15 minutes. Determination of E-coli was performed weighing 15g and dispensing in 1 litre of de-ionised water. The substance was allowed to soak for 10 minutes, swirled to mix before dispensing into final containers. The substance was then sterilized by autoclaving for 15 minutes at 121^{o}C and carbohydrates and a pH indicator added for studying fermentation reactions. For heterotrophic Bacteria determination, of powder was weighed and dispensed in 1 litre of de-ionised water and allowed to soak for 10 minutes, swirled to mix then sterilized by autoclaving for 15 minutes at 121^{o}C, cooled to 47^{o}C. On each sampling date, the collected samples and de-ionised water inoculated in separate quadruple sets of petriplates containing the growth medium. Data

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collected from the field was checked for consistency and completeness before subsequent analysis.

A free Google Earth image (60 cm resolution) for the study area was downloaded on 20th June 2015 using a python programming code and subsequently the image was geometrically rectified based on control points taken from topographic maps at 1:25,000 scale using Universal Transverse Mercator and WGS 1984 datum map projection. A subset of the study area was clipped using the district boundary to optimize effort and time for the fieldwork. Field observations using the high resolution free Google Earth imagery gave a better understanding of the infrastructural orientation of study hospitals. During the fieldwork each treated wastewater effluent sample collection point was registered with a Garmin GPS device to allow integration with spatial data in geographic information systems (GISs) and image processing systems (Jensen 1996). Field sampling points (or ground truth data) for treated wastewater effluent were collected from the two diffident treatments facilities based approved scientific methods explained above.

The results were presented in Tables, Figures and maps.

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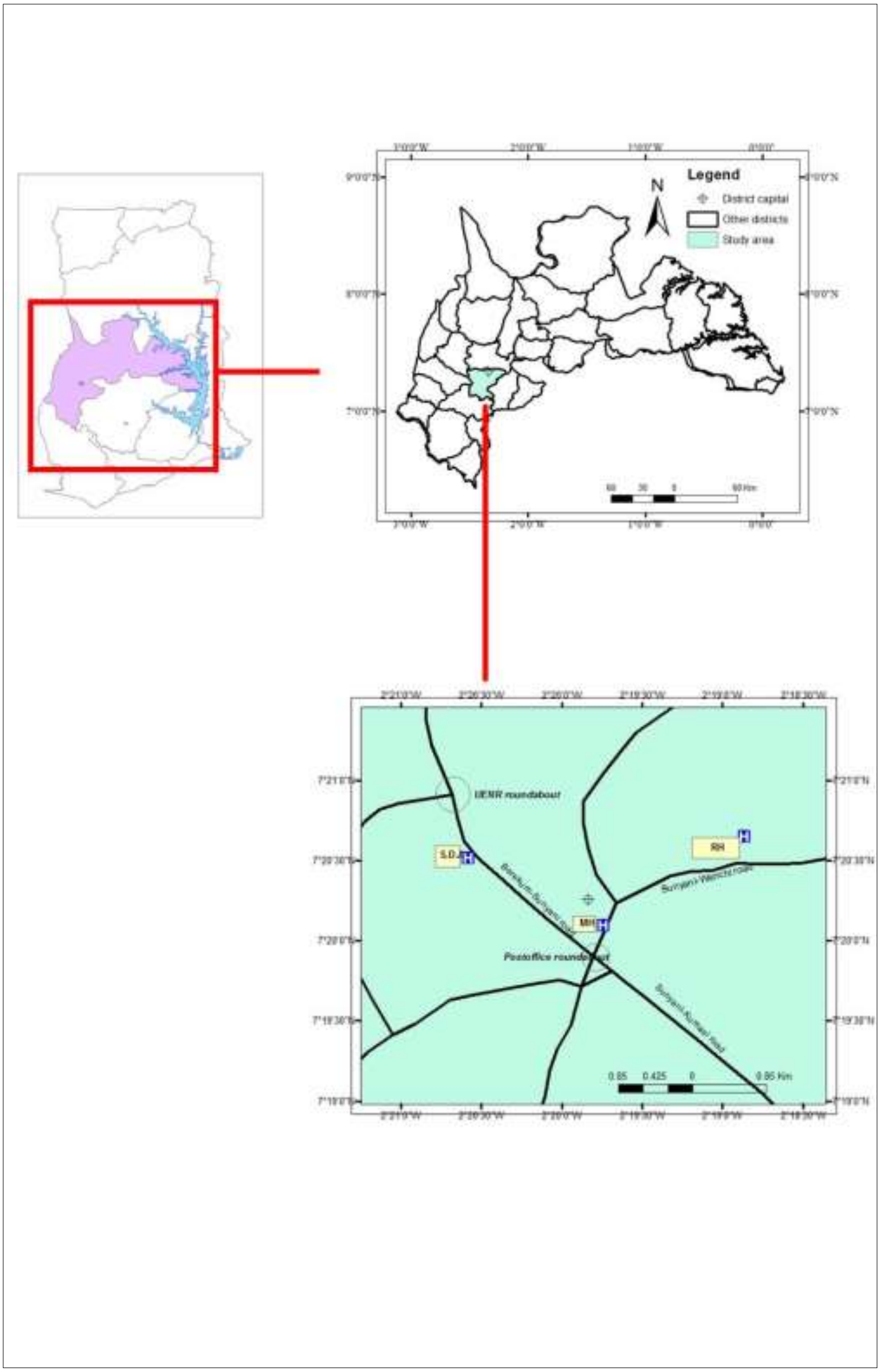

