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MANAGING AND MAXIMISING THE USE OF SEWAGE IN TAMALE

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Abstract

Treated water is used for bathing, fl;ushing toilets, drinking, cooking, washing, recreation, building, construction and gardening in Tamale resulting in high generation of sewage. Reuse of sewage at homes will supplement the national water budget especially in towns and cities. This will promote income generation, socio-economic equity and urban food security (Shaat 1998). The treatment ponds in Tamale during the research was basic (pH range 8-10) and was unaffected by seasonal variations. Turbidity values ranged from 32 to 480 NTU. Electrical conductivity varied between 1128-5035 µS/cm. The concentration of DO in sewage ranged from 3.3mg/l in the discharge pond to 10.7mg/l in the aerobic pond. The mean total coliforms of sewage ranged between 1136 and 1880 CFU while faecal coliforms ranged between 336-739 CFU. The proportion of those who pay for water use (69%) coincided with those who use tap water. About 47% of the people in Tamale who use piped water do not get regular supply of water. Willingness to pay for water use was negatively related (α= -0.01) to education.

Introduction

It is reported that seventy percent of urban areas of sub Saharan Africa including Tamale may lack household-based or public provision of drinking water because fresh water is unavailable and treatment is expensive (Gaye and Diallo, 1997). Because water treatment is expensive public –private partnership is usually the way forward for treated water in urban settlements (Batley 1996; Fiszbein and Lowden 1999) even though they are not sustainable (Tennyson, 1994; USAID, 1997; Fiszbein, 2000). Water supply is facilitated by citizen-based organizations such as Town Development Committees, Youth Associations and Home Town Development Associations (Badu and Parker, 1992; Brown, 1990). Treated water is used for bathing, fl;ushing toilets, drinking, cooking, washing, recreation, building, construction and gardening in Tamale resulting in high generation of sewage.

Sewage consists of organic matter of biological origin eg. faeces and objects such as tissue paper, stones, socks, tree branches, condoms, kitchen and bathroom waste. Until recently, sewage was discharged into streams and gutters. Untreated sewage is a source of environmental pollution of surface waters in many parts of the world, particularly, the developing world (FAO, 1977). It is the concern of environmentalists that natural water systems will not be able to assimilate nutrients without far-reaching consequences as human population continues to grow. To safeguard the environment, various conventional sewerage systems have been designed and constructed in many countries to reduce sewage toxicity and nutrient levels (Khalil and Hussein, 1997; IRCWD, 1985; Smith, 1985; Ghosh, 1983; Kuo, 1980 and Mihursky, 1969). Sewage treatment plants control the spread of wastewater-related diseases such as cholera (Ehrlich and Ehrlich, 1972).

Reuse of sewage will supplement the national water budget for domestic usage. This will ensure income generation, socio-economic equity and urban food security (Shaat 1998). Interest in sewage treatment and reuse is likely to increase as the populations of many regions in the world outgrow their water supplies (Carpenter et al., 1974; Allen and Hepher, 1979). Untreated sewage may result in the death of people from water-borne diseases alone or in combination with malnutrition (Dale, 1979).

Laws enacted in developing countries e.g. Ghana for the use of sewage is hardly enforced because compliance is economically unfeasible and enforcement is institutionally impossible. Therefore sewage reuse is uncontrolled or may not be prohibited because monitoring and control cannot be implemented. World Health Organization (WHO) guidelines are based on the objective that there should be no excess infection in the population. This is strongly criticized by critiques who think that there should be a zero-risk and advocated for guidelines which will eliminate pathogenic organisms completely in wastewater. This will involve high cost and not sustainable. Blumenthat et al., (1999) have suggested that new guidelines be set e.g. Nematode should be set at ≤ 0.1 eggs/liter based upon new epidemiological and microbiological findings. Also, 1CMSF (1995) has suggested $\leq 10^3$ faecal coliforms/100g fresh weight of excreta. Chemical exposure to humans is through the food chain.

