ASSESSMENT OF WASTE STABILIZATION PONDS (WSP) EFFICIENCY ON WASTEWATER TREATMENT FOR AGRICULTURE REUSE AND OTHER ACTIVITIES A CASE OF DODOMA MUNICIPALITY, TANZANIA

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Abstract

This study aims to assess the parameters removal efficiency of waste stabilization ponds of Swaswa area in Dodoma municipality. The study was done by analysing nine parameters in groups of biochemical and nutrients parameters. One year (2010) analysis was done in monthly intervals from January to December. Some of parameters were analysed in situ while the rest are taken to Dar es Salaam for laboratory analysis where by the water samples were taken in 4^oC equipment for transportation. Results show very low removal efficiency for most of parameters from no removal at all to 26.7% (BOD$_5$, pH, TDS, E.C, Total alkalinity, and Total hardness, NO$_3$-N and PO$_4$-P) from the influent to the final effluent. Only turbidity shows an excellent removal of 98.8%. The removal efficiencies were also compared to general removal efficiencies from other studies and find out results from this study are very low. This low removal efficiency may be due to incomplete construction of Swaswa ponds where the third stage of maturation is missing. This stage is essential for polishing water and nutrient as well as pathogen removal. There is need of frequent awareness campaign to a community for the reuse of wastewater for agriculture and its possible impacts. Ponds should be modified and addition of maturation ponds constructed. Further studies are required for pathogen removal assessment and impacts of reuse wastewater to the food crops.

Key Words: *waste stabilisation ponds, wastewater reuse, agriculture, removal efficiency, biochemical parameters, nutrients*

Introduction

Most arid and semi-arid regions especially in developing countries in Africa experience severe shortage of water. This condition encourages the search for alternative sources of water. Moazzam and Khan (2007) pointed out the possibilities of domestic wastewater reuse considerations, but it must be done after several treatment processes. In many regions of the world this technology has been used as an additional renewable and reliable source of water for irrigation purpose (Angelakis *et al.,* 2003 and Oron, 2003). Wastewater effluents if well treated can make a good contribution to water conservation and expansion of irrigated agriculture, taking on an economic dimension. It also solves disposal problems aimed at protecting the environment and public health by preventing surface water pollution (Papadopoulos and Savvides, 2003). Wastewater reuse requires effective treatment and measures to protect public health and the environment at a feasible cost (Moazzam and Khan, 2007; Sipala, *et al.,* 2003; Anderson, *et al.,* 2001). However, data on economic potential of Waste Stabilization Ponds (WSP) effluent is insufficient. There is still a risk of contamination of crops and soil irrigated with the effluent of WSP (Alcalde *et al.*, 2003).

Selection of proper treatment technology is needed in developing tropical and subtropical countries where the high costs of conventional treatment plant are not affordable. Waste stabilization ponds (WSP) technology is one of the most appropriate extensive wastewater treatment methods due to their low operation and maintenance costs coupled with effective pathogens removal. The WSP technology is widely employed, despite its need of large spaces for construction (Mara and Pearson 1998; Alcalde *et al.,* 2003; Khan and Ahmed 1992). Wastewater character is another issue to consider as it can fall into four different groups according to its BOD$_5$ amount; weak (<200mg/l), medium

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(350mg/l), strong (500mg/l) and very strong (>750mg/l) (Mara, 2003). Climatic factors are major considerations on selection of a WSP system. Factors like temperature and solar radiation favour microbial growth because wastewater consists of organic matter whose degradation largely depends upon microbial activity. Mara and Pearson (1998) pointed out that hot climate is ideal for pond operation.

Development activities on WSP are mostly based on loading rate; retention time, pond depth, solar radiation, total sunshine hours, wind velocity and rain fall (Mara, 1987; Curtis and Mara, 1994; Ellis and Rodrigues 1995a, 1995b).

