MICROBIAL REMOVAL EFFICIENCY OF A NATURAL WASTEWATER TREATMENT SYSTEM AND THE IMPACT OF ITS EFFLUENT ON RECEIVING WATERS

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Abstract

The discharge of untreated or partially treated wastewater into streams is a huge problem in developing countries in that it leads to severe environmental degradation, and, also, poses serious public health challenges to communities which live downstream. The study investigated the microbial removal efficiency of individual ponds of a waste stabilization pond system and the overall performance of the treatment systems in the removal of indicator bacteria and organic matter. The impact of the discharged effluent on the receiving waters was evaluated. Final effluent concentration of BOD and TSS were 1.7±1.2 and 10.1±4.3 mg/l, representing overall removal efficiencies of 98.7 and 98.6 per cent, respectively. Overall log removal of faecal coliform (FC) and *E. coli* were 3.8, and 4.7 log units, representing a percentage removal of 98.4 and 99.8 per cent, respectively. The mean diversity upstream was 0.11±0.09 while the downstream was 0.14±0.05, and this was not statistically different. The presence of macro-invertebrate families of Elmidae and Libellulidae downstream the point of discharged is an indication of good water quality.

Introduction

Natural wastewater treatment systems are engineered wetlands that optimize the natural biological, biochemical and physical processes involving plants and its associated fauna for the treatment of wastewater. The use of natural wastewater treatment systems is gaining popularity in developing countries in the tropics due to its low capital and operating costs. Unlike conventional treatment systems, such as the Activated Slugde System (ASS) or the Upflow Anaerobic Sludge Blanket (UASB) that depends entirely on electricity for its operations in the form of mechanical aerators, natural wastewater treatment system depends on a renewable source of energy and achieve aeration via photosynthesis and diffusion. Sludge generation, odour and noise are also much lower in natural wastewater treatment systems than conventional systems (Brissaud, 2008; Gray, 2010; Mungray & Patel, 2011).

Natural wastewater treatment systems such as Waste Stabilization Pond Systems (WSPs) generally have high purification rates, a key consideration in many developing countries. In developing countries such as Ghana, downstream communities depend on water bodies for their domestic activities and the water is usually used in its raw state without any form of treatment. The risk of pathogen infection from the use of raw water, therefore, is a serious public health concern. It is, therefore, imperative that wastewater treatment systems, discharging effluents into water bodies, operate efficiently.

WSPs are by far better in the removal of pathogens compared to conventional wastewater treatment systems. A log removal of up to 6 log units had been recorded in WSPs while removal in conventional treatment systems is 2 log units (Mara & Caincross, 1989). The performance of WSPs in the removal of pathogens as shown by indicator bacteria, however, varies from region to region. Garcia *et al* (2008) recorded a year round removal efficiency of 3.2 log units of faecal coliforms (FC) in Spain for a total retention time of 20 days while Noumsi *et a.l* (2005) recorded a removal of 3.0 log units for a retention time of 16 days in Cameroun. In Ghana, 5.3 log units removal of FC had been recorded by Hodgson (2000) at a total retention time of 40 days in Akuse (Eastern Region) while a pilot scale WSP reported a log removal of 5 units at a total retention time of 28 days in Kumasi, Ashanti Region (Awuah, 2006). Ansa *et al*. (2012) recorded an FC log removal of 4.7 in Accra, Ghana using a pilot scale WSP, operating at a total retention time of 20 days. Local operating conditions may, therefore, affect the efficiency of pathogen removal of the system.

WSPs tend to be more efficient in the removal of FC in warmer climates due to its dependency on sunlight for disinfection (Maiga *et al.,* 2009; Ansa *et al,*. 2016). Major mechanisms of pathogen disinfection in WSPs are high *p*H above 9.5 (Curtis, Mara & Silva, 1992a), fluctuating *p*H (Awuah, 2006), ultraviolet radiation (Davies-Colley, 2000) and interaction of long wavelength of sunlight with oxygen molecules and dissolved organic matter (Curtis *et al*., 1992a,1992b). Other mechanisms include predation, attachment and sedimentation (Awuah, 2006; Ansa, 2013).