Figure 2: The study area in the Brong Ahafo region of Ghana shown as a green with selected hospital locations

Source: (Wiafe et al., 2015)

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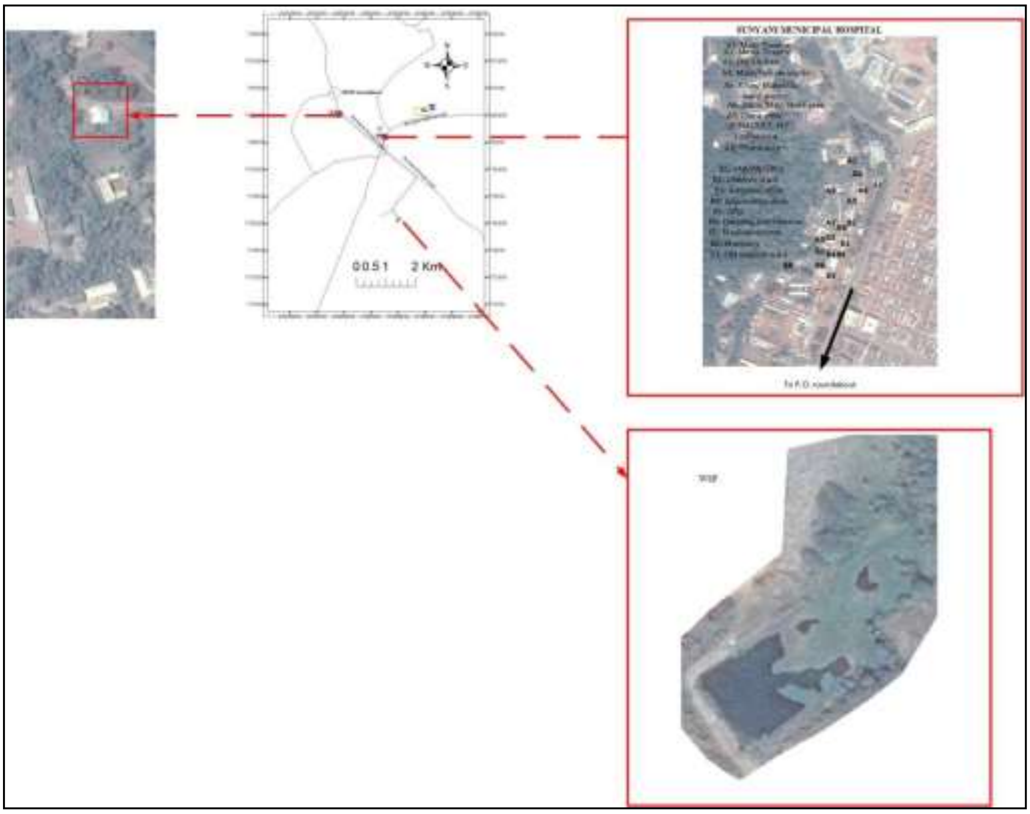

Figure 3: The study area showing sampled hospital locations

Source: Authors construct (2016)

RESULTS

Liquid Waste Generation in the Health Care Facilities

The results revealed that liquid wastes are generated mostly in the wards, surgical theatres, laboratories, pharmacy, mortuary, and the clinics by healthcare workers, patients and visitors. The results presented in Table 2 showed that the two most common liquid wastes generated at the surveyed healthcare facilities in the Sunyani Municipality are pathological and Infectious waste. The results in Table 2 indicates the highest liquid waste generation rate on average basis was found at MH with 33L/bed/day, 20L/bed/day was found at RH whilst S.D.A had the lowest generation rate of 2.5L/bed/day. The generation rate of clinical liquid waste was 15L/patient/day at RH and MH, 0.8L/patient/day at S.D.A hospital (Table 3). This resulted in an average of 30.8L/patient/day and 54.5L/bed/day for the three sampled healthcare centres. The results indicate that quantities of liquid waste generated vary with type and size of the healthcare facility, number of patients who visit the hospitals and type of services provided.