Sewage is collected from septic tanks and public toilets. This practice is common in China, Southeast Asia and Africa including Ghana (cross 1985; Immer and Visker 1998; Visker, 1998; Timmer 1999; Strans et. al., 2000). Sewage relates to urban rather than rural because of the volume of waste water and excreta generated in urban areas. Rapid population growth in Ghana in recent years has transformed Tamale (the capital city of the Northern Region) from municipal to metropolitan status. This has led to an increase in sewage generation in the city. Sewage in Tamale is transported directly from homes, institutions and public toilets to the treatment ponds at Gbalahi. The Tamale Metropolitan Assembly (TAMA) is struggling to manage the waste problem in the city. Until February 2004 when a wastewater treatment plant was built in the city, sewage generated in the metropolis was released untreated into gutters or unto agricultural fields as a fertilizer substitute to enhance food production. As a result of this inappropriate sewage disposal, outbreak of cholera and other environmental-related diseases was common in the metropolis (TAMA, 1996). The situation has not changed much because cesspit tanks are difficult to access and the treatment plant is getting choked as a result of inappropriate operation.

The use of sewage whether legal or illegal is necessary to compensate for scarce or costly treated water. Planners and decision makers must make sewage reuse a part of urban strategic sanitation and infrastructure planning policy. It is therefore the intention of this paper to suggest appropriate measures that will make sewage reuse practicable in Tamale to reduce the volume of sewage that is carried to the treatment plant.

Problem Statement

The Metropolitan status of Tamale has led to a high sewage generation. The city depends exclusively on treated water produced by the Ghana Water Company Limited (GWCL) because there are no alternatives. Besides drinking, cooking and washing, treated water is also used for building, construction and gardening in Tamale. This attitude leads to an increase in the volume of water needed by the inhabitants and put pressure on GWCL and the government. Some individuals who may not be engaged in these practices are wrongfully charged extra for the increase cost of water treatment. For fear of paying more tariffs, lawns and ornamental plants are neglected depriving the city of its beauty. Sewage generated is difficult to collect because the cesspit tanks are inadequate and cost of transport is high. If a percentage of the sewage can be reused then less sewage would be sent to the treatment plant and the life span of the treatment plant would be increased. It is noted recently that the treatment plant is getting choked and may not be able to accommodate any more sewage.

Objectives

The main objective was to find interventions for sewage reuse at homes. The specific objectives are to:

- monitor the physicochemical and bacteriology load of sewage
- monitor the volume of sewage conveyed to the treatment plant
- assess the public acceptance of sewage treated water for domestic use

Study Area and Methodology

Tamale Metropolitan Assembly (TAMA) sewage treatment plant is located at Gbalahi, a village about 5 km away from Tamale. Tamale is located between longitude $0^{0}45^{1}$ W and $0^{0}55^{1}$ W and latitude $9^{0}20^{1}$ N and $9^{0}30^{1}$ N. The sewage treatment plant consists of two units of three ponds: a 2,432 m^2 anaerobic pond, a 1216 m^2 primary facultative pond and a

1216 m^2 secondary facultative pond (Pond 4) in series, which are connected to a common 4464 m^2 aerobic pond (Pond 5). The system design allows both units to operate in rotation. However, only the left unit was in operation at the time of the research. Excreta are discharged into the anaerobic pond. The sewage is retained in the pond for two weeks to allow decomposition to take place. Sludge and grit which is collected on wire mesh at the discharge pond is used as farm manure. The ponds are connected in such a way that the sewage from the discharge pond can be opened in to the primary facultative pond through valves. Here sedimentation further takes place. When the water level in the primary facultative pond is high enough, the control valve connected to the secondary facultative pond is opened to allow water into the secondary facultative pond. Later in operation, a control valve connecting the secondary facultative pond and the aerobic pond is also opened to allow water into the aerobic pond. Generally, the quality of the water becomes cleaner as the water moves from pond to pond through the controlled valves.

pH

pH was measured three times at different locations directly from a boat with a digital pH Meter (Model CG818) respectively at a depth of 20 cm. Measurements were recorded to the nearest 0.1 units. Daily and monthly mean values were calculated.