Removal of nutrients in WSPs takes place in the form of removal of various forms of nitrogen and phosphorus. WSPs, however, are not efficient in the removal of nutrients and removal constitutes about 50 per cent of total influent concentrations (Mara, 2003). The discharge of nutrient-rich water into waterbodies makes them eutrophic, creating algal blooms that may result in fish-kills. Limited nutrient inflow, however, may increase the productivity of freshwater bodies and its self-purification capabilities through the presence of algae (Ansa *et al.*, 2011). Excessive nutrient load, however, affects the water body's Water Assimilative Capacity (WAC), which is its natural ability to withstand a certain amount of pollutants without impairing ambient water quality (VishnuRadhan *et al.*, 2015).Aquatic species respond to the impact of untreated or partially treated influent by a decrease in their diversity as some species have a narrower tolerance for adverse environmental conditions. Benthic macro-invertebrates are the commonly used aquatic species for evaluating changes in environmental conditions involving changes in chemical composition, habitat complexity or habitat requirement, assuming that the change in value of the diversity index is related to the intensity of pollution (Klemm *et al*., 2002; Teixeira *et al*., 2009; Molozzi *et al*., 2013; Abdelsalam & Tanida, 2013).

The study investigates the microbial removal efficiency of individual ponds of three parallel lines of treatment of a newly constructed WSP and its overall performance in organic matter and indicator bacteria removal. The impact of the effluent on receiving waters was also assessed using the diversities of macro-invertebrates upstream and downstream the point of discharge of the effluent.

Experimental

Description of the treatment plant

The Legon WSP is located at the University of Ghana botanical gardens, on the north-western part of Legon (5°39'50.84" N and 0°11'29.87" E). It became operational in 2012 and occupies an area of 58 ha. The WSP consists of a screening chamber, distribution chamber and three parallel grit chambers. The grit chambers open into three streams of pond systems, each stream consisting of four ponds, namely an anaerobic, facultative and two maturation ponds (Fig. 1). The anaerobic pond (2400 m^2 × 5 m depth), facultative pond (8000 m^2 × 2 m depth) and maturation ponds (6375 m^2 × 1.5 m depth) respectively had a retention time of 5, 7 and 5 days. The WSP receives influent wastewater from residencies in the neighbourhood, including the University of Ghana, University of Professional Studies, Presbyterian Boys Secondary School, and Junior Staff Quarters of the University of Ghana and Achimota School.

The influent wastewater flows by gravity from break pressure manholes into a screening chamber which removes the solids before it enters the anaerobic ponds. The final effluent is discharged into the Onyease Stream. The plant has a design capacity of 8550 m^3 out of which 1330 m^3 is being utilized, representing 15.6 per cent of its total capacity. Algal development in the ponds occurred by natural colonization. The WSP is managed by the Sewerage Division of the Accra Metropolitan Authority (AMA).

Operation and monitoring of the treatment plant

Sampling at the treatment plant for this study took place over a 6-month period, starting in October 2015 to March 2016. Using a hand-held adjustable sampler, samples were taken for influent and final effluent concentrations for the analysis of *p*H, temperature, turbidity, Total Suspended Solids (TSS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), phosphate, ammonia nitrogen and faecal coliforms (FC), according to Standard Methods (APHA, 2012). Additionally, samples of influent and effluent of each pond were taken for the analysis of BOD, TSS. *E. coli* and FC concentrations were determined once a month using spread plate technique on chromocult agar and incubating at 35-37 °C for 24 h for a colony count (Finney *et al.*, 2003). Logistical challenges did not permit the monitoring of all the parameters indicated above for all ponds. These parameters were limited only to influent and final effluent ponds unless otherwise stated. Ambient temperatures ranged from 28 to 31 °C.

