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Concentration of Faecal Sludge Solids in Waste Stabilisation Ponds in the Tamale Metropolis

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ABSTRACT

Faecal sludge treatment is necessary for waste water reuse. Among the natural biological treatment systems available, stabilization ponds have been used widely around the world with a considerable success. This research was conducted to assess the levels of faecal sludge solids concentration in waste stabilisation ponds, which consist of twin anaerobic pond, primary and secondary facultative pond and a single maturation pond at the Tamale Metropolis landfill site in Northern Ghana. The results revealed TSS concentration range of 4122.22 to 8760.37 mg/l, TDS range of 1970.20 to 9744.11 mg/l and TS range of 6092.4 to 18504.48 mg/l. Variation of faecal sludge solids concentration among different stabilisation ponds were statistically, highly significant by analysis of variances. However, variations of solids concentration within individual ponds were statistically insignificant. The anaerobic pond recorded the highest faecal sludge solid concentration relative to the other ponds as expected. The faecal sludge solids levels were observed to be higher than the Ghana Environmental Protection Agency recommended standard for the discharge of effluent into the environment. This may impede the faecal sludge treatment processes and make the entire system function below required safety levels.

Introduction

Upsurge in urban population in developing countries has led to an increased generation of faecal sludge in such communities (Kuffour, 2010). Faecal sludge as noted by Koné and Peter (2008) comprises all liquid and semi-liquid contents of pits and vaults accumulating in on-site sanitation installations, namely; unsewered public and private latrines or toilets, aqua privies and septic tanks. Natural treatment systems are considered one of the best treatment options, particularly in warm climates, such as the tropical and subtropical regions. Among the natural biological treatment systems available, stabilization ponds have been used widely around the world (Corbitt, 2004, cited by Dagne, 2010). In Ghana, stabilization and settling ponds have been the method-of-choice to date, but have however shown to be less effective where fresh undigested and highly concentrated faecal sludge from public toilets forms a major fraction delivered to the treatment plants (Kuffour, 2010). According to Koné and Strauss (2004) high solid as well as organic and nutrient load of faecal sludge affect the natural biochemical processes of treatment plants, resulting to overloading. Total solids of faecal sludge include "Total Suspended Solids" and "Total Dissolved Solids". Metcalf and Eddy (1995) define total solid as materials left in a dish after evaporation of the faecal sludge sample and its subsequent drying in an oven at a defined temperature (105˚C) in the case of wastewater during laboratory determination. The stabilization ponds (anaerobic, primary and secondary facultative and maturation) at the landfill site in the Tamale Metropolis are expected to treat both physicochemical and microbiological contaminants of the faecal sludge, which may pose threat to humanity as well as the environment. The research was carried out to determine the concentration of total solids in the stabilisation ponds.

Materials and Methods

Study Area

The Tamale Metropolitan Assembly (TaMA) has been described by Ziem (2013) as the largest urban centre in the north of Ghana, with an estimated current population of 371,351 (GSS, 2013). Geographically, the Metropolis lies between latitude 9°.16' and 9°.34' North and longitudes 00°.36' and 00°.57' West and located approximately 180 metres above sea level and a total estimated land size of 550 km2. The Metropolis experiences one rainy season starting from April/May to September/October with a peak season in July/August (TaMA, 2013). The faecal sludge stabilisation pond in the Tamale landfill site consists of two units of three ponds; anaerobic, primary facultative and secondary facultative pond in series connected to a single maturation pond.

Experimental Design and Data Collection

Each of the four main treatment ponds; Anaerobic (AN), Primary Facultative (PF), Secondary Facultative (SF) and Maturation (MT) was divided into three sections: influent point (1), midpoint (2), and the effluent point (3) which served as sampling points. Faecal sludge samples were taken from all the points during each sampling day. A total number of 12 samples were taken per each sampling time at two weeks (14 days) intervals for a period of five months (November 2013 to March 2014) in the dry season where there is virtually no dilution from rainwater. A total of 120 faecal sludge samples were analysed for the study.

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Materials

Laboratory materials used for the analysis included evaporating dish, water bath, oven, desiccators, analytical balance, graduated cylinders, dish tongs, gooch crucibles, whattman filter paper (150mm⊘), vacuum pump (sartorius type 16692 vac 230), crucible tongs, and forceps (smooth –tipped).
Total Dissolved Solids dried at 180 ˚C, Total Suspended Solids and Total Solids dried at 103-105 ˚C were the standard methods used for the determination of the faecal sludge solid levels at different points of the system of stabilisation ponds.

