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Characterization and Management of Domestic Wastewater in Two Suburbs of Kumasi, Ghana

[1]Esi Awuah, [2]Richard Amankwaah-Kuffour, [3]Samuel Fosu Gyasi, [4]Henk J. Lubberding and [4]Huub J. Gijzen

[1]Office of the Vice Chancellor, University of Energy and Natural Resources, Sunyani, Ghana
[2]Department of Environmental Sanitation and Health Education, University of Education, Winneba-Mampong Campus, Ghana
[3]Department of Energy and Environmental Engineering, University of Energy and Natural Resources-Sunyani, Ghana
[4]UNSECO-IHE Delft, Netherlands

Corresponding Author: Samuel Fosu Gyasi, Department of Energy and Environmental Engineering, University of Energy and Natural Resources-Sunyani, Ghana Tel: +233-268189473

ABSTRACT

An attempt has been made in this study to characterize the wastewater generated in two communities (i.e. Kwame Nkrumah University of Science and Technology {KNUST} campus and Asafo) within the Kumasi metropolis in the middle belt of Ghana. This study was limited to the quality as well as the quantity of the waste generated to determine the extent of this poor sanitation impacts on river quality. Flow weighed composite samples collected from 6 am to 6 pm each sampling day were prepared and parameters of interest were analyzed at least 4 times per sample collected. During the study, 24 hourly flow rates measurements were taken from the discharge points. About 720 m^3 day^{-1} of wastewater was estimated at KNUST sewage treatment works. Results of the study showed that, the wastewater generated at Asafo treatment plant was also 870 m^3 day^{-1} with a COD of 399, 667 and 2540 mg L^{-1} obtained for the KNUST grey water, KNUST sewage and Asafo sewage, respectively. BOD recorded was also 198, 310 and 1007 mg L^{-1}, respectively in the same order. With respect to the microbial analysis, the study showed that, faecal and total coliforms per 100 mL were 1.5×10^6 and 2.7×10^8 CFU, respectively for the KNUST grey water, that of KNUST sewage was 3.8×10^7, 5.4×10^9 and the Asafo sewage was 5.9×10^8, 4.2×10^{10}. In addition, Ascaris eggs, tapeworms and Fasciola were found in all the wastewaters.

Key words: Wastewater, BOD, COD, Asafo, KNUST

INTRODUCTION

An estimated 2.6 billion people lack access to improved sanitation-defined as facilities that hygienically separate human excreta from human contact (WHO, 2010). Many countries in the developing world including Ghana face the enormous challenge with an effective manner of handling large quantities of wastewater generated in their numerous urban centres due to rapid population growth (Nikiema *et al*., 2013). Attempts to address this problems have proved futile due to a plethora of reasons including lack of adequate knowledge on the nature of the wastewater, financial constrains as well as the requisite skilled labour (Graham and Polizzotto, 2013). To properly manage wastewater, the characteristics and the situational analysis must be stratified and clearly defined. This would create adequate awareness on the need to treat wastewater prior to discharge into the environment, provided the design parameters and the necessary infrastructure for operation are maintenance for sustainability (Rosa and Clasen, 2010).

It has been reported that wastewater treatment plants constructed in Ghana in the 60s and even in the early 90s have all broken down (Salifu, 1997). In Kumasi, the second capital of Ghana, West Africa, the wastewater treatment plants at the Kwame Nkrumah University of Science and Technology is no exception (Monney *et al*., 2013). The Asafo pilot plant, which was constructed in 1994, broke down in 1997 and was repaired 4 years later (November of 2001). With the breakdown of these systems, wastewater generated from domestic habitation are discharged directly into the environment untreated. This could have a possible impact on the incidence of diseases reported annually in the metropolis. Research has shown that, water related diseases form about 55% of all the diseases reported in the Kumasi metropolis which include malaria, diarrhoea and intestinal diseases (Owusu-Sekyere *et al*., 2013). However, data available on the wastewater characteristics within the Kumasi Metropoli as a whole is very scanty warranting immediate research in this area.

Currently, the Government of Ghana has started rehabilitation works on existing wastewater treatment plants and the construction of new ones are, been considered to protect human health and the environment (Anonymous, 2007). In the absence of these rehabilitation processes, it ought to be noted that the old ones are still not functioning properly but the reason for the failures has not been properly addressed. It is in the light of the above issues that this research was carried out to determine the true characteristic of the wastewater generated, determine the environmental effects on surface water quality.

