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Effect of different income housing zones on effluent quality of Biofil® toilet waste digesters in Accra, Ghana

P. Amoah, E. G. Nartey & A. Schrecongost (Ghana)

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This study was carried out to assess the effect of different income-housing zones on the quality of effluent from standard Biofil® toilet waste digesters in Accra, Ghana. Records of the digesters installed were obtained from BiofilCom and were sorted out into income-housing zones (low, middle and high income housing zones). In all, 36 toilet digesters were found accessible and sampled 3 times each for effluent. Samples were analyzed for E. coli, Total coliform, helminth eggs, BOD, TSS, NH_3-N and PO_4-P, using standard methods. Results show that effluent quality exceeded the requirements set by Ghana EPA for discharge into water bodies. However, high removal efficiencies were obtained for BOD (84%) and TSS (82%). In most cases, the pollutant concentrations were significantly higher in effluents from the high-income zones than in the middle and low income zones.

Introduction

Inadequate sanitation coverage still remains a significant challenge of urban populace in Sub-Saharan Africa (SSA) and Asia especially. Ghana is no exception to the poor sanitation coverage (Amoah and Nartey, 2015). Implications of poor sanitation have far-reaching impacts on the national economy and public health of people. Reports from UNICEF indicate that 82,000 children as a result of improper sanitary conditions die in the country before they celebrate their 5th year birthday due to diarrhea and pneumonia. Diarrhea is reported as the second most common disease, which kills young children in developing countries every 15 seconds (Yankson, 2013).

The introduction of Biofil® toilet digesters, manufactured and distributed by BiofilCom (*a Ghanaian private company*) is expected to ease the problems of over 70% of Ghanaian households without proper toilet facilities and thus makes the technology (See box 1 below) a welcomed one. The digester according to the manufacturers, is able to break down human excreta up to thirty times faster and more efficiently than the traditional septic system. This meant that the digester could be up to thirty times smaller than the septic system. It requires very little maintenance and can be serviced by semi-skilled personnel, using very simple equipment. This technology is in line with Bill & Melinda Gates Foundation's (BMGF's) program on Water, Sanitation & Hygiene which focuses on developing innovative approaches and technologies that can lead to radical and sustainable improvements in sanitation in the developing world.

There is evidence of consumer satisfaction with these toilet solutions given the ongoing market demand, low rate of service support requests and lower cost of operation in the medium to long term compared to other on-site sanitation facilities (*reported by BiofilCom*). As part of a wider study to assess the performance of the Biofil® toilet technologies with respect to effluent quality, this study was carried out to assess the effect of different income housing zones on the quality of effluent the digesters produce. Results of this study is expected to contribute to the wider study by the International Water Management Institute (IWMI, West Africa) which will offer recommendations to guide BiofilCom in targeting interventions that will improve the performance and efficiency of the digester.

Box 1: How the Biofil® digester works

The Biofil® digester comes with either a full flush or micro flush toilets using 9 – 12 or 0.15 – 1L of flush water, respectively. The digester mimics decomposition in natural environments: Living organisms in an enclosed chamber treat all decayable matter through aerobic decomposition (BiofilCom, n. d). The digester, whether used with a full flush or micro flush toilet, has same design and operational functions. Flush water (*with raw excreta and anal cleansing material*) undergo rapid solid–liquid separation through a porous concrete filter in the digester (Figure 1), the solid material is retained on the porous filter where it is decomposed aerobically by living organisms; bacteria, earthworms, cockroaches etc. The effluent (liquid) that remains after the solid – liquid separation process is filtered to a limited extent and discharged directly into the subsurface soil with or without a drain pipe.