The results from Table 4 show greater proportion of liquid wastes (both pathological & infectious) generated in the wards of the study hospitals. The results from Table 3 show that the wards generate the highest liquid waste (7,817L/day) of which 199L is pathological waste and 7,618L is infectious waste. The surgical theatre followed with a total of 1,020L of which

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560L is pathological waste and 1,060L is infectious waste. The mortuary generates 9,87L of liquid waste of which 412L is pathological waste and 575L is infectious waste. Allied department generates 363.5L of infectious waste but no pathological waste. The laboratory generates 192.5L of which 162L is pathological waste and 30.5 is infectious waste. The pharmacy and clinics generates 45.5L and 19L of infectious waste respectively.

Further the results showed that RH generates the highest waste (8,276L) from the health facility followed by MH (2,058L) and the least is S.D.A (58.5L) hospital. This result indicates that the amount of liquid waste generated is significantly linked to the size of the health facility and the findings is explained by the size of the hospitals where RH, MH and S.D.A hospitals have 413, 63 and 38 bed capacities respectively and also by average attendance rate per day (RH=550 patients/day, MH=135 patients/day, 76 patients/day).

In terms of pathological waste generation, the results show in Table 4 that the 'Surgical theatre' generates the highest liquid waste of 350L/day (RH), 210L/day (MH) respectively. The 'Mortuary' generates 310L/day (RH), 102L/day respectively. The 'wards' and the 'laboratory' RH generate 106L/day and 105L/day respectively, MH generates 86L/day and 54L/day whilst S.D.A generates 7L/day and 3L/day respectively. For infectious liquid waste generation, the results show in Table 3 that the 'wards' generate 6475L/day, 1125L/day and 18L/day respectively for RH, MH and S.D.A. The 'Theatre' follows with waste generate of 700L/day, 360L/day and 4L/day respectively. The 'Mortuary' generates 450L/day, 125L/day for RH and MH respectively. The 'Allied departments' generates 306L/day and 3.5L/day in RH and S.D.A respectively. The 'Pharmacy' generates 25L/day, 15L/day and 5.2L/day respectively in RH, MH and S.D.A. The 'laboratory' generates 15L/day, 12L/day and 3.5L/day respectively for RH, MH and S.D.A respectively.

Table 2: Liquid Waste generation rate for sampled hospital per bed/day

Hospital	**Pathological (L/day)**	**Infectious (L)/day**	**Total (L)/ day**	**No. of bed/ day**	**Gen rate (L/bed/ day)**	**Gen rate *Pathological waste*) (L/bed/day)**	**Gen rate *Infestious waste*) (L/day)**
RH	871	7405	8276	413	20	2	18
MH	452	1606	2058	63	33	7	26
S.D.A	20	38.5	58.5	38	1.5	0.5	1.0

Source: Field data computation (2015)

Table 3: Liquid Waste generation rate for sampled hospital per patients/day

Hospital	**Pathological (L/ day)**	**Infectious (L)/day**	**Total (L)/ day**	**Av. patients / day**	**Gen rate (L/ patient / day)**	**Gen rate *Pathological waste*) (L/patient/ day)**	**Gen rate *Infestious waste*) (L/patient /day)**
RH	871	7405	8276	550	15	1.5	13.5
MHl	452	1606	2058	135	15	3.4	11.9
S.D.A	20	38.5	58.5	76	0.8	0.3	0.5

Table 4: Liquid Waste generation rate in the Regional Hospital

Department	Pathological waste(L)/day			Infectious Waste(L)/day			Total
	RH	MH	S.D.A	RH	MH	S.D.A	
Pharmacy	-	-	-	25	15	5.5	**40.5**
Laboratory	105	54	3	15	12	3.5	**192.5**
Wards	106	86	7	6475	1125	18	**7817**
Clinics	-	-	-	10	9	-	**19**
Theatre	350	210	-	700	360	-	**1620**
Mortuary	310	102	-	450	125	-	**987**
Allied Dept.	-	-	-	360	-	3.5	**363.5**
Total	**871**	**452**	**10**	**7405**	**1606**	**38.5**	

PROCESS OF CLINICAL LIQUID WASTE MANAGEMENT

Liquid waste segregation, collection and handling

The results from the interview and observation revealed that the three sampled hospitals use similar system of sewerage which is termed as the separate system. The study found that both infectious and pathological liquid waste from the different department are transported through a pipe into a temporary holding areas called the 'athwart pit' whilst grey water from the kitchen and laundry are channeled directly into the storm drain. The purpose of providing temporary storage (i.e. anthwart pit) in managing clinical liquid waste is to create a place for initial retention and settlement of solid particles for removal before entering the sedimentation tank further treatment and disposal.

