PERFORMANCE OF SUBSURFACE FLOW CONSTRUCTED WETLAND FOR DOMESTIC WASTEWATER TREATMENT

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ABSTRACT

Constructed wetlands (CW) have recently emerged as efficient technology for secondary treatment of wastewater in developing countries because of its low cost, ease operation, maintenance and generally good performance. At present there are a number of small scale units of CW for wastewater treatment in Tanzania but information on their performance is scarce. This study investigated the removal efficiency of fecal bacteria indicators, inorganic nutrients and Biochemical Oxygen Demand (BOD) from wastewater by a CW at the University of Dar es Salaam. The CW received wastewater from a primary facultative pond and was a monoculture system planted with Phragmites mauritianus *(> 10 years old) with one unplanted cells as control. The results showed significantly ($P < 0.001$) higher removal of fecal indicator bacteria, in planted than in unplanted cells. Thus, the overall* E. Coli *and Fecal coliform percentage removal were 92.9±6.05% and 93.2±6.13% in planted cells as compared to unplanted cell which were 75.2±21.3% and 58.7±21.2%, respectively. The BOD_5 values in influent was also significantly ($P < 0.001$) reduced (71 ± 6.2%) in effluent of planted cells than in unplanted cells where the average percentage removal averaged 45 ± 3.3%. Similarly, nutrients were significantly ($P < 0.001$) removed in planted cells compared to unplanted cells. The results of this study show that plants enhanced the removal process and that the CW are efficient in wastewater treatment, supporting the ideas put forward by several researchers on the usefulness of these systems in developing countries. The system continues to perform efficiently for long time which signifies its cost effectiveness. It is recommended that CW be promoted for sewage treatment in a strategy to reduce wastewater pollution in Tanzania.*

INTRODUCTION

Wastewater treatment technologies involve a combination of biological, chemical and physical treatment processes. These technologies can be grouped into two main systems: Conventional systems such as activated sludge and trickling filters and the second systems are non-conventional such as waste stabilization ponds (WSP) and constructed wetlands (CW). Conventional methods are mostly used in developed nations while non-conventional methods are increasingly used in developing ones because of cost implication. Non-conventional methods (i.e. WSP and CW) have been used worldwide to treat wastewater with good performance (Marks 1999). The systems are generally inexpensive to construct, operate and maintain (Kadlec and Knight 1996, Kaseva 2004), they are of low energy consumption, have high pollutant removal efficiencies and have ability to treat different types of wastewater from various sources (Njau *et al*. 2010). In both cases (conventional and non-conventional) sewage treatments involve multistep processes. The first step is primary treatment which involves physical separation to remove large objects; and sedimentation to settle suspended solids. This is normally done in a receiving pond referred to as sedimentation pond (or anaerobic pond). The second step is the removal of dissolved organic matter and pathogens which involves anoxic and oxic processes in facultative ponds. Anoxic treatment involves complex series of digestive and fermentative reaction by microbes which break down and remove remaining organic matter as well as enteric pathogens. Oxidation of organic matter by aerobic bacteria occurs in primary facultative ponds or secondary facultative ponds (maturation pond). The third step is the removal of nutrients such as nitrates and phosphates as well as pathogens by adding disinfectants. However, addition of disinfectant is rarely done when the effluent is to be released to the environment.

The removal efficiency varies from a few minutes to many days depending upon environmental conditions such as amount of nutrients, sedimentation, predation, parasitism, sunlight, temperature, osmotic stress and presence or absence of toxic chemicals (Ashbolt 1995). A well operated system that involves anoxic and oxic conditions for wastewater treatment can remove up to 90% pathogens (WHO/UNEP 1978). It is recommended to establish CW after maturation ponds system to enhance secondary polishing of wastewater after removal of contaminants in the facultative and maturation ponds has been done (Kayombo *et al*. 1996, Mashauri *et al*. 2000, Johnson *et al*. 2007). The process is enhanced in CW by having plants such as *Phragmites* that aerate the medium and allow aerobic microbial decomposition. The removal efficiency in CW varies with hydraulic residence time, hydraulic loading rate, wetland design, temperature, substrate and vegetation type (Karathanasis *et al*. 2003 and the reference therein). Control of wastewater flow velocity has also been observed to improve pollutant removals (Njau *et al*. 2011).