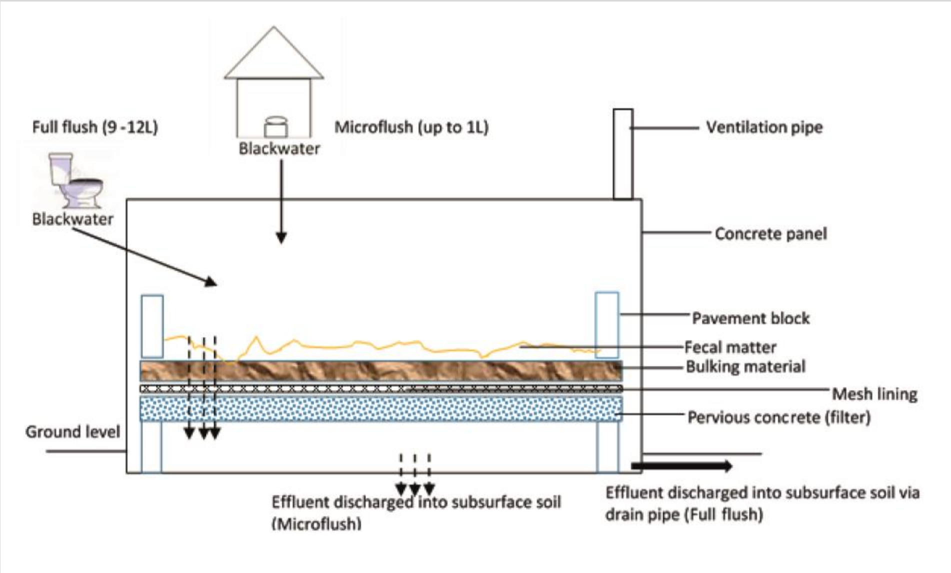

Figure 1. Schematic view (cross section) of a standard Biofil® toilet digester (adapted from Alemneh, 2014)
Source: Peter Owusu-Antwi

Materials and methods

The study was carried out mainly in the city of Accra, Ghana (Figures 2). Records of Biofil® digesters installed in Accra were obtained from BiofilCom. The locations of those installed digesters were sorted out into income-housing zones (low, middle and high income housing zones) based on the housing characteristics given by Accra Metropolitan Assembly (2006). In all, 36 toilet digesters[1] (14 in low, 4 in middle and 18 in high incomes zones) were found accessible for sampling. Three effluent samples were taken from each digester by placing sterilized plastic bowls underneath outlet pipes overnight just before the effluent gets to the environment. Influent samples from 18 out of the 36 digesters were also taken. Influent samples could not be taken from all the 36 installations because some of them had the sludge layer so high that the bowl could not be placed underneath the influent pipe. Secondly, other installations had been cemented and could not be opened. The samples were analyzed for *E. coli*, total coliform, helminth eggs, BOD, TSS, NH_3-N and PO_4, using standard methods (APHA-AWWA-WEF, 2001).

Following calculation by Gross (2005), the treatment capacity and removal efficiency of the Biofil digesters were calculated using influent concentrations and the effluent requirements.

Statistically analysis

The data were transformed (log transformation for pathogens and square root transformation for other parameters where appropriate) and subjected to analysis of variance (ANOVA) taking into consideration the unequal sample sizes. The data analysis was carried out using Genstat [9th edition (Release 9.2)] statistical package. Microsoft Excel was used to plot the other graphs.