Dodoma, capital of Tanzania lies between 6° 00′ and 6° 30′ South and 35° 30′ and 36° 02′ East, covers an area of 2769km^2 of which 542km^2 is built up area. The climate is characterized by a long three seasons lasting between April and early December and a short single wet season occurring during the remaining month with average coverage rainfall 570mm and about 85% of this fall in the months between December and April and average maximum and minimum is 31°C and 18°C respectively. In June to August, temperature is high during the afternoon up to 35°C and experiencing the chilly nights on hilly areas to 10°C (Dodoma profile, 2003).

The regional is characterized with bush or thickets type which is widespread throughout the area wherever the natural plants covers has been altered by district factors depression and sometimes mixture of Gilles mixed with wood plants. Swaswa area has a population of 831 people but recently is estimated that it has more than 1300 inhabitants (Census, 2002). This is due to the high rate of urbanization, fuelled by massive rural-urban migration, rising in urban poverty, urban agriculture practiced for income and employment generation, food security, advantages of urban environment for producers, including availability of cheap input such as wastewater and rise in food prices (WORLD BANK, 2008). The driving force makes poor people to migrate from urban to peri-urban areas. People who are living around the Swaswa wastewater stabilization ponds used the wastewater for socio-economic activities (Mghase, 2010).

The sewerage system of Dodoma municipality serves about 40,000 people at the moment which is only about 10% of its full capacity. It has a maximum diameter of 1000mm, maximum flow of 3,672m^3/hour and length of 24.3km. The trunk sewer has a capacity of serving 423,000 people. Some few areas are completely covered by lateral sewers of 23km length and 250mm in diameter. Wastewater from this system is finally treated by WSP which are located in Swaswa area. There are four waste stabilization ponds that covering an area of 40,000m^2 with 200 m by 200 m and depth of 1.5m each. The ponds have capacity of serving wastewater from 68,000 people only. Two of the ponds though in use, are not yet fully constructed. The effluent from WSP is used by farmers for rice farms irrigation (DUWASA, 2010; Mghase, 2010).

The different types of WSP can be used individually, but the most efficient and common system generally consists of three stages in series: first an anaerobic, then a facultative pond and finally an aerobic or maturation pond. Anaerobic and facultative ponds are designed for BOD (Biological Oxygen Demand) removal and maturation ponds for pathogen removal, although some BOD removal occurs in maturation ponds and some pathogen removal in anaerobic and facultative ponds (SSWM, 2012). Structure of Dodoma WSPs consists of two anaerobic and two facultative ponds working in series only, no maturation stage at all.

Statement of Problem

Waste stabilization pond (WSP) is one among wastewater treatment technologies that mainly used in hot country like Tanzania and perform well in pathogen and nutrient removal, leaving the effluent being nutrient-rich for agriculture. This will be met when the ponds were well designed and performing to the fully designed capacity. WSP that receive wastewater of Dodoma municipality was designed long time considering the number of people presented in that time. The ponds were constructed in 1979 for temporally serving before the permanent WSP to be constructed at Nzuguni area. Unfortunately, the ponds are still being used regardless the increase of population from that used during designing more than 30 years ago. Apart from two of four present ponds being not fully constructed, the systems have currently showed different problems on performances such as: lack

of maturation ponds, which is a third process on the WSP system to remove nutrients and reduce fecal coliform. Other problems are frequent blockages due to solid waste entering into the system, shortage of unblocking tools and equipment together with shortage of funds to de-sludge the ponds. The effluent from WSP is discharged in the downstream valley where it is used by the community for irrigated agriculture in rice farms.

The assessment on quality of WSP effluent gives out clear picture on what quality of water that has been used for agriculture of food crops. This study was assessing the quality of wastewater influent and effluent in terms of physical-chemical, biochemical and bacteriological performances. The results presented the efficiency of WSP and give the necessary recommendations on their performances and the use of wastewater for agriculture.