RESEARCH APPROACH AND METHODOLOGY

Study site description: Two major sites in the metropolis were selected based on the presence of waste treatment plant within their suburb. These were the Kwame Nkrumah University of Science and Technology (KNUST) with a student population of 10,000 and supporting staff and family population of 1,000 with about 45% of the student population officially living on campus at the time. Unofficially, the population was about 70% with most using the facilities in the 8 halls of residence on the campus. All black water generated in these halls of residence went to a treatment plant for treatment. With the grey water, an unknown amount also went into the sewer line. The rests were discharged into gutters and then subsequently into a nearby River (Wiwi), which ran through the campus. Only one hall (Unity) of residence's grey water channel could be assessed.

Asafo is a suburb of Kumasi with a resident population of 20,000 at the time of the study (2000 census). It covers an area of 2 km^2. This is a residential area with mechanics, some bakeries, a few restaurants and drinking bars. Any other industrial activity in this suburb was home based. Most of the people here were previously using bucket latrines and septic tanks. In 1990, as part of a World Bank/Ministry of Local Government Environmental Sanitation project, a proposal was made to centralize the treatment of all excreta generated on this site. The bucket latrines were converted into water closets and individual houses were encouraged to connect to the sewerage network to the Asafo waste stabilization ponds without any fee. The ponds were put in operation in 1994. Out of the 320 houses, about 255 homes had been connected. Initially there were black water flow problems with the manholes frequently getting blocked. This was corrected by adding the grey water from the houses as part of the wastewater, which goes through the sewers.

The city of Kumasi is endowed with natural drains of rivers, streams and streamlets. These drains receive all the grey water and untreated sewage, which goes through drainage channels in the city.

Flow rate measurements: The flow rate of the sewage generated from the KNUST and Asafo were measured with a calibrated wooden stick at the outfall of a by-pass asbestos pipe 15 cm in diameter for KNUST and 30 cm for Asafo. The discharge was then read from tables of hydraulic properties for partially filled circular sewers and open channel flows (Te Chow, 1973). The quantity of the grey water generated from Unity Hall (a residence for students) was measured with a V-notch fixed in an open channel about 20 m behind the hall of residence.

Flow rates were determined hourly over a 24 h period, 4 times during the study period. A graph of the flow rate (discharge per second (L/s) was plotted against time in hours (h).

Sampling: Composite samples from the wastewater discharge points were taken at 6 different times of the day at 2 h intervals based on the flow rate rates from 6 am to 6 pm. The samples collected were kept in an ice chest packed with ice cubes and sent to the laboratory for analysis. Temperature, pH and dissolved oxygen were measured *in situ*.

Laboratory analysis: Three composite samples were prepared for the grey water from the hall of residence, 2 for the sewage from the KNUST wastewater treatment plant and 3 for Asafo community wastewater. Parameters measured were temperature, pH, DO, SS, BOD, COD, NH_3-N, NO_3-N, NO_2-N, PO_4-P, total and faecal coliforms. Others were helminth eggs, which included *Ascaris* sp., tapeworms, *Fasciola* sp., *Trichuris* sp. and *Schistosoma* sp. The rest were metals; Hg, Pb, Zn, Cu, Al, Mn, Mg, Cd, Ca and Fe.

Temperature, pH and DO were measured with portable WTB electronic probes. BOD, COD, SS, NH_3-N, faecal and total coliforms (measured by MPN with MacConkey at 44.5 and 37°C, respectively) were determined by using procedures outlined in Greenberg *et al.* (1992) [Standard Methods for the examination of water and wastewater]. Colorimetric chemical analytical methods were used for the laboratory analyses of NO_3-N, NO_2-N, PO_4-P (Thomas and Chamberlin, 1974).

Helminth eggs assay were determined according to WHO (1989) recommended procedures. All metals were measured with Perkin Elmer Model M 1100B atomic absorption spectrophotometer.

Wastewater impact on water bodies: To measure the impacts of the city's activities on water bodies, 15 sampling points along 8 rivers were studied by analyzing grab samples for the following parameters: COD, pH, DO, temperature, *Escherichia coli* and *Salmonella*, NO_3-N, NO_2-N, PO_4-P. Bacteriological determinations were done using Chromocult agar (George *et al.*, 2001). This media was used because it was found to be better than Lauryl sulphate and MacConkey broths. Grab samples from the Asafo stabilization ponds effluent was also characterized to evaluate performance.