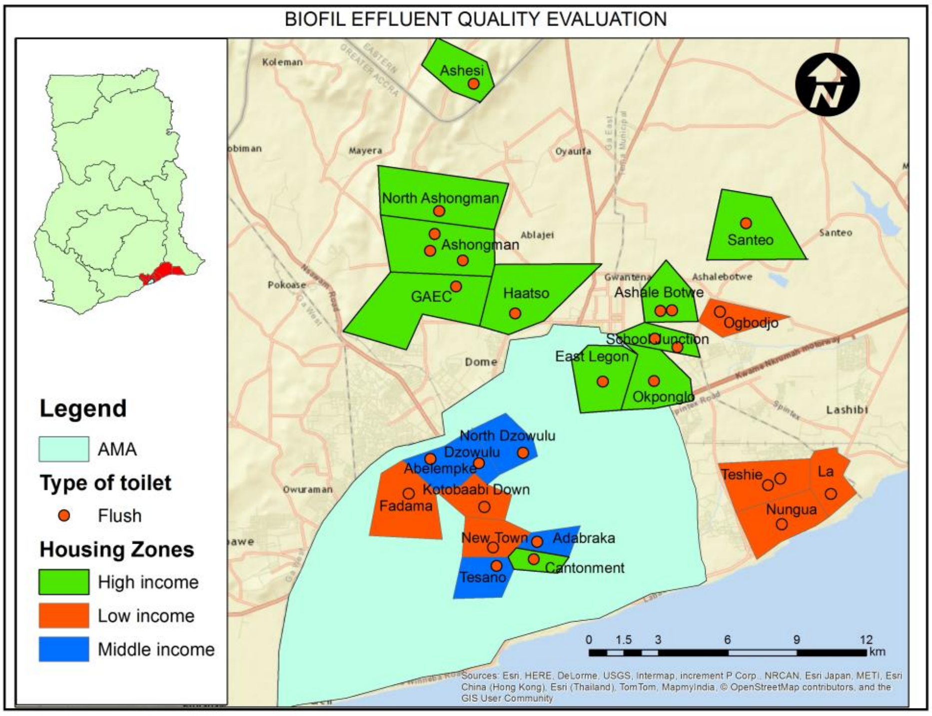

Figure 2. Map of Accra Metropolitan Area and neighboring municipalities showing effluent sampling locations

Source: Benjamin Ghansah (IWMI)

Results

Table 1 shows the general quality of effluent sampled from the standard Biofil® toilet waste digesters. Generally the levels of all the tested parameters exceeded the Ghana EPA discharge standard for water bodies.

Table 1. General characteristics of effluent from Biofil® toilet waste digesters (n = 108 for each parameter)

Parameter	Effluent characteristics		Ghana EPA standards
	Range (Median)	Mean ± SE	
BOD [mg L^{-1}]	10.0 – 984.0 (144.0)	219.0 ± 20.0	50
TSS [mg L^{-1}]	12.0 – 3440.0 (254.0)	500.0 ± 55.0	50
NH_3-N [mg L^{-1}]	2.0 – 286.0 (108.5)	117.2 ± 5.9	1
PO_4-P [mg L^{-1}]	0.2 – 36.1 (5.8)	8.9 ± 0.8	2
E. coli [CFU 100 ml^{-1}]	0.0 – 1.0×10^8 (1.0×10^7)	$1.7 \times 10^7 \pm 1.8 \times 10^7$	10
Total coliform [CFU 100 ml^{-1}]	1.0×10^2 – 3.2×10^8 (5.3×10^7)	$7.0 \times 10^7 \pm 6.4 \times 10^7$	400
Helminths [egg L^{-1}]	0.0 – 3.0 (-)	0.1 ± 0.1	-

Despite the fact that effluent quality from the main digesters did not meet the discharge standards from Ghana EPA, an assessment of their removal efficiencies (using influent from the 18 accessible digesters and their corresponding effluent) showed that they are removing so much from the influent in some cases. In others there can be very limited removal given the wide range of values for each parameter. The digesters were able to remove 84% of BOD with a deficit of 13% to meet the discharge guideline of 50 mg L^{-1}. Generally, nutrients were the least removed; the digesters removed 5% and 28% of NH_3-N and PO_4-N, respectively (Figure 3).