Temporary storage area and internal transportation

The liquid waste is internally transported through pipes buried in the ground from the hospitals departments by gravity into the temporary storage area called the anthwart pit. The anthwart pit size varies across the three hospitals. The grey water from the kitchen and laundry are transported through open drain directly into the storm drains. The study results revealed the mode of liquid waste collection is similar among the two of the hospitals namely MH and S.D.A. At the temporary storage area, The MH and S.D.A hospitals liquid waste collection from the 'anthwart pit' are dislodged by private company called Zoom lion Ghana Limited whilst at RH, the liquid waste from the anthwart pit is pump into a chamber where further screening is done to any other solid material before finally channeled into the sedimentation tank for treatment. RH has two sedimentation tanks whilst MH and S.D.A has one each of the sedimentation pool. At RH, the clinical waste from the anthwart pit is pumped into a chamber where further screening is done to remove floating and any other settleable solid material found before the clinical liquid is pump into the sedimentation tank for treatment.

Treatment and disposal of liquid waste

The results from the survey and observation revealed two different clinical liquid waste treatment facilities used by healthcare facilities within the Sunyani Municipality. There are on-site conventional wastewater treatment facility and an off-site natural land treatment facility. Figure 4 shows the schematic overview of a conventional wastewater treatment system at RH.

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The Regional Hospital (RH) uses on-site conventional wastewater treatment facility located in the hospital premises (Figure 5). The reason for RH using conventional sewerage treatment plant could be attributed to its size. RH is a referral facility and serves a teaching and research facility for entire the Brong Ahafo region. Figure 5 shows the RH with the various wards and detailed units of the on-site conventional treatment plant.

In the RH, the sedimentation tanks are in three sections with varying sizes. This indicates that the treatment process is in three stages. The first section known as the primary settling tank (Figure 5) is used for grit removal and particulate-matter removal. The second stage of treatment in the sedimentation tank is purposely meant for biological-floc removal in the activated sludge settling tank and the removal of sludge. Also, the purpose of the second section of the sedimentation tank is where mixing of the liquid waste is done a period within the day for the removal of odour from the liquid waste. The liquid waste is then discharged into the last section of the sedimentation tank for chemical-floc removal. At this stage chlorine (Figure 5) is pumped through a piping system into the tank to disinfect the liquid for any bacteria present and left over for a day and more before discharged into a tunnel joined to a stream.