Management studies: To understand why the treatment plants were not working, site investigations were made. The officials responsible for the management of the treatment plants were also interviewed. In addition to this, a questionnaire was administered to determine the educational background of workers, job training experiences, salaries of workers, incentives for workers, health hazards associated with wastewater management, safety measures put in place and job satisfaction. The survey was conducted among the attendants of sewage/ sludge/nightsoil treatment plants in Kumasi. The sites chosen were KNUST treatment plant, Asafo wastewater stabilization ponds and Kumasi Metropolitan Assembly (KMA) New Faecal Sludge/Nightsoil treatment ponds at Kaasi. These sites were chosen because they were the only sites that had workers on site to manage it.

RESULTS AND DISCUSSION

Flow rates analysis of the Asafo pilot plant study showed a rate of 2,250 m^3 day^{-1} with a current sludge accumulation of about 50% of pond space in the anaerobic pond. The expected wastewater contribution from other communities is provided in Table 1.

The study also showed that the lowest flow rates occurred at night time between 1 am and 5 am for all the wastewater flow with morning peaks depicting a higher level than night time (Fig. 1). The average flow rate of grey water at KNUST was estimated at 0.07 L sec^{-1}. This means that each of the 1,300 occupants generated approximately 4.1 L of grey per day. This was found to be very small in comparison with the theoretical per capita per day of 90 L in hot climates (Mara, 1984) with the city of Kumasi's average water consumption of 60 L/capita/day. Using the city's average for comparison, about 93% of the grey water could not be accounted for. This could be part of the sewage going into the KNUST treatment plant.

The KNUST sewage had an average flow of 4.3 L per second, equivalent to about 370 m^3 day^{-1}. Unfortunately, the trickling filter of the KNUST treatment plant had broken down for several years, so the wastewater also trickled into an adjacent wetland which was used by farmers for taro tubers cultivation which then finally flows into the Wiwi River. The Wiwi River is intensively used for vegetables (carrots, lettuce, cabbage and spring onions) cultivation especially in the dry season.

Table 1: Asafo pilot plant design flows and expected addition estimates

Site	Flows m^3 day^{-1}
Design flow	2,250
Current capacity of treatment plant with 50% sludge accumulation	1,124
Current Asafo connections	873
Public toilets connection	*
With full Asafo community connection	1453
Komfo Anokye teaching hospital	1441
Bantama army barracks	300
City hotel current (2002)	30
City hotel full operation (near future)	150

*Refers value not known at the time of going to the press

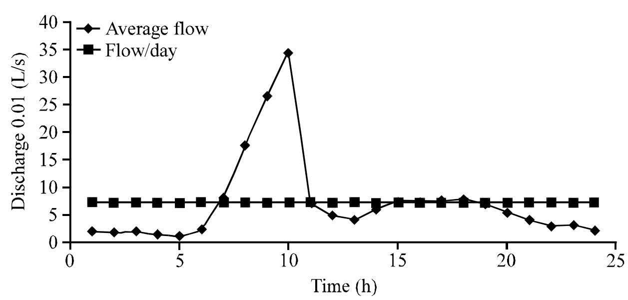

Fig. 1: Average flow rate of KNUST grey water

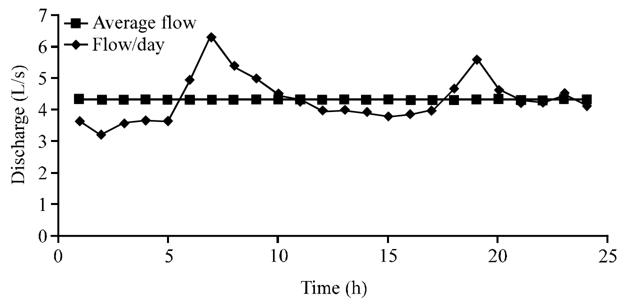

Fig. 2: Average flow of KNUST wastewater

The quantity of wastewater determined for KNUST is just from a section of the university campus that is connected to the sewer line. Some of the wastewater is treated in septic tanks and these are periodically removed as septage and discharged via., the same grit chamber into the environment untreated. About 35 m^3 of septage is discharged into the grit chamber of the treatment plant daily.