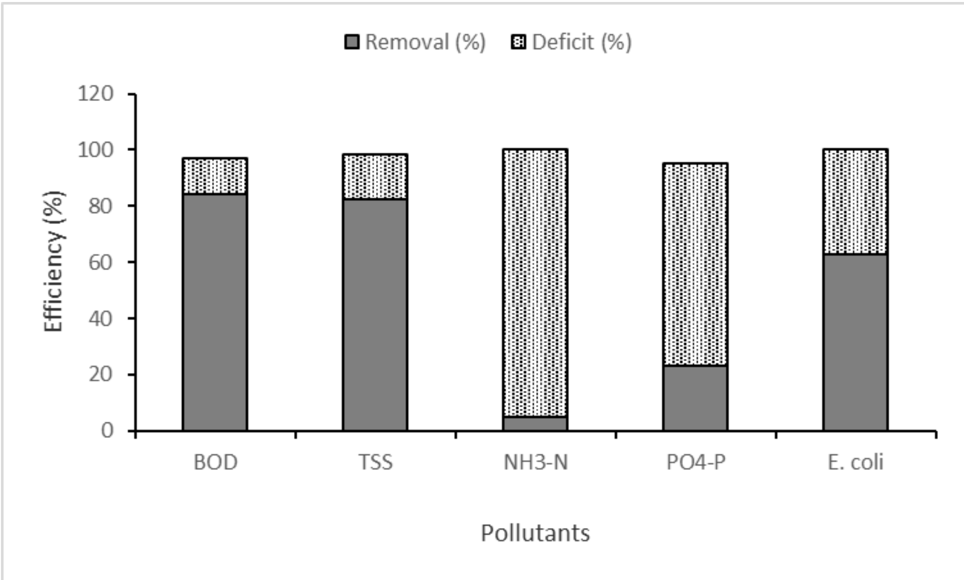

Figure 3. Pollutant percentage removals and deficits of Biofil® digesters to meet Ghana EPA discharge guidelines. Deficit is the removal needed to meet EPA requirements

Source: from present study

Figure 4 shows the pollutant concentrations in effluent from the different income zones in Accra. Significant differences ($p \leq 0.05$) were observed between parameters from high-income zones and those from the middle and low income areas with most of those from the high income zones recording the highest values. For example, significantly higher BOD concentrations were recorded in effluent from high-income zones than the middle and low-income zones.

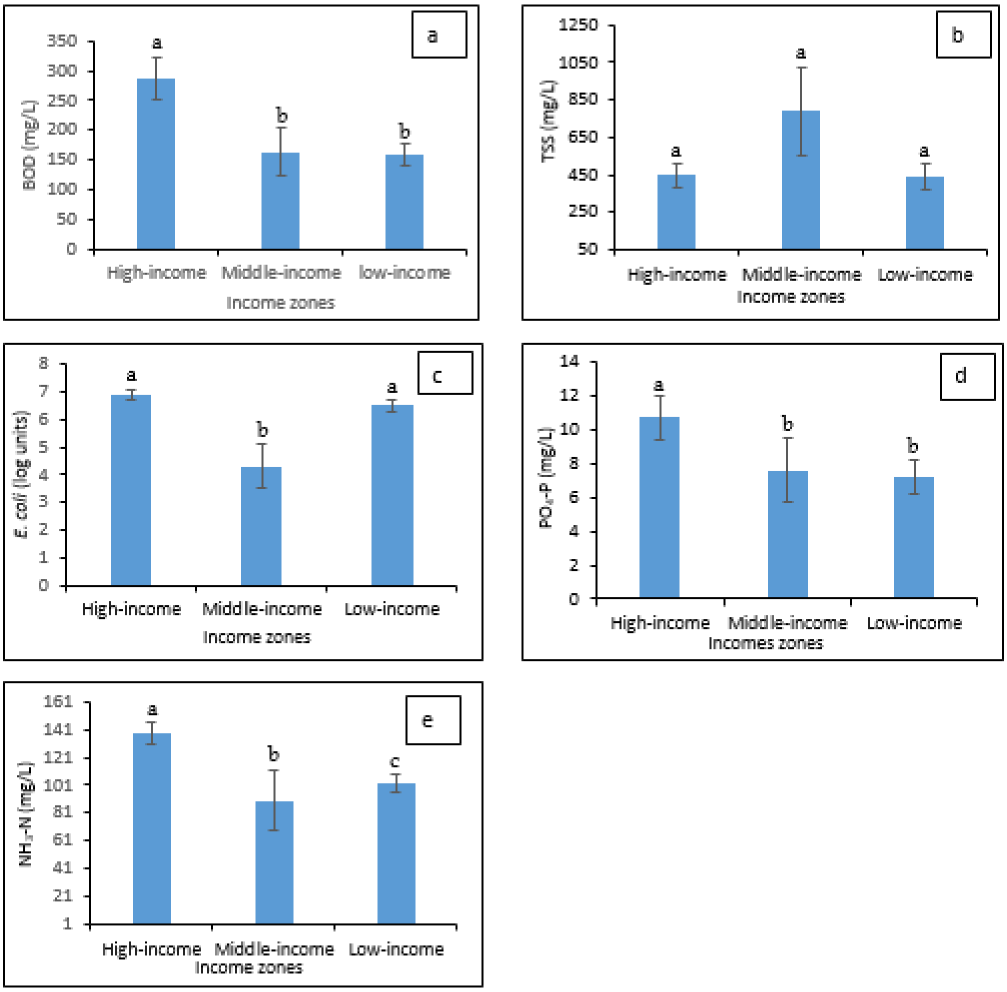

Figure 4. Pollutant levels in effluents from different income housing zones.
Bars with different letters are significantly different.