Effectiveness of treatment systems at improving water quality is normally assessed by Biochemical Oxygen Demand (BOD), nutrient and fecal indicator bacteria (pathogens) removal (WHO 1999). Biochemical Oxygen demand is a measure of the amount of dissolved oxygen consumed by microorganisms for the oxidation of organic and inorganic matter; it provides a measure of the organic content of wastewater and indicates how much oxygen is required to break it down (Lee *et al*. 2002). It is an indirect measure of organic matter. A well operated treatment system can reduce up to 95% of BOD after five days. According to WHO (1995), wastewater to be released to environment should have a BOD of less than 30 mg/l. Pathogen removal is assessed by using indicator bacteria such as total coliform (TC), fecal coliform (FC), *Escherichia coli* (EC), enterococci (ENT) and *Clostridium perfringens* (CP). Indicator bacteria are harmless bacteria that occur in human and warm blooded-animals. A measure of their concentration provides an indication of the degree of fecal contamination and therefore the risk of pathogens being present (Prescott *et al*. 1996). According to WHO (1995), maximum limits of FC and EC bacteria in wastewater for release to environment has been established at < 1000 cfu/100 ml (APHA 1998, WHO 1999).

Although considerable number of reports have contributed to our understanding of the physical, chemical and biological process that facilitate the removal process, inconsistence results suggest that further studies are required to optimize system functioning. For example, many studies show that, a wetland system with vegetation has a higher efficiency of pollutant removal than that without plants (Merlin *et al*. 2002, Kaseva 2004, Bwire *et al*. 2011) while others did not detect any significant difference between planted and unplanted systems (e.g. Baldizon *et al*. 2002). This study therefore, aimed at assessing the performance of constructed wetlands on fecal bacteria indicators, nutrient and BOD removal from wastewater (effluent of WSP) at the University of Dar es Salaam. The removal efficiencies of planted and unplanted cells were compared.

METHODOLOGY

Study site and sampling

Sampling was conducted on subsurface flow constructed wetlands built in 1999 at the University of Dar es Salaam (UDSM) main campus. This CW was planted with *Phragmites mauritianus* plants (three plants /m^2) and is used for the treatment of wastewater from main campus students' hostels, office toilets and staff residents. It has four units (three planted and one unplanted cells) of rectangular shape covering a surface area of 41 m^2 and water depth of 0.5 m. It is built downstream of one of primary facultative pond and lined with concrete. The sewage flow was adjusted by using a mechanical gate valve to ensure constant inflow (a flow rate of about two m^3/day/cell and a retention time of about 12 days).

Sampling was done on weekly basis from November 2009 to January 2010 making a total of 10 sampling visits while students were in session for first semester. During each sampling occasion, six samples were collected (three from inlets and three from outlets i.e. two from planted and one from unplanted cell (control) using sterile bottles (500 ml). The bottles were kept in ice cooled box and transported to the laboratory of Department of Molecular Biology and Biotechnology, UDSM, for analysis of fecal indicator bacteria, Biochemical Oxygen Demand (BOD) and nutrients. In addition, pH and temperature of the influent and effluent were measured on site using a portable pH meter and an alcohol thermometer, respectively.

Analyses

Indicator bacteria

Analysis for Fecal Coliforms (FC) and *Escherichia coli* (EC) was done using membrane filter technique according to standard methods (APHA 1998). Thus, an amount of 100 mls of diluted samples (inlet and outlet samples were diluted 1000 and 100 times respectively) were filtered through a membrane filter (Whatman, 47 mm Dia. and 0.45 µm pore size). The membrane filters were removed aseptically from the filter assembly (Sartorius AG, Goettingen, Germany) and placed onto agar media in pre-prepared plates. The media for FC and EC were Fecal coliform Agar base (mFC) and *E. coli* selective chromogenic media (MERCK and CONDA), respectively. The plates were then incubated at 44.5 ± 0.5 ^oC for 24 hours. Blue and yellow colonies in mFC were counted as fecal coliforms and *E. coli* respectively. When *E. coli* Chromogenic agar media were used, blue colonies indicated *E. coli* and pale yellow/reddish colonies were fecal bacteria (Manafi and Kneifel 1989). The numbers (cfu/100 ml) were computed from mean values of duplicates and the dilutions factors used.

Biochemical Oxygen Demand and Inorganic Nutrients

Biochemical Oxygen Demand test was performed using dissolved oxygen (DO) test meter (model YSI 5100), following standard methods as described in APHA (1998). Inorganic nutrients (phosphates and nitrite/nitrate) determinations were done according to standard method UNESCO (1993).