Research Question
What is the efficiency of Waste Stabilisation Ponds (WSP) used for urban wastewater treatment which finally being reused for irrigation and other activities?

Objectives
This study was undertaken to examine the efficiency of WSP on the treatment of wastewater that finally used for urban agriculture and other activities that need second quality water. The broad objective of this study is to assess the efficiency of waste stabilization ponds by determining the quality of wastewater influent and effluent and to propose the proper procedures for upgrading their performances. To fulfil the main objective, there are several specific objectives which are;

To quantify the biochemical parameters and nutrients of wastewater influent and effluent points of WSP.To perform the efficiency assessment of WSP for biochemical and nutrients parameters. Lastly is to propose the proper procedures for upgrading pond performance.

Material and Methods
Research Design
This research was conducted as a cross sectional single case study, by using qualitative and quantitative data collection approaches. The case of this study was waste stabilisation ponds

(WSP) of Dodoma municipality. It was a single case study because it involves a single area to be studied bounded in a specific time, and with a single reference period of study as cross sectional design. The phenomenon within the case was the efficiency of WSP on the wastewater treatment that used for the irrigation. The relevant stakeholders involved throughout of the study was the local communities in Swaswa area near the WSPs that use treated wastewater for irrigation, government officials in water utility (DUWASA) and all those who were involved.

Data Collection Methods
Since it was a case study, multiple sources of data were involved to obtain a desirable relevant data. Two data types (primary data and secondary data) were collected from different data sources. For primary data, qualitative and quantitative data were collected. The qualitative data for WSP performances obtained by an interview at Dodoma urban water and sewerage authority (DUWASA) office while the quantitative data were obtained by laboratory analysis. Secondary data obtained from different previous data sources like research reports, journals, text book, census book, planning reports, and all relevant information to gather all required data mainly through internet and from DUWASA documents. The literature review was conducted to obtain the most relevant information on water and wastewater management in Dodoma municipality.

Experimental Methods
Sampling and in-situ analysis
Water grab samples were collected in polyethylene bottles on a monthly basis (once in a month) throughout the year (early January to early December 2010) at the influent and effluent locations of ponds. *In situ* measurements were done for Electrical conductivity (EC) and pH by using HQ 30d and KTO, SENSION 156 equipment for temperature, conductivity and total dissolved solids (TDS). Samples for laboratory analysis were stored in sterilized polyethylene bottles at 4°C and transported to Dar es Salaam for analysis at Ministry of water laboratory (Ubungo) for BOD_5, Turbidity, Total Alkalinity, Total Hardness, NO_3-N and PO_4-P. Detailed information on analytical methods is available in Ahearn *et al*. (2004). To obtain the total efficiency of WSP, the wastewater samples were

collected at the influent and effluent points of the pond.

Laboratory Analysis

At Ubungo laboratory the wastewater samples analysed immediately on the arrival. The analysis was done for BOD_5, Turbidity, Total Alkalinity, Total Hardness, NO_3-N and PO_4-P by using mass spectrophotometer. Analysis for all parameters was done according to the Standard Methods for the Examination of Water and Wastewater (APHA 1992).

Statistical Analysis

Microsoft Excel program was used for analysis of statistical values; average and their standard deviations. To evaluate the performance of each pond removal efficiencies for all the parameters monitored were computed on the basis of concentration. The concentration-based efficiency *(E)* was computed according to Equation (1) below (ref.).

$$E_T(\%) = \left(\frac{Ci - Ce}{Ci}\right) \times 100 \quad \text{...................Eqn.(1)}$$

Where:

E_T is Total efficiency of the ponds
Ci is influent concentration to the ponds
Ce is effluent concentration from the pond

Results and Discussion

The average temperature in the coldest and hottest situation was observed to be 16°C and 29°C respectively. This condition is within one of the reported to be the good condition for the WSP functioning (Mara and Pearson, 1998). The average wastewater flow rate during this study was 4,690m³/day (EWURA, 2010). The annual mean values of analysed parameters are presented in table 1. The mean values are for the influent to the anaerobic pond, its effluent which is also the influent to the facultative pond and the total effluent from the facultative ponds. Total removal efficiency for each parameter was calculated and results presented in table 1.