The samples were collected in duplicates 10 cm below the pond surface. Physical parameters such as *p*H, temperature and dissolved oxygen concentrations were measured *in-situ* once a month in all the ponds using a hand held Aqua Lytic SD 50 instrument from 8:00 – 9:00 a.m. Characteristics of influent wastewater are described in Table 1

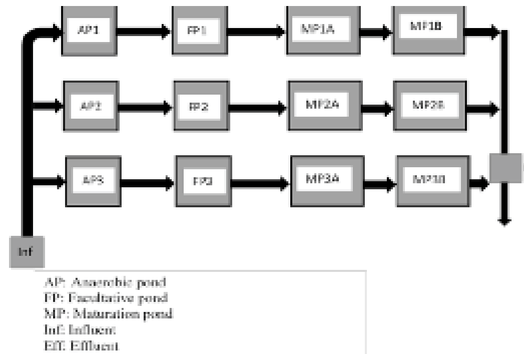

Fig. 1. *Schematic diagram of the waste stabilization pond system*

Macro-invertebrates sampling

Macro-invertebrate samples in the Onyease stream were collected with a handnet of 295 µm mesh size over 1 m^2 area. Four replicates were collected downstream and another four upstream the point of discharge. The samples were washed through the mesh net to remove debris. The macro-invertebrate retained were preserved in 70 per cent alcohol (APHA, 2012) for identification and counting under the microscope using identification keys (Needham, & Needhan 1969; Dejoux, Forge & Mashlin,1982).

Data and statistical analysis

Student's t-test and one-way analysis of variance of SPSS were used to compare bacterial concentrations and decay rates, respectively. Macro-invertebrate abundance and diversity were calculated using the Plymouth Routines in Multivariate Ecological Research (PRIMER) version 6.0 software. The diversity of the macro-invertebrates was calculated using the Simpson's diversity.

Results

Characteristics of influent wastewater

The mean temperature of the raw influent wastewater during the study was 29.8 ± 0.7 °C. The *p*H of the raw wastewater ranged from 6.9-7.5 and that of BOD was 133.9 ± 67.4 mg/l. Faecal coliforms and *E. coli* were, respectively, $2.7 \times 10^8 \pm 3.3 \times 10^7$ and $8.8 \times 10^7 \pm 1.8 \times 10^7$ cfu/100 ml (Table 1).

TABLE 1
Characteristics of influent and effluent

Parameter	*Influent*	*Effluent*	*Removal efficiency (%)*	*Ghana EPA guideline*
pH (pH unit)	6.9-7.5 (12)	6.9-7.7 (8)		6 - 9
Temperature (°C)	29.8 ± 0.7 (12)	29.4 ± 0.5 (8)		<3 °C above ambient temp.
Turbidity (NTU)	475.2 ± 118.1 (9)	17.8 ± 7.0 (8)		75.0
TSS (mg/l)	303.2 ± 140.1(12)	10.1 ± 4.3 (8)	98.6	50.0
BOD (mg/l)	133.9 ± 67.4 (7)	1.7 ± 1.2 (4)	98.7	50.0
COD (mg/l)	328.0 ± 47.9 (6)	8.5 ± 9.7 (6)		25.0
DO (mg/l)	0.4 ± 0.1 (8)	6.4 ± 0.7 (6)		
PO_4-P (mg/l)	1.9 ± 0.5 (9)	0.07 ± 0.0 (9)		
NH_3-N (mg/l)	36 ± 0.8 (9)	0.05 ± 0.0 (8)		
Faecal coliform (cfu/100 ml)	$2.7\times10^8 \pm 3.3\times10^7$ (7)	$43\times10^3 \pm 8.4\times10^3$	98.4	*10^3
E. coli (cfu/100 ml)	8.8×107 ± 1.8x107 (6)	1.6×103±1.1×103 (6)	99.8	*10^3

*WHO guideline (maximum acceptable concentrations) for use of effluents in unrestricted irrigation (WHO, 1989; 2006). Values in bracket represents numbers of replicate samples taken.