Data analysis

Statistical tests were carried out using Graph Pad Instant tm 1990 to 1993 software. Prior to the analysis, the data were subjected to normality and homogeneity of variance tests. Parametric, Tukey-Kramer Multiple comparison test (F test) was used for data that were normally distributed while non-parametric tests, Kruskal-Wallis (KW), Dunn's Multiple Comparison post-test and Mann-Whitney U test were used for data which were not normally distributed. P-values less than 0.05 were considered to represent significant differences.

RESULTS

pH and Temperature status of the Influents and Effluents

The pH values in the influent and effluent were variable among the cells. The pH of influent ranged from 7.1 to 7.4 with an average of 7.2 ± 0.1. In the effluents of planted cells, the pH ranged from 7.5 to 7.7 with an average of 7.5 ± 0.1 while in unplanted cell ranged from 7.2 to 7.4 with an average of 7.3 ± 0.1. The pH values in the influents were significantly ($P < 0.0001$; KW = 31.1) lower than in effluents. The Dunn's multiple comparison results showed significant ($P < 0.001$) differences between influents and effluents of planted cells while there was no significant ($P > 0.05$) difference between influents and effluent of control (unplanted) cell. In addition, pH values in effluents of planted cells were significantly ($P < 0.01$) higher than the unplanted cell. The temperature values during the study period ranged from 29 to 33 ^{o}C, with an average of 31 ± 1.2 ^{o}C and did not vary significantly ($P > 0.05$) between influent and effluents of different cells.

Escherichia coli

The variations of numbers of *Escherichia coli* (EC) in 100 ml sample (cfu/100 ml) of the influents (inlets) and effluents (outlets) of both planted and unplanted (control) cells are presented in Figure 1. They ranged from as high as 85 x 10^3 cfu /100 ml in the influent to as low as 1.1 x 10^3 CFU/100 ml recorded in effluents of planted cells. On average the EC numbers were 60.4 ± 14.2; 7.30 ± 1.42 and 3.51 ± 0.68 x 10^3 cfu /100 in influent; effluent of unplanted cells and effluent of planted cells, respectively. This translates to the overall EC percentage removal of 92.9 ± 6.05% in planted cells and 75.2 ± 21.3% in unplanted cell. Statistically, it was clearly shown that there were significant ($P < 0.0001$; KW = 28.1) higher numbers of EC in influent than in the effluents. However, Dunn's multiple comparison results shows extreme significant ($P < 0.001$) differences between influents and effluents of planted cells, while there was a slight significant ($P < 0.05$) difference between influents and effluent of unplanted cell. In addition the numbers of EC in effluents of planted cells were significantly ($P < 0.05$) lower than in the effluents of unplanted cell. Thus, the percentage EC removal in planted cells was significantly ($P = 0.001$; U = 9.00) higher than in unplanted cell.

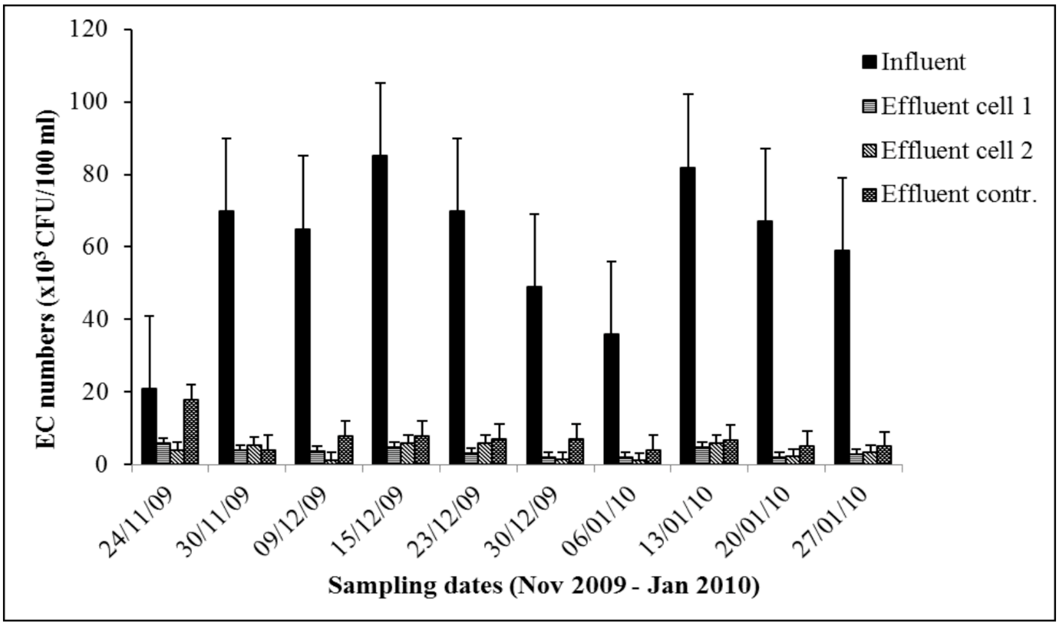

Figure 1: Mean concentration of *E.coli* in influents and effluents in cells 1, 2 and the control (Bars are standard deviation (+).