Microbiological Analysis

The membrane filtration technique (APHA, AWWA, WEF, 1998) was used in determining total coliform and faecal coliform bacteria in the water samples. Three replicates of the samples were cultured and their mean value calculated. This method gives a direct count of total and faecal coliforms. Each sample was diluted differently depending on the pollution load before filtration. A measured volume (100 ml) was filtered under vacuum through a cellulose acetate membrane with pore size of 0.45 µm. Bacteria retained on the surface of the membrane were incubated on Sterile Endo Agar at $36^oC \pm 1^oC$ (for total coliforms), or on sterile MFC agar at $44^oC \pm 0.5^oC$ (for faecal coliforms). Incubation time was 24 hours. Dark red colonies with metallic shine were considered total coliform bacteria while blue/green colonies were considered facecal coliform bacteria. Coliforms were confirmed using MacConkey broth. All the coliform bacteria were counted by the coliform forming units (cfu).

Determination of Turbidity

Turbidity was measured immediately without altering the original sample conditions such as temperature and pH using the Nephelometric method (APHA, AWWA, WEF, 1998) from three portions of the same sample. The average turbidity of each was calculated to represent the entire pond. Air and other gases trapped in the sample were removed by adding non-foaming type surfactant before the measurement. The sample was then agitated gently and allowed some time for the bubbles to disappear. The sample was poured into a cell and the turbidity read from the turbidimeter (Model 210p).

Determination of Dissolved Oxygen (DO)

Dissolved oxygen was determined by Azide modification of Winkler's method (APHA, AWWA,WEF, 1998). Water samples were collected in 1L plastic bottles and transported at 10^oC to the laboratory. DO was determined by collecting diluted samples in BOD bottles and adding 2 ml $MnSO_4$, followed by 2 ml alkali-iodate-azide solutions to the samples and inverted several times to allow precipitate to settle at the bottom of the sample. After the precipitate had settled, 2 ml concentrated H_2SO_4 was added to dissolve the precipitate, which gives an intensive yellow colour. Exactly 100 ml of the precipitate solution was taken and titrated with sodium thiosulphate solution (M/80 i.e. 0.0125 M) to a pale yellow colour after which a 2 ml starch indicator solution was added and the titration was continued until the blue/black starch disappeared. The titration was repeated three times to determine the average value. DO Content was calculated from the following formula:

$$\text{Mg/l of } O_2 = \frac{\text{Volume of titre x 101}}{\text{Volume of sample use}}$$ (APHA, AWWA, WEF, 1998)

Determination of Ammonia-Nitrogen

The Nesslerization Method (APHA, AWWA, WEF, 1998) was used to determine ammonia in the samples after the addition of the Nessler's reagent. The yellow to brown colour produced was read in the range of 410nm in a 1cm light path inside a spectrophotometer. Turbid samples were filtered before the analysis. 1mL of the supernatant was diluted to 50mL with ammonia free water. Rochelle salt and Nessler reagent (2 drops each) were added and mixed. Samples were allowed to stand for 10 minutes to develop the colour before the absorbance was determined. A blank was used to zero the spectrophotometer. The procedure was repeated three times to obtain the mean ammonia nitrogen.

Electrical Conductivity

Conductivity meter (Model CMD 200) was used to determine conductivity (Eaton et al., 1995) from three portions of the same sample.

Volume of sewage conveyed to the ponds

Cespit tankers were monitored daily at the gate of the fenced treatment site. The number of tankers that carried sewage into the ponds were counted and recorded.

Assessment of public perceptions

Questionnaires (Appendix) were administered alongside stake holder meetings to ascertain the acceptance of sewage reuse and treated sewage for domestic use. The questionnaire was analyzed using SPSS and Microsoft Excel.

Result and Discussion

Discharge of sewage

Domestic sewage was not separated at the source of generation. Bath and kichen waste are lump together with excreta in one septic tank. For effective recycling of sewage kitchen and bath waste water should be discharge into a separate septic tank and excreta in another. The waste water from bath and kitchen can then be used to water ornamental plants at home and also backyard gardening. This is because such waste water is relatively free from pathogenic bacteria. Alum can also be added to settle the impurities and it can be used for washing cars and domestic animals instead of treated water. Adoption of this technique will reduce the volume of sewage conveyed daily to the treatment plant and save cost. The excreta sewage can then be conveyed to the treatment plant for treatment.

The discharge of sewage to the plant was regular and varied throughout the months (Fig 2), an indication that sewage treatment ponds would never be dry.