Statistical Analysis of Collected Data

The data was analysed using GENSTAT Teaching Edition 4. The analysis was for variation of solids concentration in faecal sludge solids in samples. The levels of variation were evaluated through Analysis of Variance (ANOVA) to test whether the mean levels of quality parameters are the same for the treatment ponds. Minitab 16 was used for multiple mean comparison analysis. Tables and graphs were generated using Microsoft Excel 2007.

Results and Discussion

Faecal Sludge Solids Concentration in Anaerobic Pond

Faecal sludge solids concentration in the anaerobic pond range from 6720.30 to 10960.53mg/l, 7196.33 to 12217.54 mg/l and 13916.63 mg/l to 23178.07 mg/l for TSS, TDS and TS respectively. As can be observed from Table 3.1, influent point AN1 recorded the highest concentration whiles effluent point AN3 recorded the least for all the faecal sludge solids analysed for the anaerobic pond.

Variation among the anaerobic pond faecal sludge solids concentration for the various sampling points showed to be statistically insignificant. Fpr values were greater than 0.05 by analysis of variance (ANOVA) at 5% level of significance for all the parameters.

Table 3.1. Concentration of Solids in Anaerobic Pond

Parameter	Sampling Points Mean Concentration			ANOVA	
	AN1	AN2	AN3	Fpr < 0.05	LSD
TSS	10960.53	8600.3	6720.3	0.217	4919.3
	(±3614.38)	(±4923.57)	(±4220.22)		
TDS	12217.54	9818.46	7196.33	0.26	6232.4
	(±7148.24)	(±3187.37)	(±3961.20)		
TS	23178.07	18418.76	13916.63	0.052	7336.6
	(±6336.40)	(±6976.32)	(±3261.14)		

Values in parenthesis (±) indicates Standard Deviation

Faecal Sludge Solids Concentration Primary Facultative **Pond**

Unlike the anaerobic pond, TSS recorded the highest level of 6752.67 mg/l at the influent point which reduced to the lowest of 3526.33 mg/l at the midpoint and increased to 6524.00 mg/l at the effluent point. TDS increased from 3504.67 mg/l at the influent point (PF1) to the highest of 6489.67 mg/l at the midpoint (PF2) and finally reduced to the lowest of 2998.67 mg/l at the effluent point (PF3).

Faecal sludge solids distribution for TSS, TDS and TS in the primary facultative pond showed to be statistically insignificant by the analysis of variance as indicated by their corresponding F probability and LSD values in Table 3.2.

Table 3.2. Concentration of Total Solids in Primary Facultative Pond

Parameter	Sampling Points Mean Concentration			ANOVA	
	PF1	PF2	PF3	Fpr < 0.05	LSD
TSS	6752.67	3526.33	6524	0.995	5983.1
	(±4751.83)	(±4993.77)	(±4837.20)		
TDS	3504.67	6489.67	2998.67	0.961	4528.6
	(±3893.09)	(±3781.93)	(±3341.78)		
TS	10257.33	10016	9522.67	0.797	2348.6
	(±1445.29)	(±1685.45)	(±2448.92)		

Values in parenthesis (±) indicates Standard Deviation Source

Faecal Sludge Solids Concentration Secondary Facultative Pond

Results from the secondary facultative pond revealed that TSS level of 5428.67 mg/l at the influent point (SF1) increased to the highest of 5886.00 mg/l at the midpoint (SF2) and sharply reduced to 5570.00 mg/l at the effluent point (SF3). TDS steadily increased from 2313.33 mg/l at the influent point (SF1) to 2419.67 mg/l at the effluent point (SF3). TS was in the range of 7742 to 8301.33 mg/l at the influent and midpoint respectively as indicated by Table 3.3.

Statistically, variation among faecal sludge solids concentration at the various sampling points showed to be statistically insignificant by the analysis of variance as presented in Table 3.3.