Environmental and microbial conditions of ponds

Total suspended solids (TSS), BOD, FC and *E. coli* were monitored for all ponds while other parameters such as pH, temperature, turbidity, COD, DO, phosphate and ammonia were measured for only influent and final effluent ponds. Final effluent ponds showed pH and DO values of 6.9- 7.7 and 6.4 ± 0.7 mg/l, respectively, which were much lower than expected. There was very little variation in temperature moving from influent to final effluent ponds (Table 1).

Removal of BOD and TSS. Generally, the removal of BOD across ponds varied from 49 - 65 per cent in stream 1, 47 - 66 per cent in stream 2 and 58 - 81 per cent in stream 3. In stream 1 and 2, highest removal of BOD occurred in the anaerobic ponds at 56 per cent and 66 per cent, respectively, Stream 3, however recorded highest BOD removal in the facultative pond (80%) and this was significantly higher than the 53 per cent and 56 per cent recorded in the facultative ponds of stream 1 and 2 (P> 0.05). The mean overall removal (percentage of mean initial concentration that is finally removed) of BOD was 99 per cent with mean effluent concentration of 1.7 ± 1.2 mg/l.

The removal of TSS varied from 30- 58 per cent in stream 1, 47 – 66 per cent in stream 2 and 53-75 per cent in stream 3. Highest removal of TSS occurred in the facultative pond of stream 3 and this was significantly higher than the 30 per cent and 47 per cent removal observed in the facultative ponds of stream 1 and 2 ($P > 0.05$). The mean overall removal of TSS was 97 per cent with a mean effluent concentration of 10.1 ± 4.3 mg/l.

Removal of FC and E. coli. Generally, removal of FC and *E. coli* were higher in the maturation ponds. Disinfection of FC and *E. coli* in each maturation pond was more than 90 per cent. FC and *E. coli* removal in the maturation ponds varied from 84 per cent to 95 per cent. Decay rates of FC and *E. coli* increased across the pond systems from anaerobic ponds to maturation ponds, with the highest rates of decay occurring in the maturation ponds. Decay rates of FC and *E. coli* of stream 1, 2 and 3 of anaerobic and facultative ponds did not differ significantly ($P > 0.05$). Decay rates that differed significantly had different letters (Table 3). Overall log removals of 3.8 and 4.7 log units were observed for the removal of FC and *E. coli* representing a removal of 98.4 per cent and 99.8 per cent, respectively.

Effluent impact on macro-invertebrate diversity

A total of 217 individuals representing five families of macro-invertebrates were recorded upstream of the point of discharge. Down stream the point of discharge, a total of nine families representing 97 individuals were observed (Table 5). Upstream, macro-invertebrate diversity as indicated by the corrected Simpson's diversity index (1- λ) varied from 0.09 to 0.21 where as downstream diversity varied from 0.10 to 0.22 (Table 6). A t-test comparison of diversities using PRIMER 6 software did not show a significant difference ($P > 0.05$). Sensitive taxa of Libullulidae and Elmidae were recorded downstream the point of discharge.