Fecal Coliforms

The number of Fecal Coliforms (FC) in the influents and effluents of both planted and unplanted cells are presented in Figure 2. They ranged from 40.0 x 10^3 cfu/100 ml in influent to 0.30 x 10^3 cfu/100 ml in the effluent of planted cells. On average, the numbers were 26.5 ± 2.42, 10.2 ± 0.93 and 1.76 ± 0.34 x 10^3 cfu/100 ml in influent, effluent of unplanted cells and effluent of planted cells, respectively. Statistical comparison of the numbers of FC in the influents and effluents showed that there were significantly ($P < 0.0001$; KW = 31.03) higher numbers in influents than in the effluents with Dunn's multiple comparisons test showing that the significant differences were between influents and effluents of planted cells ($P < 0.001$) and between influents and effluents of unplanted cell ($P < 0.05$). The number of FC in effluents of planted cells was significantly ($P < 0.05$) lower than in the effluents of unplanted cell, and that the two planted cells did not show significant ($P > 0.05$), difference. Likewise, the FC percentage removal was significantly ($P < 0.0001$; U = 5.00) higher in planted cells than unplanted cells, with an average percentage removal of 93.2 ± 6.13% and 58.7 ± 21.2% respectively.

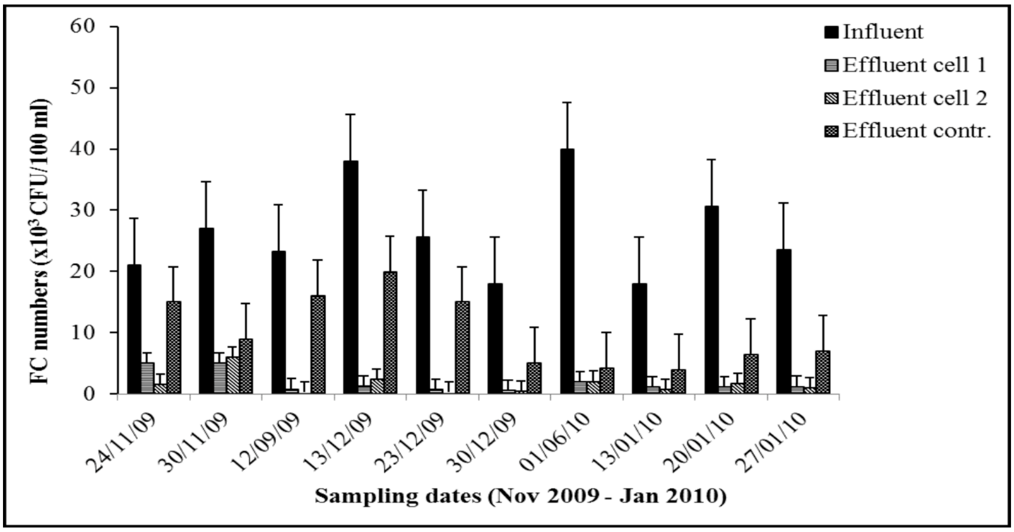

Figure 2: The average number of FC in influent and effluents in cells 1, 2 and the control cell (Bars are standard deviation (+).

Biochemical Oxygen Demand

Influents and effluents BOD levels are presented in Figure 3. In the influent, BOD level ranged from 60 to 70 with an average of 65 ± 8.6 mg/l. Effluent BOD of planted cells ranged from 12 to 27 mg/l with an average of 16 ± 6.1 mg/l while in unplanted cell, BOD ranged from 31 to 38 mg/l with an average of 35 ± 14 mg/l. Thus, the BOD levels in the influents were significantly ($P < 0.001$; KW = 33.13) higher than in effluents with post hoc results showing significant differences to be between influents and effluents of planted cells ($P < 0.001$) as well as between influents and effluent of unplanted cell ($P < 0.05$). Also, the BOD levels in effluents of planted cells were significantly lower than in the effluent of unplanted cell ($P < 0.01$), while the two planted cells did not differ significantly ($P > 0.05$). Likewise, there was a significantly ($P < 0.0001$; U = 0.0001) higher percentage removal of BOD in planted cells (ranged from 54% to 76% with an average of 71 ± 6.2%) than in unplanted cell (ranged from 39% to 48% with an average of 45 ± 3.3%).