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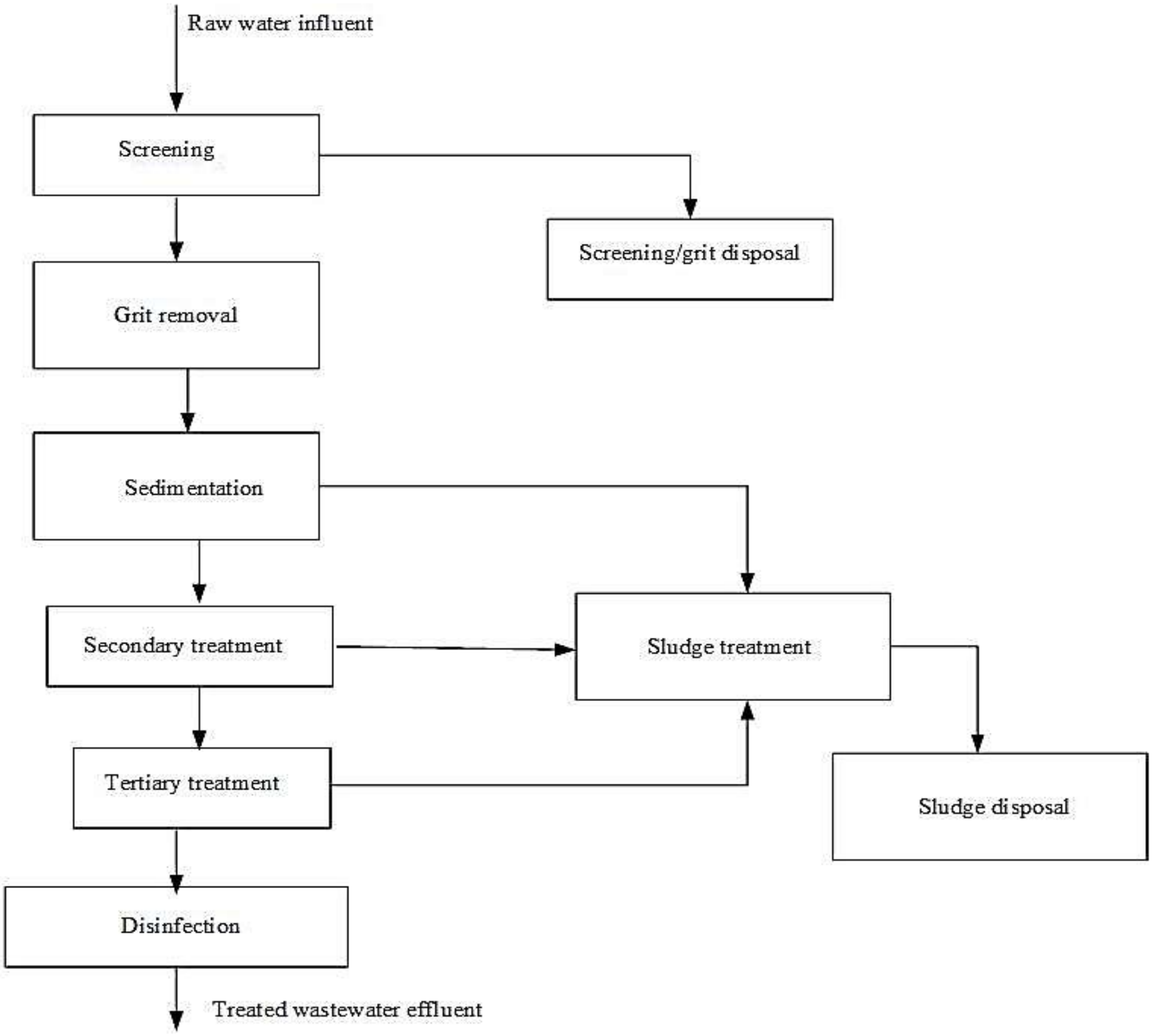

Figure 4: Schematic overview of a conventional wastewater treatment system in RH

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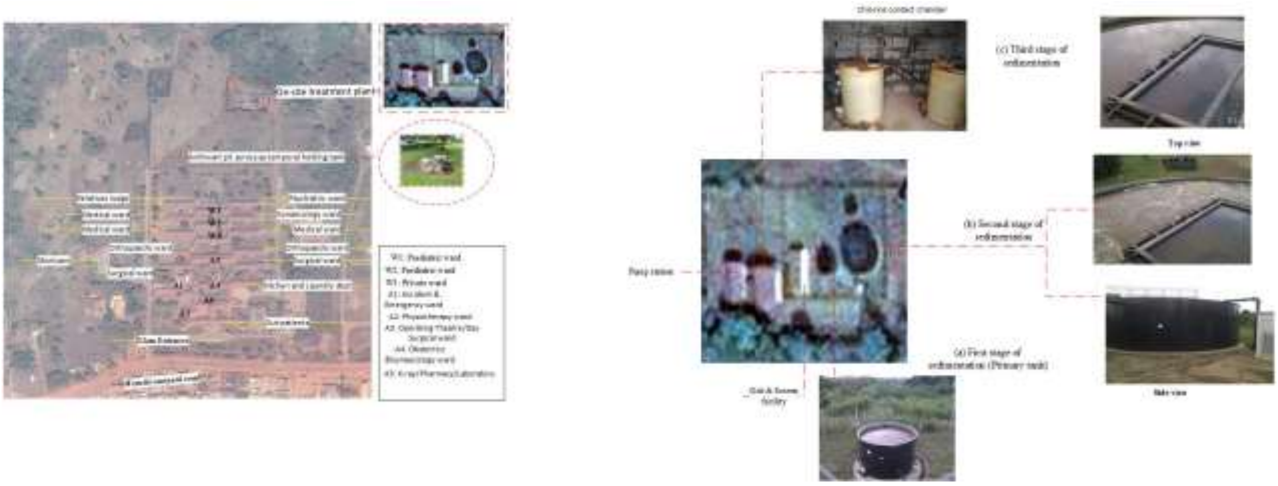