TABLE 2

Removal of BOD and TSS in pond systems

Ponds	*Parameter*	*Stream 1*		*Stream 2*		*Stream 3*	
		BOD5(mg/l)	*TSS (mg/l)*	*BOD5(mg/l)*	*TSS (mg/l)*	*BOD5(mg/l)*	*TSS (mg/l)*
AP	Influent	133.9±67.4	303.2±140.	133.9±67.4	303.2±140.2	133.9±67.4	303.2±140.2
	Effluent	46.6±26.72	141.7±69.6	46.0±28.5	75.1±39.0	53.6±35.5	111.6±126.5.0
	Removal (%)	65.2	53.	65.7	68.	60.0	52.8
FP	Influent	46.6±26.72	141.7±69.6	46.0±28.5	75.1±39.0	53.6±35.5	111.6±126.5.0
	Effluent	22.1±13.4	104.9±50.7	20.3±11.6	39.2±29.3	10.3±4.2	27.8±15.6
	Removal (%)	52.5	30.	55.9	47.	80.7	75.1
MPA	Influent	22.1±13.4	104.9±50.7	20.3±11.6	39.2±29.3	10.3±4.2	27.8±15.6
	Effluent	11.2±13.1	50.0±20.4	10.7±7.9	17.2±13.3	5.9±2.9	13.1±6.9
	Removal (%)	49.2	52.	47.0	56.	57.9	52.8
MPB	Influent	11.2±13.1	50.0±20.4	10.7±7.9	17.2±13.3	5.9±2.9	13.1±6.9
	Effluent	5.3±4.1	20.7±4.4	3.9±2.7	5.2±3.5	1.9±0.2	5.3±3.4
	Removal (%)	52.7	58.	64.0	69.	67.2	59.0

TABLE 3

Decay rates of E. coli and FC in the pond systems

Ponds	*Stream 1*		*Stream 2*		*Stream 3*	
	E. coli (cfu/100 ml)	*FC (cfu/100 ml)*	*E. coli (cfu/100 ml)*	*FC (cfu/100 ml)*	*E. coli (cfu/100 ml)*	*FC (cfu/100 ml)*
AP	1.85±0.19a	2.13±0.32a	2.48±0.63a	2.33±0.38a	2.25±0.35a	2.52±0.27a
FP	2.41±0.32a	2.52±0.30b	2.75±0.67a	2.36±0.53a	2.80±0.22a	2.64±0.34a
MPA	3.09±0.20b	3.07±0.14c	3.19±0.25a	2.58±1.23a	3.01±0.43b	3.42±0.36b
MPB	3.43±0.34c	3.51±0.13c	3.57±0.22b	3.33±0.59b	3.20±0.22b	3.52±0.25b

* K_d with same letters in the same column is not statistically different

TABLE 4

Removal of E. col*i and FC in pond systems*

Ponds	Parameter	*Stream 1*		*Stream 2*		*Stream 3*	
		E. coli (cfu/100 ml)	*FC (cfu/100 ml)*	*E. coli (cfu/100 ml)*	*FC (cfu/100 ml)*	*E. coli (cfu/100 ml)*	*FC (cfu/100 ml)*
	Influent	$8.8x10^{7}±1.8x10^{7}$	$2.7x10^{8}±3.3x10^{7}$	$8.8x10^{7}±1.8x10^{7}$	$2.7x10^{8}±3.3x10^{7}$	$8.8x10^{7}±1.8x10^{7}$	$2.7x10^{8}±3.3x10^{7}$
AP	Effluent	$8.7x10^{6}±2.5x10^{6}$	$2.4x10^{7}±6.6x10^{6}$	$7.3x10^{6}±3.4x10^{6}$	$2.1x10^{7}±3.6x10^{6}$	$7.2x10^{7}±4.8x10^{6}$	$2.0x10^{7}±2.5x10^{6}$
	Removal (%)	90.0	91.2	91.6	91.7	91.5	92.0
	Influent	$8.7x10^{6}±2.5x10^{6}$	$2.4x10^{7}±6.6x10^{6}$	$7.3x10^{6}±3.4x10^{6}$	$2.1x10^{7}±3.6x10^{6}$	$7.2x10^{7}±4.8x10^{6}$	$2.0x10^{7}±2.5x10^{6}$
FP	Effluent	$6.7x10^{5}±1.9x10^{5}$	$1.8x10^{6}±4.8x10^{5}$	$5.1x10^{5}±2.9x10^{5}$	$1.8x10^{6}+4.4x10^{5}$	$4.9x10^{5}±1.1x10^{5}$	$1.4x10^{6}±2.3x10^{5}$
	Removal (%)	72.4	92.5	92.7	91.8	93.3	92.9
	Influent	$6.7x10^{5}±1.9x10^{5}$	$1.8x10^{6}±4.8x10^{5}$	$5.1x10^{5}±2.9x10^{5}$	$1.8x10^{6}±4.4x10^{5}$	$4.9x10^{5}±1.1x10^{5}$	$1.4x10^{6}±2.3x10^{5}$
MP-A	Effluent	$4.1x10^{4}±1.2x10^{4}$	$1.1x10^{5}±2.8x10^{4}$	$2.45x10^{4}±9.3x10^{4}$	$2.5x10^{5}±3.3x10^{5}$	$3.0x10^{4}±7.2x10^{4}$	$7.8x10^{4}±1.1x10^{4}$
	Removal (%)	93.9	93.9	94.8	83.9	93.5	94.4
	Influent	$4.1x10^{4}±1.2x10^{4}$	$1.1x10^{5}±2.8x10^{4}$	$2.5x10^{4}±9.3x10^{4}$	$2.5x10^{5}±3.3x10^{5}$	$3.0x10^{4}±7.2x10^{4}$	$7.8x10^{4}±1.1x10^{4}$
MP-B	Effluent	$2.3x10^{3}±6.8x10^{3}$	$5.8x10^{4}±15.2x10^{3}$	$1.6x10^{3}±1.0x10^{3}$	$1.4x10^{4}±1.71x10^{4}$	$1.8x10^{3}±5.7x10^{3}$	$4.3x10^{3}±8.4x10^{3}$
	Removal (%)	94.4	94.6	93.3	94.1	94.1	94.6