Septage was described to be 10 times more concentrated as sewage (Metcalf and Eddy, 1991). This meant that, a sewage equivalent of 350 m^3 per day was generated beside the central sewer system. Therefore, a total of about 720 m^3 of sewage was generated from the KNUST campus of about 15,000 people. An average of about 48 L of sewage per head per day was produced for the treatment plant in a day. The obtained values showed that, not all the domestic water ended up in the treatment plant. Using the city's average consumption of 60 L per capita per day, about 20% is discharged as grey water. The result also suggested that, a high percentage of the grey water from the halls of residence joined the sewer lines going into the treatment plant.

Asafo sewage had the highest flow rate of 10.1 L per second (Fig. 2) with an average flow rate of about 872.6 m^3 per day. The Asafo pilot plant had a series of 4 ponds, which are 1 anaerobic pond followed by 1 facultative and 2 maturation ponds. The maximum capacity of the treatment plant was 2,250 m^3 day^{-1}. This meant that, the ponds could cater for the wastewater generated in the Asafo community. However, the anaerobic pond had 50% sludge accumulations. The city administration making plans to connect 3 other sites to the treatment plant. These are: Okomfo Anokye Teaching Hospital which had an estimated flow rate of 1441 m^3 day^{-1}, the Bantama Army Barracks, with an estimated flow rate of 200 m^3/day and the City Hotel currently with a very low flow rate of about 30 m^3 (Table 1).

The Asafo pilot plant cannot obviously handle the additional load the city officials are considering (Table 1). At the moment about 60% of the Asafo Community representing 12,000 people are connected to the sewer lines. The ponds could handle the wastewater flowing through it, if there are no additions to exceed the current capacity of 1124 m^3. At the time of going to the press.

CHARACTERIZATION OF WASTEWATER AT KNUST CAMPUS AND ASAFO

Characterization of wastewater with respect to KNUST and Asafo relative to temperature showed that there was a temperature range of 25-35°C (Table 2). This range has been identified as adequate for sewage treatment (Mayo and Noike, 1996). The suspended solids were least in grey water samples collected from KNUST grey with values of 212, 595 mg L^{-1} for KNUST sewage whiles the Asafo sewage recorded a value of 1151 mg L^{-1}. These are all within the range of values reported by Metcalf and Eddy (1991).

Table 2: Characteristics of wastewater generated at Asafo and KNUST (Means±Standard deviation)

Parameters	KNUST grey water	KNUST sewage	Asafo sewage
pH	7.5±0.2	8.2±0.1	8.0±0.0
Temperature (°C)	29.2±0.7	28.5±0.2	27.7±0.5
Dissolved oxygen (mg L^{-1})	2.7±0.8	0.62±0.10	1.03±0.48
Suspended solids (mg L^{-1})	212.0±20.8	595±220.9	1151.67±345.0
BOD (mg L^{-1})	198.3±33.3	310±75.5	1006.7±377.5
COD (mg L^{-1})	399.00±108.4	667±103.2	2540±640.9
Ammonia-nitrogen (mg L^{-1})	8.4±1.8	120.8±0.5	48±9.5
Nitrate-nitrogen (mg L^{-1})	0.7±0.06	1.7±0.6	18.7±9.0
Nitrite-nitrogen (mg L^{-1})	0.00±0.00	0.02±0.04	0.16±0.11
Phosphorus (mg L^{-1})	11.8±4.0	11.17±1.9	17.0±9.9
Fe	0.37±0.08	0.97±0.01	0.01±0.04
Hg	0.4±0.03	0.2±0.13	<0.01
Ca	2.81±0.01	2.44±0.01	2.72±0.02
Cd	0.01±0.001	<0.01	0.01±0.001
Pb	<0.01	<0.01	<0.01
Cu	<0.01	0.03±0.03	0.01±0.03
Zn	0.03±0.001	0.02±0.001	0.1±0.003
Al	<0.01	0.7±1.67	0.6±0.8
Mn	0.04±0.01	0.13±0.02	<0.01
Mg	6.1±0.4	4.79±0.1	4.5±0.1