Table 3.3. Concentration of Total Solids in Secondary Facultative Pond

Parameter	Sampling Points Mean Concentration			ANOVA	
	SF1	SF2	SF3	Fpr > 0.05	LSD
TSS	5428.67 (±3982.47)	5886 (±4193.06)	5570 (±2936.52)	0.980	4915.2
TDS	2313.33 (± 2520.34)	2415.33 (±2966.57)	2419.67 (±3797.24)	0.997	3464.3
TS	7742 (±1539.36)	8301.33 (±1498.19)	7989.67 (±1081.79)	0.786	1708.8

Values in parenthesis (±) indicates Standard Deviation

Faecal Sludge Solids Concentration Maturation Pond

TSS of 4126.667 mg/l in maturation pond appreciably reduced to a minimum of 3961.33 mg/l at the midpoint and later increased to the maximum of 4278.67 mg/l at the effluent point. TDS rather increased from 1884.33 mg/l at the influent point to the maximum of 2052.94 mg/l at the midpoint and again reduced to 1973.33 mg/l at the effluent point. TS in the range of 6011 to 6252 mg/l recorded an increased trend from the influent through to the effluent point as presented in Table 3.4.

Variation among faecal sludge solids concentration in the maturation pond was statistically insignificant by the analysis of variance.

Levels of Total Suspended Solids (TSS) in Faecal Sludge Stabilisation Pond

Faecal sludge TSS mean level reduced from the anaerobic pond through to the maturation pond. A high TSS level of 8760.37 mg/l and a low of 4122.22 mg/l were respectively recorded for the anaerobic pond and the maturation pond as shown Figure 3.1. TSS level in the primary facultative pond was higher than that of the secondary facultative pond.

Table 3.4. Concentration of Total Solids in Maturation Pond

Parameter	Sampling Points Mean Concentration			ANOVA	
	MT1	MT2	MT3	Fpr < 0.05	LSD
TSS	4126.667	3961.33	4278.67	0.995	5983.1
	(±3001.01)	(±2869.29)	(±3206.53)		
TDS	1884.33	2052.94	1973.33	0.961	4528.6
	(±2109.39)	(±2288.06)	(±2160.52)		
TS	6011	6014.28	6252	0.797	2348.6
	(±1068.69)	(±914.33)	(±1384.18)		

Values in parenthesis (±) indicates Standard Deviation

Data labels that do not share a letter (a or b) are statistically different.

The analysis of variants performed at 5 % significance level realised an Fpr value of 0.006 and the least significant difference (LSD) of 2584.4 thus variation among TSS mean levels for the stabilisation ponds is statistically significant. The statistical difference, however, exists between anaerobic pond and both secondary facultative and maturation ponds as separated by the superscripts in Figure 3.1.

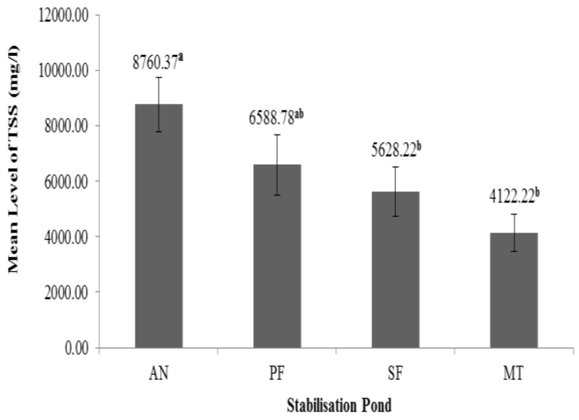


Figure 3.1. Mean Levels of Total Suspended Solid in Faecal Sludge Stabilisation Ponds

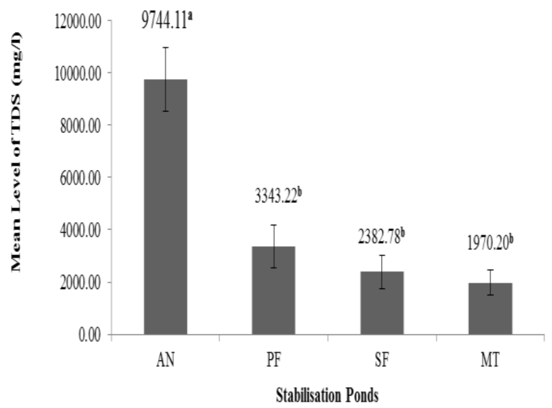
In spite of the reducing trend observed for faecal sludge TSS mean levels were all far above the allowable limit of 50 mg/l by Ghana EPA (2000) for effluent reuse. This implies that, faecal sludge TSS levels in the stabilisation ponds may not be environmentally safe for irrigation purposes or effluent discharge. The high TSS levels according to Ariffin (2009) may release obnoxious odours and also indicate the presence of disease causing organisms as well as organisms such as toxin producing strains of algae. High total suspended solid particles in the stabilisation ponds may absorb heat from the sunlight, increasing the temperature, and so reducing the concentration of oxygen in solution (Sewe et al., 2013). The suspended particles can also scatter light, as a result decreasing the photosynthetic activity of algae, which contributes to lowering the oxygen concentration (Lenntect, 2014).