TABLE 5
Macroinvertebrate taxa found upstream and downstream of the Onyease stream

	Replicates							
	Upstream				*Downstream*			
Species	1	2	3	4	1	2	3	4
Melanoides tuberculata	89	16	37	66	325	105	311	179
Bulinus			2	4	1			1
Pila africana				1				
Chironomidae		1			16	5	9	1
Libellulidae*							1	
Belostomidae						1	3	1
Syrphidae					12	3	3	
Elmidae*							1	
Gerridae						1		
Total (species)	1	3	2	3	5	6	7	5
Total (individuals)	89	18	39	71	335	118	330	188

*Highly sensitive taxa of macroinvertebrate indicating good water quality

TABLE 6
Macroinvertebrate diversity index at various locations during the study

Site	*Simpson's Corrected Index (1-λ)*	*Mean Diversity*	*Standard Deviation*	*P-value*
Upstream	0.00 0.22 0.10 0.13	0.11	0.09	0.58
Downstream	0.16 0.21 0.11 0.09	0.14	0.05	

Discussion

Removal of BOD and TSS

Wastewater influent of BOD 133.9 ± 67.4mg/l can be classified as low strength according to the classification of Metcalf and Eddy Inc. (2003). This BOD is much lower than the 209 mg/l BOD observed in domestic wastewater obtained from the treatment plant at the Kotoka International Airport, Accra (Ansa *et al*., 2012). The BOD measured by Ansa *et al*. (2012) had a BOD to ammonia ratio of 1:3 compared to 1:4 observed in this study. A BOD to ammonia ratio of 1:5 was observed by Awuah (2006) in Kumasi and 1:8 by Metcalf & Eddy (2003). The observed ratio in this study is indicative of some decomposition of the wastewater having taken place before entry into the anaerobic ponds. Hydrolysis of organic nitrogen can take place under anaerobic circumstances and this can occur in the grit chamber.

A BOD removal efficiency of 65 per cent, 66 per cent and 60 per cent in the anaerobic ponds of stream 1, 2 and 3 were low compared to the 92 per cent reported by Ansa *et al.* (2012) and 95% by Awuah (2006) in the same country. Overall removal of BOD, however, was 99 per cent, which is high compared to 72 per cent by Ansa *et al* (2012) also in Accra. This high BOD removal was due to comparable removal of BOD in the facultative ponds and to some extent even in the maturation ponds (Table 2). This may have contributed to the condition of lower than expected dissolved oxygen concentration of 6.4 mg/l in the final effluent pond (Table1). Another reason also could be because currently the treatment plant loading is less than 20 per cent of its carrying capacity.