Figure 5: Regional Hospital showing conventional treatment plant

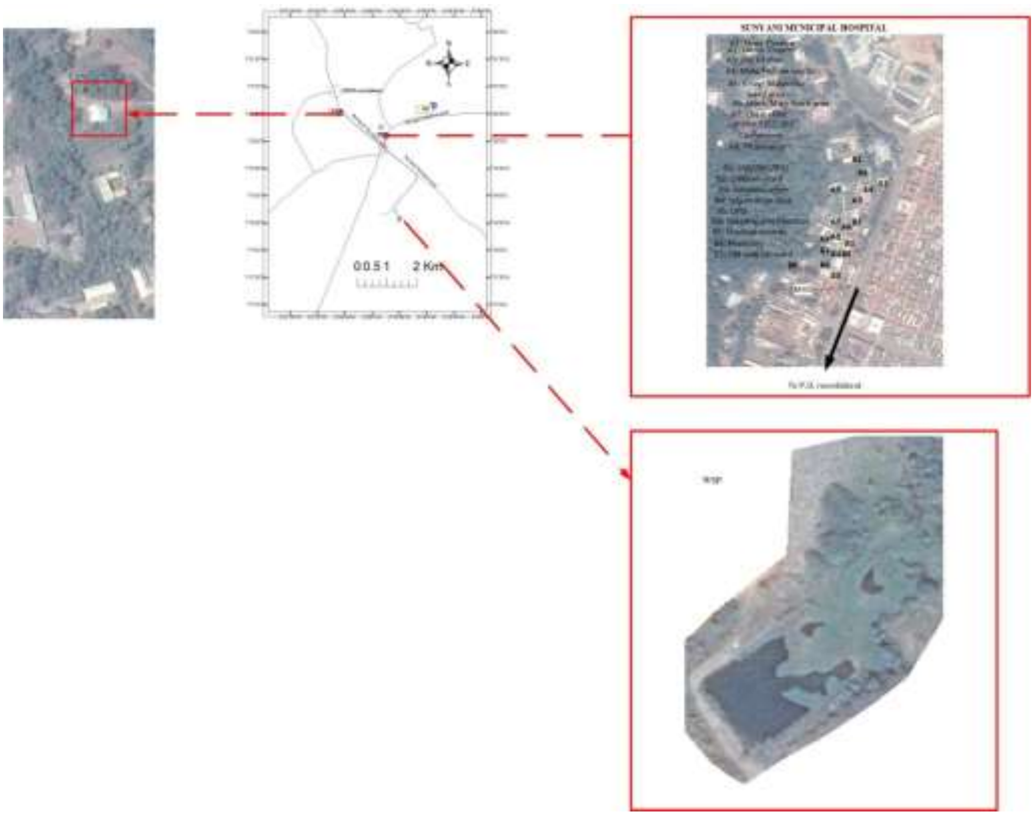

Figure 6: M.H. and S.D.A. showing the Waste Stabilization ponds location

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The Municipal Hospital (MH) and S.D.A share and uses the same off-site sewerage treatment facility (geographically located on (2°19'30.44''W and 7°18'32.77''N) for treating clinical liquid waste. Figure 6 shows the stabilization pond that serves as the natural land treatment plant. The WSP is physically located behind Getfund Hostel of the Sunyani Polytechnic. They have contracted private companies such as Zoom Lion Company Ghana Limited and Alhaji Awudu Issaka waste management to dislodge the liquid waste to be disposed off into sedimentation pool owned by the Municipal Assembly for treatment. This result means clinical liquid waste from MH and the S.D.A Hospital do not receive pre-treatment of their liquid waste before transportation from the hospitals to the natural land treatment plant. The natural land treatment facility is situated at distance of 5.2 km away from the S.D.A hospital and 5.6 km from the MH.

Microbial Analysis of treated liquid waste

The microbial analysis results of sample taken from the RH sewage treatment plant show that Total Coliform bacteria and Feacal coliform bacteria recorded 18 and 16 respectively. Both results means that total and Feacal coliform in comparison to both the WHO and GWCL standards do not meet the standards which are 0 and 0 respectively (Table 4). This finding indicates that there are still bacteria present in the treated effluent from the RH, and is far above both the WHO and GWCL standards. The results of presence of E-coli bacteria in the treated effluent from the RH suggest presence of the bacteria from the samples as E-coli recorded 9 and in comparison with WHO and GWCL, do not meet their standards. Total coliform and Feacal coliform results indicate environmental pollution. The results confirmed presence of E. coli bacteria which indicates presence of infectious microorganisms in the water. Results obtained from the laboratory shows that large amount of heterotrophic bacteria (i.e. 1292) presence in the sample collected from the RH for testing. In comparison with WHO standard of 0 and GWCL of 500, the results clearly far exceed the acceptable limits. The results from the sample taken from the sedimentation pool shared by MH and S.D.A showed 84 for Total coliform bacteria and 46 for Feacal coliform exceeding the recommended WHO and GWCL standards. The finding is an indication of bacteria presence in the sample carried from the sedimentation pool. The results obtained from the samples carried indicates presence of large of amount of E- Coli bacteria in the sample by recording 38 which is above WHO and GWCL standards of 0 and 0 respectively for MH and S.D.A. Results obtained from testing heterotrophic bacteria showed large amount of heterotrophic bacteria presence (i.e. 4525) in the sample collected which in comparison to WHO and GWCL higher than the standards of 0 (WHO) and GWCL (500).