The study also showed organic load measurement and this did not include xenobiotic compounds. The BOD for the grey water of KNUST was 198 mg L^{-1}, with KNUST wastewater recording a value of 310 mg L^{-1} whiles that of Asafo pilot wastewater was 1006 mg L^{-1}. The COD were respectively, 399, 667 and 2540 for the KNUST grey water, KNUST wastewater and Asafo wastewater as shown in Table 2. The three types of wastewater sources had a COD/BOD ratio of 2.15, 2.52 and 2.01 for Asafo, KNUST sewage and KNUST grey water, respectively. The ammonia nitrogen was highest in the KNUST sewage with a value of 120, 48 mg L^{-1} for Asafo and 1.4 mg L^{-1} in the KNUST grey water (Table 2). The values for Asafo and that of the grey water were consistent with earlier study (Canter and Knox, 1985; Metcalf and Eddy, 1991; Eriksson *et al*., 2002). The high ammonia at KNUST could be attributed to the grit channel, which was also used for discharging septage. Strauss *et al*. (1997) reported earlier that, high levels of ammonia in septage i.e., <1000 mg L^{-1} and a range of 30-70 mg L^{-1} were recorded for tropical sewage.

In analyzing the metals from these wastewater, the study showed that, phosphorous level was highest in the Asafo wastewater (Table 2). Personal observation has shown that the flushing of toilet with laundry wastewater during interruptions in municipal water supply system was a common practice in the Kumasi metropoli. This some argue could lead to a reduction in water bill payment for the household embarking on this technique. Of all the metals analysed during the study, it was only magnesium and calcium levels which were above 2 mg L^{-1} for all the three sources of wastewater generated. These levels were not different from values reported elsewhere. Eriksson *et al*. (2002) reported of a range of 1.8-30 mg L^{-1} for calcium and 1.1-7.3 mg L^{-1} for magnesium in grey water. The source of these high levels in Kumasi metropolis could originate from the metropolis's water supply (Metropolis's raw water calcium level is 6.7 mg L^{-1}

Table 3: Microbial characteristics of wastewater generated at Asafo and KNUST (Means±Standard deviation)

Parameters	KNUST grey water	KNUST sewage	Asafo sewage
Total coliforms100 mL	$2.7\times10^7\pm0.6\times10^8$	$5.4\times10^8\pm7.1\times10^9$	$4.2\times10^{14}\pm5.9\times10^{10}$
Faecal coliforms 100 mL	$1.5\times10^6\pm0.2\times10^6$	$3.8\times10^7\pm3.5\times10^7$	$5.9\times10^{11}\pm5.4\times10^8$
Helminth eggs No. (L)			
Ascaris sp.	2333±1527	7000±4044	62116±45000
Tapeworms	6500±658	14200±608	25306±6985
Faciola sp.	1300±282	2400±670	3473±225
Trichuris sp.	Nil	Nil	1236±108
Schistosoma sp.	Nil	Nil	373±71

(Awuah *et al*., 2001)) since all the three sites obtain water from the same source. The absence of heavy metals means that the wastewaters have high potential for reuse as high concentrations of heavy metals can be toxic.

Pathogen levels: Indicator organisms like faecal coliforms and total coliforms together with helminth eggs were measured in this study. The concentrations of total coliforms in KNUST grey water, KNUST wastewater and Asafo wastewater were 2.7×10^8, 5.4×10^9, 4.2×10^{10}/100 mL, respectively (Table 3). That of faecal coliforms was 1.5×10^6, 3.8×10^7 and 5.9×10^8/100 mL in the same order as shown in Table 3. The content of the Asafo sewage is rather high but considering the high organic loads, this value could be expected. Research has shown that, about 10^9 faecal coliform is discharged person per/day (Ramakrishna, 2007). At the current water usage of the communities studied, the values of faecal coliforms were expected, even though they appeared higher than what Metcalf and Eddy (1991) reported. Eriksson *et al*. (2002) also reported high values of faecal coliforms in grey water with values rising as high as 10^6/100 mL (Table 3).

The helminth eggs counted included *Ascaris* sp., Tapeworms, *Fasciola* sp., *Trichuris* sp. and *Schistosoma* sp. For all the helminth types considered, Asafo sewage recorded the highest number of eggs followed by KNUST sewage and KNUST grey water (Table 3). These values were at variance with the WHO (1989) standard of helminth eggs, which is 1 per litre for wastewater irrigation. The values recorded during the study were unusually large in comparison with figures given by Strauss *et al*. (1997) as 300-2,000 of helminth eggs per litre for tropical sewage.

The helminth values during the study could be compared to that of septage. The inhabitants of Asafo community appeared sicker than that of the university. Due to the constant movement of surface water in the environment, the pathogens from one community could be transmitted from one community to another within hours. The removal of pathogens is of particular importance since waterborne diseases are responsible for 80% of the sickness in the world (Webb, 2001).