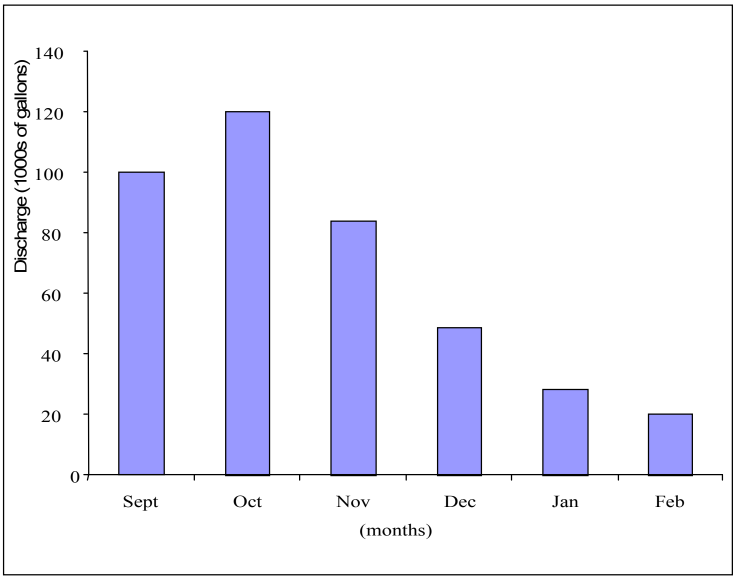

Fig 2. Discharge into the ponds from September 2006-February 2007

Sewage discharge was highest during the wet months (September and November) and lowest during the dry months because normally water related domestic activities increase in the rainy reason. Sewage which is collected at homes is sold moderately to farmers because it contains higher concentration of nutrients such as nitrogen, phosphorus and potassium which are vital for plant growth.

pH

The treatment ponds were basic (pH range 8-10) and was unaffected by seasonal variation. The pH was outside the range of 6.5 – 8.5 stipulated for drinking and cooking purposes (WHO, 1993). The range was largely within the acceptable range (6-9) stipulated by the EU for fisheries and crop production (Chapman, 1996). Sewage therefore could be used for some domestic purposes but not drinking and cooking.

Turbidity

Turbidity values ranged from 32 to 480 NTU. This was far beyond the background values of 0-5 NTU for human consumption (WRC, 2003). An excessive value of turbidity is an indication of the presence of disease causing organisms and makes water purification processes difficult which may increase treatment cost. High turbidity values are an indication of microbiological contamination (DWAF, 1998). This suggests that sewage cannot be consumed directly by human beings without treatment.

Electrical Conductivity

Electrical conductivity varied between 1128-5035 µS/cm. Conductivity was lowest in the maturation pond and highest in the discharge pond. The high conductivity was an indication of metallic substances from kitchen waste. The values of conductivity were far greater than 350µS/cm recommended for unpolluted water (Koning and Roos 1999) and indicated that sewage water was not suitable for direct consumption.

Dissolved Oxygen (DO)

DO concentration in unpolluted water is normally about 8-10 mg/l at 25°C (DFID, 1999). Concentrations below 5.0mg/l adversely affect aquatic life. The concentration of DO in sewage ranged from 3.3mg/l in the discharge pond to 10.7mg/l in the aerobic pond and so the aerobic pond was suitable for domestic use and aquatic life at least for DO.

Microbial analysis

The mean total coliforms of sewage ranged between 1136 and 1880 CFU while Faecal Coliforms ranged between 336-739 CFU. WRC (2000) has indicated that microbial quantity of sewage was high. Total and Faecal coliforms were present and so sewage was not suitable for domestic use without treatment. There is the possibility of contamination of pathogenic bacteria. WHO (1987) has indicated that, water that is without risk has no faecal pollution; so sewage pose a serious health risk to consumers.