Hospital	**Total coliform**	**Feacal coliform**	**E-coli**	**Heterotrophic Bactria**
RH	18	16	9	1292
MHl	84	46	38	4525
S.D.A	84	46	38	4525
WHO	0	0	0	0
GWC	0	0	0	500

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DISCUSSION

The study observed that the two most common type of liquid waste generated in the health care facilities in the Sunyani Municipality are Pathological waste and Infectious waste. The clinical liquid wastes are generated by the health workers such as doctors, nurses and veterinary officers and on the other hand from the patients which is the out- patients and the in-patients as well as the visitors. The findings from this study indicate that the quantities of liquid waste generated at the three surveyed hospitals depend on type and size of the hospital, number of patients and type of services rendered as they constitute the factors that explains significantly liquid waste generation rate. This findings is in line with clinical waste generate rate in Chen et al., (2009) and Abd El-Salam (2010). RH generates the highest clinical liquid waste than MH and S.D.A hospitals because RH serves as a teaching facility as well as referral hospital which receive a lot of patients from other healthcare facilities in Sunyani Municipality and surrounding districts. The waste generated by municipal hospitals and S.D.A. are explained by their size in terms of number of bed and number of patients visits. The daily clinical liquid waste generation rates for the three hospitals were consistent with past studies for developing countries and largely explained by the explained by their size in terms of number of bed and number of patients' visits as well as the type of health services provided by the facility.

The results findings found that the Pharmacy does not generate pathological waste because it's a place for storing and processing patients' drugs prescription. The low liquid waste generation rate in the clinics is attributed to the fact that the clinics in both the Regional (RH) and Municipal hospitals (MH) do not admit patients but rather diagnose their sickness/illness, treats and discharges the patients on the same day. Also, the clinics operate 8 hours daily and five days a week unlike the main hospitals where patients are admitted and operate on a 24 hour basis. The Allied department is combination of the kitchen, workshop and the laundry, and basically no pathological waste comes from this department because of the nature of the duties that's washing for the laundry, cooking for the Kitchen and storing of equipment, tools and materials meant for the Workshop. The S.D.A. hospital does not have a clinic and mortuary and thus explains why they don't generate both pathological and infectious disease. The findings from the Laboratory indicates it generates both low pathological and infectious waste as the laboratory is the place where experiments and series of test done but most of the surgeries do not go on in the laboratory but samples of blood are taken for the test. The size of the facility in terms of patients' visits as well as the type of test to be conducted determines the waste generation rate.

The findings suggest the wards generate the highest proportion of infectious waste in all three sampled hospitals. The ward is the place where in-patients are admitted to receive medical care. It is the ward size in terms of bed occupancy that tends to explain the size of a health facility in this municipality. On the hand, the operating theater where surgical operation in the health care facility takes place on in-patients that are to be operated on generates the highest pathological waste. Pathological waste from as tissues, organs, body parts, human fetuses and animal carcasses, blood and body fluids are generated in this department. The mortuary is where the dead bodies are been kept and preserved until the time and day of burier and is the second palace where both pathological and infectious waste are generated from as a results of autopsy made at this department and during autopsy many tissues are been removed from the body.

One of the specific aims of this study was to identify the current clinical liquid waste management strategies used by health facilities in Sunyani Municipality, Ghana. The result of

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waste segregation and collection practice in the selected hospitals were within Ghana Health Service and WHO standards as well as recommended best practice worldwide. The RH has a conventional treatment plant with varying size and have liquid waste from the different department which are collected, segregated and handled from source. The pathological and infectious waste passes through a different pipe line into the treatment facility. The liquid waste segregation and collection methods practice in all three selected hospitals could be explained by a strong internal administrative policy and Ghana Health Service guidelines for establishing a health facility. However, some challenges remain significantly in the way both pathological and infectious wastes are stabilized in the sampled health facilities. The short-comings were associated with the level of treatment and disposal of liquid waste. The poor treatment of the liquid waste from RH may be attributed to factors such as; serious power outage experienced 2015 in the country or malfunctioning of the some component the treatment plant. Further, conventional treatment plants has a major drawback which is that relatively large amount of pathogens remain even after the treatment process is completed. This finding is consistent with Abdul-Raoul et al., (2012). The MH and S.D.A liquid waste do not receive any pre-treatment before transported to the waste stabilization pond. For MH and S.D.A. hospitals results showed a very high contamination From the study observation the waste stabilization pond is open to air or expose to the atmosphere for the bacteria in the liquid waste to die due to the temperature acting on it. Base on the results of the sample collected from sampled hospitals, it is confirmed that there is the presence of large amount of total coliform bacteria, feacal coliform bacteria, and heterotrophic bacteria that far exceed the country's and international standards. This contrary to studies by Parhad & Rao (1976) and Shelef et al., (1977) which found waste stabilization ponds to be generally more effective than conventional sewage treatment systems in percent reduction of coliforms counts and *Salmonella*. Further, the result is consistent with a study by Kayombo et al. (1999) in Morocco where due to lack of proper operation and maintenance, many of these systems have performed below the required standards. The findings suggest an environment problem due to the contamination of treated effluent from the sampled hospitals which are used for agricultural irrigational purposes, drinking and cooking.