The values of pathogens recorded were rather high. The values obtained calls for immediate treatment of all sewage generated in the city prior to disposal and reuse. These studies should be confirmed by carrying out investigations on the worm loads especially in school children and follow it up with a de-worming exercise.

The quality of the water bodies in the city has deteriorated in comparison to the River number 6 (Kwadaso), which is in a village with very little development. The water quality is worse, where urbanization is high (Table 4). *E. coli* and *Salmonella* were found in most of the water bodies examined, a clear indication of faecal contamination. Unfortunately, the polluted

Table 4: Mean pollution levels of water bodies

River	Sampling points	pH	PO_4-P	DO ($mg\ L^{-1}$)	COD ($mg\ L^{-1}$)	*E. coli* No./100 mL	*Salmonela* No./100 mL	NO_2	NO_3
Bamfowa	Breman	6.8	2.5	1.2	112	1×10^3	1.3×10^4	0.03	0.01
Akyem-ponmeni	Breman	7.3	2.0	1.6	288	5×10^3	+	0.05	0.00
Sisai	Duase	7.1	1.4	4.6	112	1.4×10^4	1.2×10^4	0.00	0.02
Aboabo	Airport roundabout	7.3	2.4	0.8	160	2.3×10^5	3×10^5	0.19	0.00
Nsuben	Zoo	6.9	2.5	1.1	240	2.4×10^5	+	0.01	0.00
Kwadaso (standard for comparison)	Kwadaso village	4.7	0.0	2.6	32	Nil	Nil	0.04	0.11
Aboabo	Anloga junction.	7.3	2.5	0.8	400	1.1×10^7	5×10^4	0.18	0.02
Sisai	Accra road	6.8	2.5	3.1	128	1.0×10^4	Nil	0.03	0.00
Wiwi	Accra road	6.5	2.4	1.9	16	2×10^3	+	0.04	0.03
Kentikrono	Kentikrono	5.9	2.4	1.8.	16	3×10^3	1×10^4	0.05	0.00
Wiwi	Hall 6	6.6	1.6	1.4	80	Nil	Nil	0.00	0.05
Nsuben	Georgia hotel	7.5	2.5	0.4	464	8.40×10^5	$1\ 5\times10^5$	0.01	0.01
Kwadaso	Opoku ware secondary school	7.0	1.6	1.9	160	4×10^3	1.3×10^4	0.01	0.12
Wiwi	Inside campus	6.7	2.5	2.1	64	1.4×10^4	Nil	0.01	0.00
Confluence of Aboabo, Sisai and Wiwi	Atonsu	6.9	2.6	0.3	400	1.6×10^5	+	0.18	0.00

+Present but uncountable

water is also a source of water for vegetables irrigation including lettuce, which is eaten raw. The quality is well below the WHO guideline value of 1000/100 mL of faecal coliforms for irrigated crops and <100/100 mL coliforms for crops of restricted irrigation (WHO, 1989). The results show the negative impacts of urbanization without domestic wastewater treatment. Of all the sampling points tested the sampling site 12 (Nsuben River near Georgia Hotel) was the most polluted, followed by Aboabo at Anloga Junction. This is expected because Nsuben River passes through the Central Market in the Metropolis (The second largest open market in West Africa) where urinals have been erected directly on the drains. Food residues/refuse are also dumped into the Nsuben from chop bars (local restaurants) and traders. The quality of this River appears to be worse than the KNUST sewage in terms of organic load. The River has become a sewer line.

Site investigations showed that the river bodies have been grossly polluted as a result of:

- Direct dumping of nightsoil, sewage and septage in the Nsuben, Sisai and Aboabo
- Direct dumping of refuse into drains in the densely populated areas especially Aboabo, Anloga, Asawase, Tafo, Bantama, Ayigya and Nsuben Valley
- Siting of refuse dumps along riverbanks such as Aboabo, Anloga, Sisanso, Tafo and Dichemso
- Use of fertilizers and pesticides for vegetable production in river basins
- Unauthorized construction of residential and commercial buildings in river basins at Sisanso, Aboabo, Tafo, Buokrom
- Deforestation along river basins
- Discharge of industrial effluent into Sisai, Atonsu, Kentikrono and Akyeampomeni of Magazine and Kwadaso
- Dumping of wastewater from chop bars at Kejetia and grey water from houses into the Nsuben drain