The removal of TSS, expectedly, showed a similar trend as the removal of BOD as both are removed through sedimentation and oxidation, the overall TSS removal being 97 per cent (Table 1). Most studies, however, limit the assessment of performance of treatment systems to the removal of BOD, nutrients and indicator bacteria. In this study adequate assessment of nutrient removal could not be done due to logistical constraints. The BOD effluent concentration of 1.7 ± 1.5 mg/l met the Environmental Protection Agency Ghana guide-line of 50 mg/l for discharge into water bodies.

Removal of faecal coliforms and E. coli

Waste Stabilization Ponds (WSPs) are usually excellent in the removal of FC and *E. coli* and this usually takes place in the maturation ponds. Indeed some removal of FC and *E. coli,* do take place in the anaerobic and facultative ponds via attachment and sedimentation. Awuah *et al*. (2004) observed that attachment and subsequent sedimentation accounted for 99 per cent of removal in an algal based pond system. This may explain the comparable removal efficiency observed in Table 4 although Table 3 show that decay rates were relatively higher in maturation ponds than the other pond types. Dacay rates of 3.24 ± 0.22/d and 3.25 ± 0.38/d were observed for FC and *E. coli* and this is comparable to decay rates of 3.0 ± 1.2/d for FC observed by Awuah (2006). The overall removals of 3.8 log units for FC was comparable to the 3.3-3.6 recorded by Zimmo *et al*. (2002) in the Middle East but lower than the 5.0 reported by Awuah (2006) in Kumasi, Ghana, both operating at a retention time of 28 days.

The effluent FC and *E. coli* concentrations of 4.3×10^4cfu/100ml and 1.6×10^3cfu/100 ml respectively, met only the WHO guideline for restricted irrigation of 10^5cfu/100 ml. Given that the effluent is being discharged into a water body that can be used in its raw state, the effluent quality need to be better than the guideline for unrestricted irrigation of 10^3cfu/100 ml (WHO 1989; 2006). It is highly recommended that instead of discharging the effluent into a water body, the effluent microbial quality should be improved at least to the level for unrestricted irrigation (10^3cfu/100 ml) so that it can be used for crop irrigation. This can be done by increasing the retention time in the maturation pond through the alteration of the flow rate. This would provide a nutrient rich source of water for the many farming activities that are ongoing in the locality.

Impact of effluent on stream

Environmental stress imposed by pollutant load impacts negatively on aquatic macro-invertebrate community structure and diversity. This may result in highly diverse species representing a few individuals of macro-invertebrates changing to a few species with many individuals representing low diversity. In this study, diversities of four locations upstream and downstream of the point of effluent discharged, statistically compared showed no significant difference. This suggests that the discharged effluent did not impact negatively on the water body. Indeed species that are highly sensitive to pollution such as those belonging to the families of Libullulidae and Elmidae were recorded downstream the point of discharge, indicating water of good quality.

Conclusion

FC and *E. coli* removal efficiency in the maturation ponds varied from 84-95 per cent and decay rates FC and *E. coli* were 3.24 ± 0.22/d and 3.2 ± 0.38/d, respectively. Overall removals of 98.4 per cent and 99.8 per cent, respectively was recorded for FC and *E. coli*.Final effluent FC and *E. coli* concentrations of 4.3×10^4cfu/100 ml and 1.6×10^3cfu/100 ml, however, were above WHO recommended maximum acceptable concentration of 10^3cfu/100 ml for use in unrestricted irrigation. It is recommended that effluent microbial quality be improved to the level for unrestricted irrigation by increasing the retention time in the maturation ponds. The discharged effluent did not impact negatively on the water body. Indeed species that are highly sensitive to pollution, such as those belonging to the families Libullulidae and Elmidae, were recorded downstream the point of discharge, an indication of good water quality.

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