Inorganic Nutrient

Results on the concentration of nitrate and nitrite combined (NO_x) and that of Phosphate in influent and effluents varied slightly among sampling occation (Figure 4). The NO_x concentration averaged 0.615 ± 0.157, 0.463 ± 0.305 and 0.133 ± 0.001 µM in the influent, effluent of unplanted cell and effluents of planted cells respectively. Thus, there was a significantly ($P < 0.0006$; KW = 17.53) higher concentration of NO_x in the influents than in the effluents with post hoc results showing a significant ($P < 0.01$) differences between influents and effluents of planted cells as well as between influents and effluent of unplanted cell ($P < 0.05$). Also, the concentration in effluents of planted cells was significantly ($P < 0.05$) lower than in unplanted cell.

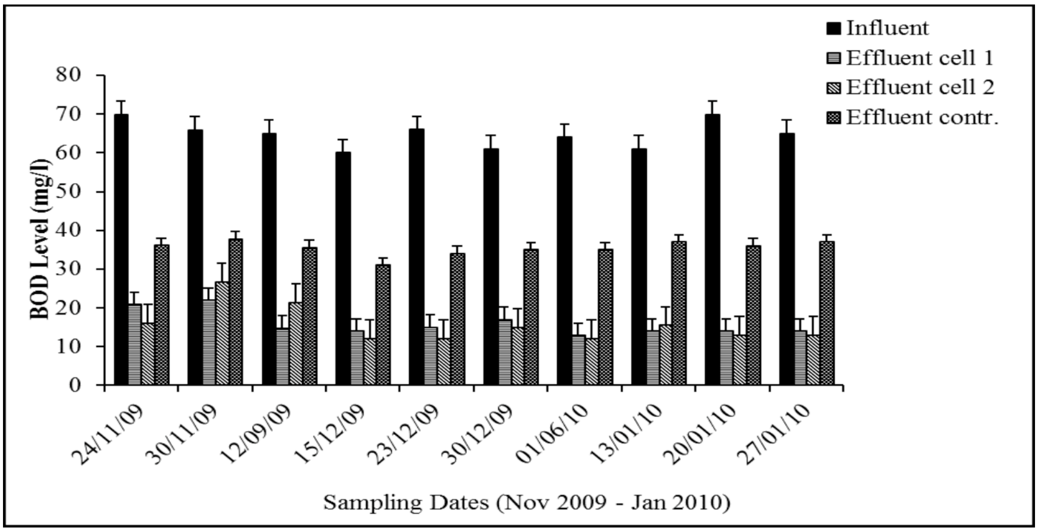

Figure 3: BOD levels (mg/L) in influent and effluents (cells 1, 2 and control) in the studied CW (Bars are standard deviation (+).

The phosphate concentration (Figure 4B) ranged from 0.004 in effluent of planted cells to 0.013 µM in influent. The values averaged 0.0095 ± 0.001, 0.0085 ± 0.0005 and 0.0055 ± 0.0004 µM in influent, effluent of unplanted cells and effluent of planted cells respectively. The concentration in the influents was significantly ($P < 0.0001$; $F = 22.68$) higher than in effluents with post-hoc results showing significant ($P < 0.001$) differences between influents and effluents of planted cells, while there was no significant ($P > 0.05$) difference between influents and effluent of unplanted cell. It was also shown that the phosphate concentration in effluents of planted cells was significantly ($P < 0.01$) lower than in the effluent of unplanted cell.

In general, the percentage nutrients (nitrates/nitrite and phosphates) removal obtained in various experiments was significantly ($P < 0.01$) higher in planted than in unplanted cells. Thus, the nitrate/nitrite percentage removal averaged 58.1 ± 35.3% for planted cells and 21.6 ± 8.3% for unplanted cell while phosphate percentage removal averaged 40.1 ± 14.5% for planted cells and 5.2 ± 1.9% for unplanted cell.