MANAGEMENT OF WASTEWATER IN THE KUMASI METROPOLITAN AREA

Laws governing sanitation had been lacking until recently. These are:

- The legislative instrument (LI 1614) Act 480 of the National Development Planning System (1994) that requires municipalities and local assemblies to take over wastewater management
- The Sanitation policies of 1998, which details out the role of all stakeholders in waste management. The adoption of the policies and its implementation has been very slow. It is not surprising therefore, that management of wastewater has not been given the recognition that it deserves

A survey conducted around the treatment plants showed that the plants have been neglected and are being maintained by unskilled labour. A long hierarchy of officials, at least six officers comes between the attendants and directors for the management the treatment plants. Top management staff rarely visit the sites. Finance is a major constraint as none of the system users pay anything for operation and maintenance costs. There is no budget allocation for maintenance. Problems are solved on *ad hoc* basis. These plants were constructed with external funding with no user participation. Such projects are bound to fail. Self-financing projects by communities have always proved more successful than the former (Gillard and Hanke, 1982). However, the ability and willingness to pay need to be addressed. Observation and interaction with a community at Ahensan, another suburb, which is facing serious sewage disposal problems as a result of frequent blockage, is willing to pay for the operation and maintenance of wastewater stabilization ponds provided for them. The question is how to address the management issue, in particular, how to collect the revenue and how to see to the operation and maintenance.

The questionnaire administered showed that the workers are underpaid. About 10% of the workers receive an annual salary of less than UD$140, which is even less than the minimum wage of Ghana, which is about 1 US$ per day. Eighty percent and ten percent who receive a salary range of 140-280 US$ and 280-420US$ respectively, are still small (Fig. 3). These salary ranges are far below the ILO minimum wage of 5 US$ a day. Thirty percent were satisfied with their work.

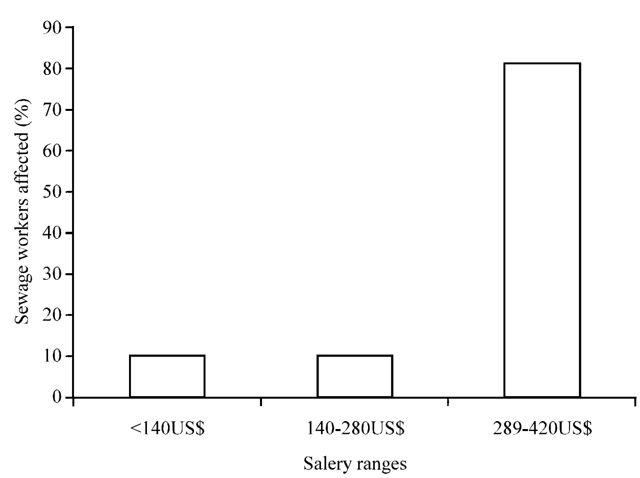

Fig. 3: Annual salary of sewage treatment plant attendants

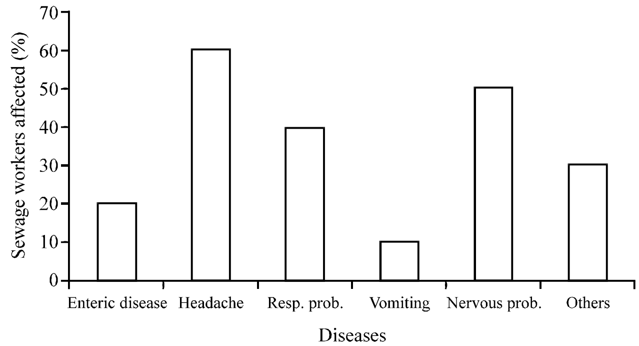

Fig. 4: Health complaints among sewage treatment plants attendants

Seventy percent were not satisfied. Reasons given were high risks (80%) tedious nature of the job (60%) and low salary (60%) and lack of incentives (30%). If workers are treated like this, it is almost impossible to expect a good output from such a situation. The success of wastewater management does not depend on the technical aspects but rather the human component. Mancross and Winter (1990) observed that it was the people, their organizations, expectations and training needs that ensured the success of a number of water and wastewater treatment plants they studied. They recommended that the management of water and wastewater plants should follow suit.