Levels of Total Dissolved Solids (TDS) in Faecal Sludge Stabilisation Pond

The anaerobic pond recorded the highest TDS level of 9744.11 mg/l whiles the maturation pond the least level of 1970.20 mg/l. Faecal sludge TDS level in the primary facultative pond was higher than that of the secondary facultative pond as shown in Figure 3.2.

The reduction in faecal sludge TDS may be attributed to the settling down of solids and eventually forming a sludge layer at the bottom of the ponds (FAO, 1992).

Variation in the mean TDS level of the stabilisation ponds was realised to be statistically significant by ANOVA, at 5 % significance level with Fpr value of < .001 and LSD of 2359.1. The significant difference exists between anaerobic pond and the other ponds as indicated by the superscripts in Figure 3.3.



Data labels that do not share a letter (a or b) are significantly different.

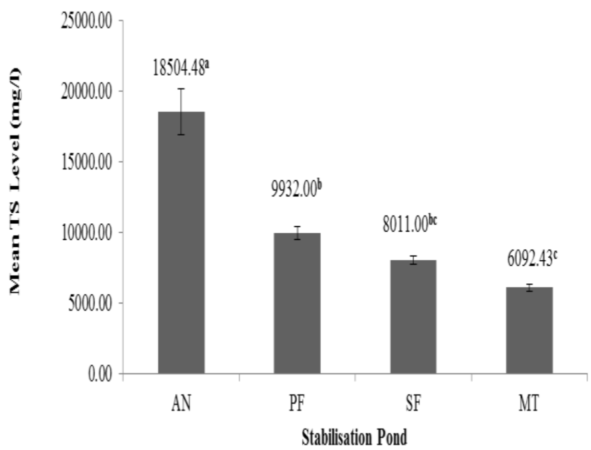
Figure 3.3. Mean Levels of Total Dissolved Solid in Faecal Sludge Stabilisation Ponds

The mean TDS levels of all the treatment ponds were realised to be above the Ghana EPA (2000), allowable limits of 1000 mg/l for irrigation or discharge.

Levels of Total Solids (TS) in Faecal Sludge Stabilisation Pond

Total solids are the sum of both total suspended solids and total dissolved solids of faecal sludge in the stabilisation ponds. The TS in the anaerobic pond was 18504.8 mg/l which reduced to 9932 mg/l in the primary facultative pond. The secondary facultative recorded TS level of 8011 mg/l whiles the maturation pond the lowest of 6092.43 mg/l as shown in Figure 3.4. The reducing trend is the combined effect of both TSS and TDS in the stabilisation ponds. The maturation pond relatively receives a lower amount of TS from the secondary facultative pond, which has undergone apparent settling and decomposition in preceding pond hence, the least with TS levels.

Mean concentration of TS in stabilisation ponds recorded a variation which was observed to be statistically significant with Fpr (<0.05) value of <.001 and LSD of 2415. TS level for the anaerobic pond was significantly different from all the other ponds. The primary facultative pond was significantly different from the maturation pond, but not with the secondary facultative pond. There was no statistical difference between the secondary facultative pond and the maturation pond as indicated by the data label superscripts in Figure 3.3.



Data labels that do not share a letter (a, b or c) are significantly different.

Figure 3.4. Mean Levels of Total Solids in Faecal Sludge Stabilisation Ponds

Conclusion

Varied concentrations of faecal sludge were noted to occur in waste stabilisation pond in the Tamale metropolis. Variation within individual ponds showed to be statistically insignificant. Nonetheless, variation among the stabilisation ponds proved to be statistically significant by analysis of variance. Mean concentrations of total suspended solid (TSS) and total dissolved solids (TDS) were realised to be above the Ghana EPA (2000) recommended limit for effluent discharge into the environment. This finding raises issues of concern about the general performance of the treatment ponds as well as their effect on the environment once effluent is discharged. There is the need to re-think this technology use in the current, rapidly urbanising environment of the developing world.

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