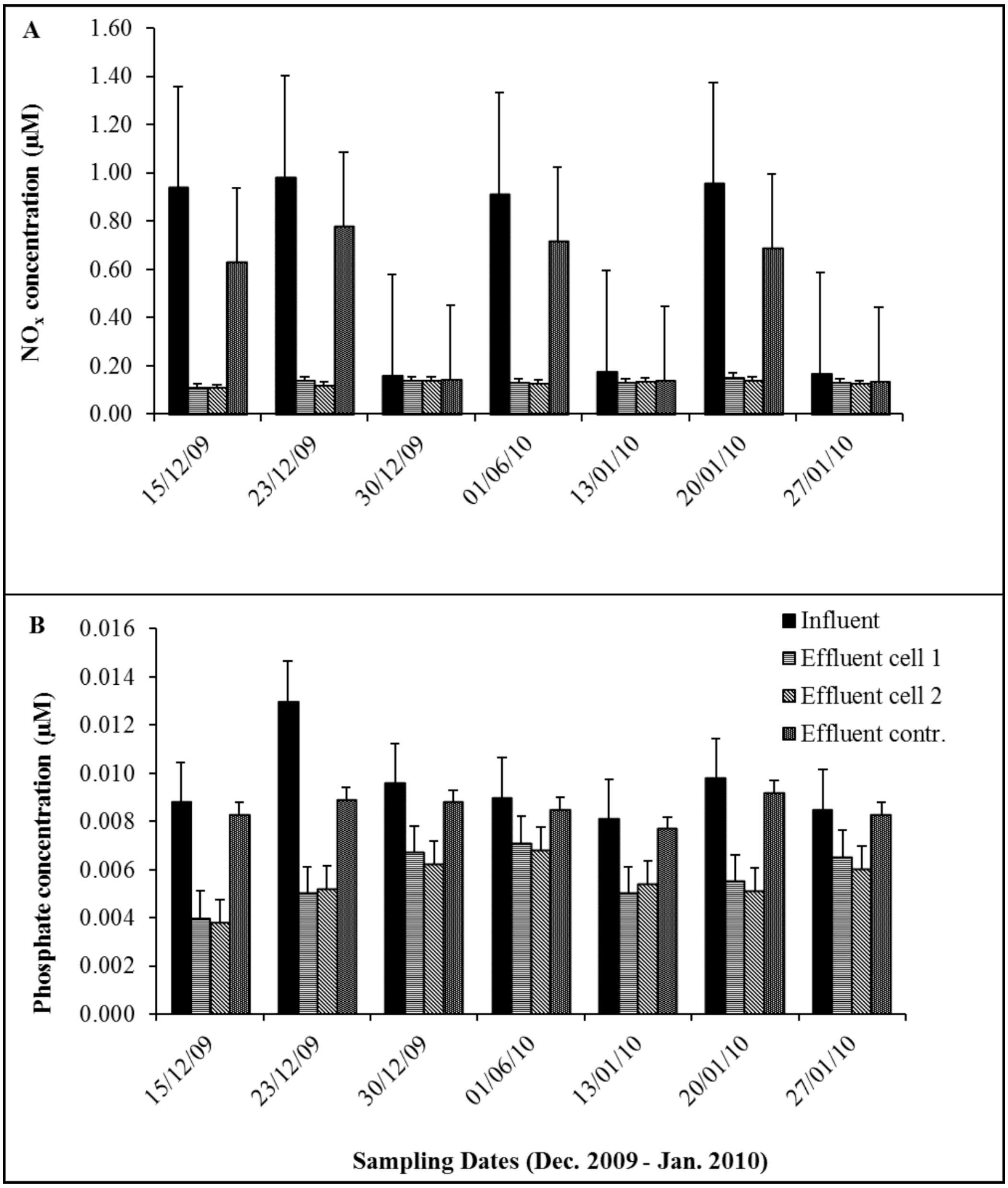

Figure 4: Average nutrient concentration during the different sampling occasions. A) Nitrate and nitrite combined (NOx), (B) phosphate .

DISCUSSION

Temperature and pH values in the present study corresponded with other reports in the studied area (e.g. Kayombo *et al*. 1996, Kaseva 2004, Zenorina 2008). These ranges are suitable for high microbial activities as they are within the optimal values of 6.5 to 7.5 for pH and between 25°C and 35 °C for temperature (Metcalf and Eddy 1995, Prescott *et al*. 1996). The variations in pH and temperature may be explained by differences of weather during sampling days (i.e. sunny or cloudy day and contents and amount of sewage released). There was also an influence of the wetlands system due to presence of plants and gravels that prevent direct sunlight from reaching the wastewater as it passes through the wetland. The higher pH values in effluents than in influents of the CW may be due to plants exudates or uptake of carbon dioxide during the day by photosynthetic plants and microorganisms (Kaseva 2004, Kyambadde *et al*. 2005).