All the attendants were males. Protective clothing was lacking. Disinfectants and nose masks were absent on all sites. Most workers lacked boots and worked with bare hands. In contrast to workers in developed countries, where 97% of the workers wore gloves and 57% wore boots, 69% wore overalls and 37% wore nose masks (Levin *et al.*, 2000). Health complaints among the attendants in Kumasi included headache (60%), nervous problems 50%, respiratory problems 40%, enteric disease 30% and vomiting 10% (Fig. 4). Sewage workers are exposed to hazardous materials and need to be protected (EPA, 1997; Kraut, 1992). Douwes *et al.* (2001) found 13.8% respiratory symptoms and headache 9.5% as frequently reported cases among 147 sewage plant workers (all males) in the Netherlands. 39% reported of occasional diarrhoea. They concluded that good hygienic practices at the work place might prevent some of these symptoms. In a similar study, Sridhar and Oyemade (1987) found that sewage workers in Nigeria had higher levels of avoidable health risks such as malaria, helminthiasis, respiratory infections, cuts, chlorine poisoning and sand fly bites which they attributed to non-provision of safety materials, unsatisfactory upkeep of the premises and ignorance about the associated hazards. Workers working with sewage always have higher levels of pathogens than control groups. Other researchers however, found no differences in the health risks of sewage workers and control groups (Varadarajan *et al.*, 1991). Even though there was no control group in our study, the health complains among the workers are higher than the local levels (Owusu-Sekyere *et al.*, 2013).

Workers also had large families. Eighty percent were married and sixty percent had family sizes of more than 6 children. Only two (10%) of the respondents have a family size ranging between 1 and 3, 30% of the respondents have a family size ranging between 4 and 6. All attendants were male. Sixty percent were illiterates with 20 with secondary and 20 basic education. None had tertiary education. The background of these workers exposes them to a number of hazards associated with domestic wastewater. Levin *et al.* (2000) observed in his studies in Israel that the less educated sewage worker (without a high school diploma) were 100% positive to seropositivty for Hepatitis A, whiles the those with formal education showed seropositivity of 65% which was significant, 95% CI of 0.9.

The Asafo wastewater stabilization ponds are under the care of Consultants to be funded by KMA, but the needed funds are not released for its maintenance.

At the time of going to the press, the Government of Ghana had provided funds for the rehabilitation of the existing trickling filters at KNUST. No reuse option has been proposed and no maintenance cost retrieval from the beneficiaries had been incorporated in the proposal. The University should take at least 5% of student user fees for sanitation including maintenance of the treatment plant. All stakeholders enjoying the sanitation services must contribute to at least the operation and maintenance of the facilities provided for sustenance.

Two other treatment plants had been commissioned in two other suburbs (Chirapatre and Ahensan) of Kumasi lately. The plants are currently working but not without problems. Ahensan does not have any buffer zone yet and odour may become a problem in the near future. The Chirapatre ponds were not properly lined and compacted. The clay lining continues to erode into the ponds creating turbid conditions, which are not favorable for algal growth, which is important for pathogen removal. In addition, the outfall goes into a wetland, which is below the ground level. Backflow of water into the ponds will occur during flooding. No reuse options have been considered in both designs. Management of the two treatment systems has not been clearly defined. The authorities are considering communal maintenance practiced in rural communities for water supply and sanitation. This must be done with caution since conditions in the rural areas are different from urban centres.

Alternatively, a private contractor could be hired to provide maintenance with the residents paying for the service. A good system of retrieving money from the community should be put in place before this is implemented.

Sanitation projects must be monitored by the implementing agencies and sector institutions to ensure sustainability. If this is not done, the systems may collapse, this has been the case of many wastewater treatment plants in Ghana.

Reuse and recycling of resources in wastewater must be encouraged. The organic carbon can be harnessed for energy as biogas. The maturation ponds of the Asafo wastewater stabilization ponds could be used for duckweed cultivation for fish culture to generate income. The sludge produced from all treatment plants could be used for compost for crop production while the effluent could be utilized for irrigation (Golueke, 1972; Awuah *et al*., 1996).

CONCLUSION

Results from the study have shown that, the wastewater generated at KNUST and Asafo are harmful with high pathogenic levels with heavy metal content of the domestic wastewater, however low. The poor management of domestic wastewater and abuse of fundamental hygienic principles could have a negative impact on the quality of water bodies in the city.

Developing countries like Ghana are currently battling with the problem of handling and managing wastewater properly but they are also constantly being confronted with new technologies and guidelines to follow. The best solution will be to evaluate these problems holistically and harness the available resource for effective implementation.

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