Table 1: Annual average results of analysed grab samples from the ponds

	Parameters	Influent to Anaerobic pond	Influent to Facultative pond	Removal efficiency of anaerobic pond	Effluent from Facultative pond	Total Removal Efficiency (%)
1	TDS mg/l	971.17	920.33	5.23	849.08	12.6
2	E.C* μS/cm	1768.17	1628.67	7.89	1538.83	13.0
3	Temp °C	24.46	24.24		24.38	
4	BOD_5 mg/l	27.89	38.71	0	29.25	0
5	pH	8.05	7.91	1.74	7.79	
6	Turbidity NTU	>4000	>4000	0	44.97	98.8
7	Total Alkalinity mg/l	643.17	676.67	0	557.17	13.4
8	Total Hardness mg/l	382.58	283.00	26.02	280.58	26.7
9	NO_3-N mg/l	3.32	3.24	2.41	3.23	2.7
10	PO_4 –P mg/l	4.78125	3.4	28.89	4.78125	0

*1000 μS/cm = 1mg/l

Overall Ponds removal efficiencies

Raw wastewater can be categorised into four groups of weak, medium, strong and very strong using amount of BOD_5 and/or COD in its typical compositions (Mara, 2003). Raw domestic wastewater of Dodoma municipality falls into *weak* group based on BOD_5 amount which is less than 200mg/l. Based on TDS values, wastewater is characterised as *strong* wastewater (Sincero *et al.*, 2002). For weak wastewater one can assume

that its treatment especially biological parameters will be easier. The WSP was able to reduce parameters in very low performances less than 50% efficiency for all. BOD_5 and PO_4-P show an increase and with no removal at all respectively from the influent. Other parameters have been removed at low percentage. This shows that regardless the weak wastewater (BOD_5< 200mg/l) of a raw domestic wastewater collected, the ponds fail to reduce it and let the amount to increase due to its incomplete construction. The

ponds show 2.7% removal of nutrient (NO_3-N) from the influent to the effluent which is very low compared to the general design performance of facultative ponds according to suggestions former researches. Sperling, (2005) suggested that general removal efficiency characteristic for the facultative (in this case is the last step) should remove 75-85% of the influent BOD_5.

The amount of nitrates (NO_3^-) allowed by the Tanzania standards to be discharged is 20mg/l (TBS, 2005). The effluent contains 3.23mg/l of NO_3-N regardless the lower removal efficiency (2.7%) the ponds fall within the allowable limit. The small amount of nitrate-nitrogen at the effluent does not give a good picture of the performance but it tells that domestic wastewater collected has low nitrate-nitrogen. Also the low performances can be because of lack of stage-three of the ponds series which is *Maturation pond(s)* to complete the removal of nutrient.

WSP has managed to reduce electrical conductivity value by 13% from annual average of 1768.17µS/cm (1.768mg/l) to 1538.83µS/cm (1.538mg/l) for influent and effluent respectively. According to TBS, (2005) the allowed limit of EC to the effluent wastewater is 400mg/l, so the amount of measured EC is within the required standard. The WSPs have shown an excellent removal of turbidity by reducing more than 4000 NTU at the influent of the first and second steps

to the 44.97NTU at the final effluent which is almost 98.8% removal.

Wastewater pH ranges from 6.8 - 8.5 in average which is the essential range for the desirable bacteria (TBS, 2005). In this study, wastewater PH ranges from 8.05 at the influent to 7.79 at the effluent. The range of PH at all stages is within the required amount.

In a comparison to what has already been studied, the general pond removal performances to some parameter have been suggested by Sperling, (2005) as shown in table 2 below. This parameter compared with this study to give a general idea of how the ponds of the same type can perform. Dodoma facultative ponds show poor performances in all analysed parameters (BOD, N, and P).