The numbers of Fecal coliforms (FC) and *E. coli* (EC) in the CW influent (i.e. effluents of primary facultative pond of the UDSM WSP) were low as compared to many other studies elsewhere. For example, Garcia-Armisen *et al*. (2008) reported EC counts averaging 9.7 x 10^6 cfu/100 ml for the influents before entering a CW system. In their system, raw wastewaters were subjected to a primary treatment to reduce the amount of solid waste in the wetland. The lower numbers in effluent of UDSM WSP may be explained by the fact that the wastewater passed through first ponds (anaerobic ponds) where it stayed for some days (between one – three days) during which purification processes were ongoing. Bacteria may be reduced by sedimentation, chemical reactions, natural die-off and predation by zooplankton, nematodes, lytic bacteria and attacks by bacteriophages (Kadlec and Knight 1996, Denny 1997).

The higher percentage removal of fecal indicator bacteria in planted cells in this study corresponded with other findings that have demonstrated an improved removal in the presence of wetland plants (Decamp and Warren 2000, Merlin *et al*. 2002, Karathanasis *et al*. 2003, Boutilier *et al*. 2010). In many cases, removal efficiencies have been reported to be nearly greater than 90% for fecal coliforms and greater than 80% for *E. coli* (Kadlec and Knight, 1996) using reed beds (*Phragmites*) plants in wetlands. Choate *et al*. (1993) for example, reported fecal coliforms removal efficiency of 88 to 99%, in Kentucky (United States) while Byers and Young (1995) indicated average reduction of FC of 93.8% in rural Kentucky. They both used decorative flowering plants (canna lilies, irises, green tarrow, Thalia, umbrella palms, and rushes) planted in the gravel of CW. Boutilier *et al*. (2010) reported 95% *E.coli* removal in constructed wetland using cattails (*Typha)* plants in Bio-Environmental Engineering Centre in Truro, Nova Scotia, Canada. Decamp and Warren (2000) using *Phragmites* plants in both pilot scale CW and laboratory systems (microcosm) in United Kingdom, reported average *E. coli* removal efficiency of 72% for microcosm and 98% for pilot scale systems. All these studies showed the ability of constructed wetland systems using various plant species in treating domestic wastewater hence preventing pollution problems. The role played by plants in relation to the treatment of wastewater is the physical effects brought about by the presence of the plants. The macrophytes stabilize the surface of the beds, provide good condition for physical filtration and provide huge surface area for attached microbial growth (Brix 1994). Furthermore, macrophytes reduce velocity of wastewater into the wetland system, and also supply oxygen at the root zone which is used by aerobic microbes, thereby enhancing purification process of wastewater, in addition to purification done by anaerobic microbes (Watson *et al*. 1989).

The BOD and nutrient levels in influents were also low due to the same reasons of purification activities in the preceding stages. However, the values were similar to other earlier reports (e.g. Bilha 2006, Seswoya and Zainal 2010). Average BOD removal efficiency in this study was 73% which was much higher than the earlier value of 53.9% reported previously by Bilha (2006) from the same wetland. Higher values of BOD_5 removal had been reported by a number of other researchers including Teck *et al.* (2009) who worked in a subsurface flow wetland planted with *Phragmites mauritianus* who reported removal efficiency of 96%. Also, Kivaisi (2001) working in a surface flow constructed wetland system using floating macrophytes (*Eichhornia crassipes)*, a water hyacinth species reported removal efficiency of 81%. Likewise, Ismail *et al.* (2008) found BOD removal efficiency of up to 85% by *Phragmites* in CW system in Egypt. Watson *et al.* (1989) noted that apart from the removal due to microbial decomposition process of organic matter in the water column, also removal process is by sedimentation/filtration process. The possible reason for lower values in the current study as compared to other reports may be due to low levels of degradable organic matter entering the constructed wetland systems as such much of it might have been reduced in WSP systems. However, the organic matter content of the studied sewage was not determined and remains a subject of future studies. Another possible reason could be a lowered efficiency of the studied CW due to the fact that it has been operating for more than 10 years with the same planted macrophytes. As Moshiri (1993) pointed out that the oxygen required for aerobic degradation in wetland is obtained through diffusion, convection and oxygen leakage from macrophyte roots into the rhizosphere. Hence, treatment efficiency of constructed wetland for the removal of organic matter is also dependent on how it supports the oxygen concentration in the gravel bed.