When Faecal coliforms are exposed to the sun, survival periods are shortened (Table 1). Bacterial die-off in urine is rapid (Stenstron et al., 1999) than virus. Pre-application storage of sewage may contribute to die-off. Over 99% of removals are required for viruses, bacteria and protozoa. A reduction in the worm eggs (80 – 90%) will exhibit a major public health effect. For example Ascaris eggs takes half a year to one year for a complete egg die off (Feachem et al., 1983, Stranss 1985, Phi et al., 1999). Pathogens from sewage may survive in the bio-solids for varying periods unless they are inactivated by natural die-off such as UV radiation or predation while in the liquid portion. WHO (1989) has suggested 1000 CFU/100ml for unrestricted use and ≤ 0.1 nematode egg/litre for a nematode (roundworm). Much stricter guidelines have been enacted by individual countries e.g. California to ensure that they satisfy drinking water standards (State of California 1978). However Ghana has no local guidelines for waste water but depends on the WHO guidelines. The sewage and sludge at the treatment ponds in Tamale are subjected to UV radiation to kill pathogenic bacteria.

The Current Situation of the Sewage Treatment Plant in Tamale

Macroscopic objects in sewage are removed at the point of discharge through filtration by means of a wire mesh (Fig 3).

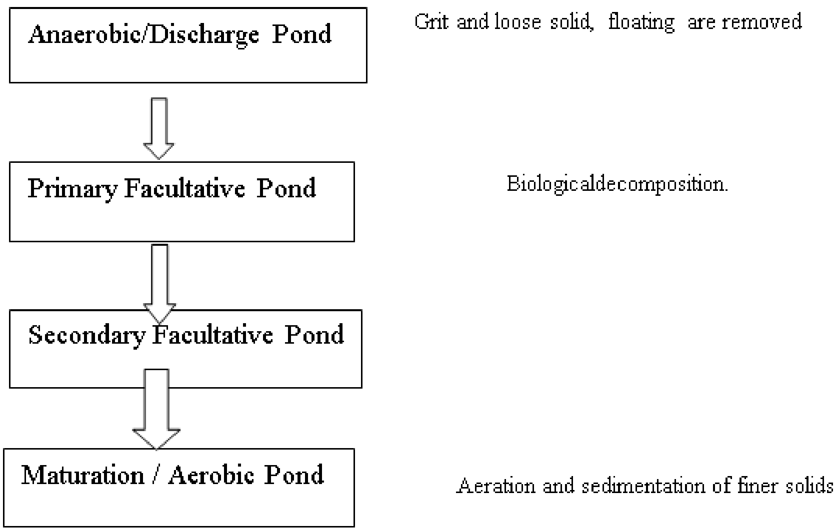

Fig 3. Current Treatment of Sewage in Tamale

Sludge collected on the wire mesh is allowed to dry and may be collected as manure to fertilize farm lands. Sewage is allowed into the primary facultative pond periodically through a control valve and is retained for a period of two weeks. Within two weeks of retention, most of the pathogenic bacteria die because of exposure to the UV radiation from the sun. In the primary facultative pond sewage is aerated and finer solids are allowed to go through sedimentation. Aeration improves the oxygen content of the pond and aquatic organisms can survive in this pond. The secondary facultative pond enables biological decomposition to take place. Currently, the ponds are getting choked due to siltation because the solid waste at the adjacent side is not well managed and solid waste including plastic waste are carried into the ponds by wind.

The Intervention

The management of sewage begins at home. Kitchen and bath water including urine should be separated at the home level from toilet waste. This waste should pass through filtration bed and activated charcoal and be collected into another tank. Depending on usage, alum may be added to settle any debris before use. Planners and building contractors' must ensure that sewerage system in homes and institutions should have separate pipe lines for both toilet waste and other waste. This waste is relatively free from germs and could be used for washing cars, building and construction, and home gardening. The primary facultative pond at the treatment plant may be used for crop production while the secondary facultative and aerobic ponds may be used for fish culture. This is because the primary facultative pond may contain high concentration of hazardous inorganic compounds in solution, and is not ideal for fish culture. Toxicity increases along the food chain and so if fish is cultured in the primary facultative pond they may not be suitable for consumption. Activated charcoal could be put in place between the secondary facultative pond and the aerobic pond. Activated charcoal traps any harmful inorganic compounds in solution. This could make the aerobic pond most suitable for fish culture. Water in the aerobic pond may also be released into existing water sources for treatment for domestic usage, irrigation of vegetables, parks and aesthetic plants along our streets.