This low amount of parameters at the effluent might give promising results of pond removal efficiency. In a contrary, the ponds show the poor performances on removing some parameters. This may be explained because of two reasons; the municipal wastewater collected from Dodoma comprises only domestic wastewater, which means the wastewater is quite weak and the parameters are low even from the influent. The other reason is because of poor construction and partial completion of WSP stages (no maturation pond as a last stage).

Table 2: General characteristics of the main pond performance system

Pond Removal efficiency (%)			
Parameter	Facultative pond	Maturation pond	Facultative pond (This study)
BOD	75-85	80-85	0
COD	65-80	70-83	N/A
SS	70-80	73-83	N/A
Ammonia	<50	50-65	N/A
N	<60	50-65	2.7
P	<35	>50	0
Coliforms	90-99	99.9-99.999	N/A

Source: Adapted from Sperling, (2005), N/A=not applicable

Effluent quality and the standards

Table 1: Overall effluent from the pond with comparison to TBS

Parameters	Units	Total annual average on Outlet (Effluent from Facultative pond)	TBS standards
TDS		849.08	3000
E.C	µS/cm	1538.83 (1.54mg/l)	400[*]
BOD$_5$		29.25	30
PH		7.79	6.5-8.5
Turbidity	NTU	44.97	300
T.Alk	mg/l	557.17	N/A
T.Hard	mg/l	280.58	N/A
NO$_3$-N	mg/l	3.23	<0.5
PO$_4$ -P	mg/l	4.78125	N/A

Source: TBS, (2005)

Quality of wastewater effluent was then compared to the effluent standards of Tanzania Bureau of Standards (TBS). Table 3 shows the summary of amounts of analysed parameters together with that allowable limit from TBS. Most of analysed parameters (TDS, E.C, BOD$_5$, pH and Turbidity) are within the required limits. Only NO$_3$-N does not meet the required amount of <0.5mg/l. The rest of the parameters (Total alkalinity, total hardness and PO4-P) have no TBS limits available for comparison.

Conclusion

Based on this study, it can be concluded that, wastewater to waste stabilization ponds show high amount of biochemical parameters (BOD$_5$, PH, Turbidity, TDS, E.C, Total alkalinity, and Total hardness on the influent point, and little different on the effluent. The quantity of nutrients (NO$_3$-N and PO$_4$-P) of wastewater at the influent is almost the same from that of effluent from the WSP.

One of the most important problem of the WSP is the very low overall removal efficiencies of WSP for all analysed parameters (biochemical and nutrients), ranging from 0% to 27%.Only turbidity has been removed by 98.8%. In a comparison with Tanzania Bureau Standards of wastewater to be disposed of or reused, most of effluent parameters meet the required thresholds.

This low amount of parameters at the effluent might give promising results of pond removal efficiency. In a contrary, the ponds show the poor performances on removing some parameters. This may be explained because of two reasons; the municipal wastewater collected from Dodoma comprises only domestic wastewater, which means the wastewater is quite weak and the parameters are low even from the influent. The other reason is because of poor construction and partial completion of WSP stages (no maturation pond as a last stage), which is another important problem of the pond.

There is need of upgrading the performance of this pond for better removal. This might be done by frequent desludging of present ponds where necessary and additional of a third stage (maturation) especially for nutrients and pathogen removal. Also frequent maintenance is required for the present ponds to make sure they are performed to the required designed level. Frequently awareness campaigns to a community are required for wastewater reuse in agriculture, especially for the food and vegetables that are directly eaten. Further research is required for the pathogen removal and impact of reused wastewater to those crops at Swaswa area.

If the wastewater is well treated by the ponds, there is opportunity of wastewater reuse especially to the uses that do not need drinking water quality, like car wash, gardening and other cleaning purposes.

Acknowledgment

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