Inorganic nutrient removal is controlled by similar factors as BOD. This could be explained by the fact that nutrients in wastewater are bound in organic matter, and are slowly released as the organic matter is decomposed. Due to sedimentation process of organic matter in WSP system and a retention time of 1.0–3 days of wastewater in WSP, much of the nutrients may have been used while others were still bound in organic matter. This implied lower nutrient levels available in the wetland system. The phosphate removal mechanism includes chemical adsorption, precipitation in substrate, biological transformations and to a lower percentage by plant uptake (Kadlec and Knight 1996). The removal mechanisms for nitrate include uptake by plants and microorganisms, ammonification, nitrification, denitrification, ammonia volatilization and cation exchange for ammonium (Vymazal 2006). The results showed that plants played a big role in the removal of nitrate and phosphate from wastewater to corroborate other studies. In his study, Kaseva (2004) reported removal efficiency of nitrate-nitrogen of 40.3% in CW *Phragmites* planted cells while in the unplanted cell the removal was 32.2%. Sarafraz *et al.* (2009) working with subsurface CW planted with *Phragmites* in Teheran University (Iran), reported removal efficiency of nitrate-nitrogen of 79% in planted cells. These studies demonstrated the ability of plants in the removal of nutrients from wastewater. In the present study, removal efficiency in unplanted cell for nitrate-nitrogen was low, suggesting that plants play a big role in the nitrate/nitrite uptake from the water column. This was in contrary to observations made by Armstrong and Armstrong (1991), Brix and Schierup (1989) and Sarafraz *et al*. (2009) that for the removal of nitrate-nitrogen (NO_3-N), the gravel–bed wetland system without vegetation was found to be the optimal one. In addition, Sarafraz *et al*. (2009) reported that subsurface flow CW can remove phosphorus with removal efficiency as high as 96.12% in unplanted cells and as low as 76.65% in planted cells.

When compared to WHO standards, the pH of the effluent in the UDSM CW remained relatively neutral, and no pH levels were observed above or below the WHO/ UNEP (1997) pH guidelines for the protection of freshwater aquatic life of less than 6.5 and greater than 8.5. Although the numbers of EC and FC of planted cells were low, they did not meet WHO standards for release into the environment. The EC and FC numbers in the effluents of the CW were on average higher than recommended levels of less than 1000 cfu/100 ml for discharge into environment (WHO 1999) may be due to little retention time of wastewater in CW. The low retention time could have been caused by clogging of the system by accumulating solids, or channeling of wastewater through the wetland. However, in some samples from the planted cells, the numbers were lower and met standards for release into environment. In order to meet standards, it is suggested to increase retention time, and wetland size to allow more wastewater to be treated to match with amount of wastewater produced**,** in addition to regular maintenance of the wetland to enhance sewage treatment. Wetland treatment systems require longer retention time to allow more time for contact between sewage, root systems, soil, sand or gravel (Katima 2005). It is also suggested to use wastewater from maturation ponds instead of the facultative and anaerobic ponds. Higher values of fecal bacteria are a warning of possible presence of pathogens in water systems posing health risks to humans. Discharging such kind of effluent may lead to disease outbreak due to possible presence of pathogens (Haile *et al.* 1999). The disease outbreak may be due to primary body contact and consumption of food which may be contaminated by the pathogens (Henrickson *et al*. 2001, Daby *et al*. 2002,).

The mean values of BOD and nutrients obtained at effluents of CW met the recommended discharge standards. The permissible WHO standards for discharge should not exceed 30 mg/l for BOD, 5 mg/l for phosphate, and 45 mg/l for nitrate (WHO 1999, 2004) are higher than the obtained values in planted effluents observed in this study. Thus, a combination of various treatment methods results into a best way of BOD and inorganic nutrients removal (Kivaisi 2001, Katima 2005). This suggests the use of both WSP and CW in order to meet the discharge standards.

In Tanzania the use of CW has been adopted since 1990's for wastewater treatment jointly with WSP (Katima 2005). When are jointly used they bring best results in wastewater treatment particularly in fecal indicator bacteria and BOD removal. Also they are of low cost and easy to maintain compared to conventional wastewater treatment methods. Basing on the results of this study, it is evident that constructed wetlands in tropical countries are efficient in wastewater treatment as already recommended by several researchers on these systems. Planted cells of constructed wetland perform better than unplanted cells. The 10 year's old *Phragmites mauritianus* constructed wetland studied was found to still treat wastewater and continue to be efficient. Treatment performance in the reduction of fecal coliform bacteria, BOD and nutrients was demonstrated. The wetland is maintained by harvesting of plants when they reach maturity to allow regeneration, and also by clearing/ uprooting undesired plants that naturally may grow into the wetland systems. It is also recommended for the UDSM to construct more CW after the maturation ponds and not from facultative or anaerobic ponds. The results suggest that CW is a viable wastewater treatment option where conventional treatment options cannot be met.

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