Source: from present study

Discussion

The effluent qualities of the standard Biofil® toilet waste digesters were generally above the effluent discharge requirements set by Ghana EPA for discharge into water bodies. This could be attributed to instant rapid filtration processes (solid – liquid separation) within the digesters which separates the sludge from the raw wastewater before further processing. Though discharge of Biofil® digester effluent is not directly into water bodies but rather sub-surface soil, comparison with the above standard becomes relevant and crucial taking into account areas of periodic flooding and high groundwater table. There is however no national standard for helminth eggs, but the digesters achieved the WHO standard of <1 egg for safe use of wastewater, excreta and greywater (WHO, 2006). High removal efficiencies obtained for BOD and TSS could be due to the ability of the waste digester system to effectively separate the solids from the liquid. This allows the liquid effluent to trickle down leaving the solid materials behind to be degraded. By this separation process, a substantial amount of the organic matter and total solids are removed from the influent.

Some earlier studies reported relatively low removal efficiencies even in septic tanks (Rahman *et al.*, 1999; Ed, 2009) and other feacal treatment plants (Kagya, 2011) which have higher retention times. Due to the very short contact time for dissolved substances, not so much dissolved nutrient removal was expected from the digesters. This was confirmed in the present study as relatively lower amounts of NH_3-N and PO_4-P were actually removed. BiofilCom is already piloting modified treatment options which aims at polishing further the effluent from the digesters to meet the national and international discharge standards.

In most cases, the pollutant concentrations were significantly higher in effluents from the high-income zones than in effluents from the middle and low–income zones. It appears that this finding could be as a result of excessive use of very powerful antiseptics and detergents in the high-income homes to maintain clean and hygienic toilets. A recent study by Alemneh (2014) showed that cleaning agents: sodium hypochlorite (Parazone) and lactic acid ("Mr Muscle") caused 100% mortality of earthworms in the Biofil® digester over 21 days' exposure time. Teck-Yee *et al.,* (2010) also found NO_3-N to be high in effluents from high-income areas confirming the higher rate of detergent use by high-income dwellers. Most laundry detergents contain concentrations of salt, PO_4-P and NO_3-N. This indicates that though the effluent quality is not meeting the standards, the technology is better suited for the urban poor to lower middle income zones, where they cannot afford to buy powerful detergents and antiseptics to clean the toilets regularly, even though it is known that using these detergents is required for cleaner toilets. As a result, the living organisms are able to effectively and efficiently breakdown the sludge making the Biofil® toilet work better in low to lower middle income zones. These findings support BMGF's WASH approach which aim to expand the use of toilet and sanitation technologies that do not connect to a sewer, as this is the most likely technical solution to reach the poor with quality sanitation services

Conclusion

In conclusion, effluent quality of Biofil® toilets digesters from high-income zones are lower than that from low and middle-income zones. It is however recommended that further studies should be carried out to ascertain the reasons for these findings.

Acknowledgements

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Note/s

[1] These 36 digester are standard digesters and BiofilCom is currently testing a number of effluent polishing options connected to each digester to improve the quality of the effluent.

Contact details

Dr Philip Amoah is a Senior Researcher at International Water Management Institute (IWMI). He is an expert in water quality and food safety with international recognition. Eric G. Nartey is an Environmental Scientist, with a specific interest in water, sanitation and agriculture.

Dr. Philip Amoah	Eric Gbenatey Nartey	Alyse Schrecongost
IWMI, PMB CT, 112, Cantonments, Accra	P. O. Box 22, Ada	Independent WASH
Tel: +233 20 815 4661	Tel: +233 24 208 3704	Consultant (USA)
Email: p.amoah@cgiar.org	Email: flerigo@yahoo.com	amschrecongost@gmail.com