Implication for research

Clinical Liquid Waste Management (CLWM) still is important issue for maintaining public health. As such applying suitable treatment methods will not only reduce incidence of communicable disease but decrease pressure on our health facilities as well as save money. One of the key principles of any waste management process is by integrating liquid waste management practices in all processes from the point of collecting the liquid wastes through appropriate treatment process to disposal and discharge into water bodies. This is not the case found in the three surveyed hospitals as both hospital administrators and healthcare professionals ignore the monitoring of liquid waste treatment process which is fundamental. This challenge brings the integrity of hospital policy of protecting public health into serious question. One managerial implication of this study is that the treated wastewater effluents are discharged into a nearby stream which is mostly used for irrigational purposes and most instances stray animals drink from it. Villages downstream along the stream (not connected to the GWCL service pipeline) depend on the stream for cooking and drinking water. This is very dangerous to the inhabitants around the sedimentation pool because flies can go and sit on it and then sit on their foods and drinking waters, and this can also permeate into the ground water. Potential health effects include gastroenteric infections and diseases due to presence of feacal coliform and E-coli.

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CONCLUSIONS

CLWM standards and best practices were appropriately applied for clinical liquid waste collection, segregation, handling and transportation in all three hospitals. The Regional Hospital (RH) has an on-site sewerage management facilities located in the hospital premises whilst the Municipal Hospital and S.D.A uses an off-site waste stabilization pond treatment facility where liquid waste such as infectious and pathological, expired pharmaceuticals and other wastes are sent for treatment. By legislation in Ghana, liquid waste must be managed and disposed of in accordance with the EPA Waste Regulation, and / or other relevant international regulatory requirements. Thus illegally discharging liquid waste that is assessed as hazardous waste under the EPA Waste Regulation into water bodies such as streams or rivers deemed unlawful. This means that generally, all hazardous liquid waste from healthcare facilities in the country need to be treated to required discharge standards prior to disposal. However, the study identified shortcomings associated with the current clinical waste treatment process applied in the three selected hospitals in the Sunyani Municipal Assembly of Ghana. The shortcomings basically are found in lack of monitoring the treatment process in both facilities and lack of compliance in standards outlined in WHO and Ghana Health Service Sanitation Act by hospital administrators and waste collectors. This could partly be attributed to insufficient education/awareness campaigns of health implication associated with exposure to clinical liquid waste. Clinical liquid waste management standards and best practices in treatment were not appropriately applied and checked after treatment before disposal into water bodies. This was confirmed in the presence of large amount of total coliform bacteria, feacal coliform bacteria, E-coli and heterotrophic bacteria that suggest a serious environment threat to both the public and the environment.

These study findings suggests that a holistic approach needs to be adopted to successfully manage clinical liquid waste in developing countries. Another managerial implication of this research is that due to the potential health hazards of clinical liquid waste to the general public and the environment, interim remedial measure has to be adopted and implemented to avert an epidemic. The medium to long term managerial solution is that political and financial power needs to be focused on training and awareness programs as well as monitoring and evaluation to reverse the negative trend of managing clinical liquid waste in Ghana healthcare facilities.

Future research

The sample collection for microbial analysis was relatively small and analysis was limited to only one season and in the case of RH, period of power outage could explain the results obtained in Sunyani Municipality. Thus the results could not be used to generalize the entire healthcare facilities in Ghana. The study recommends further studies to increase sample size and coverage to include other public and private hospitals where infrastructural facilities and certain differ. Also, a further research should be conducted to include period of reliable power supply to ascertain clinical liquid waste treatments in the municipality. Nonetheless, further research is required to determine whether reasons such as season of the year and effects of land encroachment in and around the WSP can explain the inefficiency in treatment.

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