However sewage intended for domestic use, may be collected in to tanks for tertiary treatment involving the use of chemicals to take place (Colin, 1999). Chlorine may be added as disinfectant (WHO, 2004) and is also used to provide residual disinfection in the distribution system. Chlorine monitoring in drinking water is normally considered to be a high priority because the residue in monitoring indicates that disinfection has taken place. A residual concentration of chlorine is 0.6mg/1. Residual concentration of more than 0.6mg/l may cause problems of acceptability for some consumers on the basis of taste. In order to ensure the microbial safety of drinking-water, disinfection should never be compromised in trying to meet guidelines for any disinfection by –products. This makes the treatment of sewage very costly as more chemicals are required for disinfection.

Coagulation and flocculation serves as barriers to microbiological contaminants and also reduces naturally occurring organic matter and turbidity, which affects the efficiency of disinfection. Chemicals used as coagulants in sewage treatment include aluminium and iron salts. Addition of alum will lower the alkalinity of the water and brings sewage to a near neutral position. Concentrations above 0.3mg/1 for iron and 0.2mg/1 for aluminium can give problems in water treatment.

Socio-economic and Demographic Data

A sample of thousand (600 female and 400 male) (Table 2) were interviewed from a cross section of the public.

Table 2. Socio-economic and Demographic Data

Sex	%	Educated	%	Employment Status	%	Water Payment	%
Male	39	No education	14	Employed	32	Yes	69
Female	61	Educated	86	Unemployed	68	No	31

The proportion of those who pay for water use (69%) coincided with those who use tap water. This agreed with Gaye and Diallo (1997) who said that only 70% of urban areas have access to pipe water and indicated that river, well and dam waters are used by 30% of the people in Tamale especially those at the pere urban areas. It was also clear that rain harvested water is not popular in Tamale. 84% of the population who use other water sources besides tap water thinks that their water was clean enough and needed no further treatment. About 47% of the population who use piped water do not get regular supply of water. Most (15%) of the population thinks water cannot be treated and 21% was never prepared to accept sewage treated water no matter the circumstances. The acceptable use of sewage in the home are gardening, flushing toilets, building, construction, Irrigation, Cooling engines and fish production.

Willingness to pay for water use was negatively related (α= -0.01) to education. Therefore the more people are educated the lesser the refusal to pay for water. Willingness to accept sewage treated water was influence by marital status α= 0.04 and age α=0.006. Employment status also affected the acceptance of sewage treated water α= 0.005. This is because treated water is expensive and more expensive even in sewage treatment. The fear of too much tariff to the consumer will negatively affect acceptance. The high unemployment (68%) could have been the reason for 31% of the population not paying for water use. Some respondents did not accept sewage treated water on the basis of religion (α= -0.002). This was as a result of pride since no religious scripture condemns the use of sewage. The availability of clean water highly influenced (α= 0.02) the acceptance of treated sewage and the regular supply of water (α= -0.03). In general 78% of the population would accept sewage treated water for domestic use if its safety is guaranteed.

Conclusion

Sewage is generated daily and in large volumes by urban dwellers. Treatment of sewage is a necessary evil since its treatment involves cost and non treatment may cause environmental pollution that could result in epidemics. To reduce cost source separation of excreta from toilet, kitchen and bath water is necessary. The later can be reused while the former is treated at the treatment plants. The treatment of sewage for use has a triple advantage of controlling pollution, fish and crop culture and domestic use at home to augment the scarce treated water in the nation.

Recommendation

For effective treatment of sewage for domestic use the following suggestions are made:

- Bath and kitchen waste water must be separated from toilet waste
- Treated sludge should be sold moderately to farmers to entice them buy sludge from the treatment plants instead of using untreated and raw excreta illegally from drivers
- Activated charcoal should be used between the secondary facultative ponds and aerobic ponds during construction of treatment ponds
- Solid waste should be compacted periodically and frequently to avoid solids waste transport and siltation of the ponds by wind.
- Every metropolitan and municipal assembly should own a sewage treatment plant
- Public education is necessary to boost the acceptance of treated sewage for domestic use
- There is the need for the Ministry of Local Government and Rural Development and the Ministry of Water Resources, Works and Housing to collaborate in the implementation and management of sewage treated water as a domestic resource

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