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Environmental Impact of Sand Filter Backwash Water and its Use as a Pretreatment for Biogas Production

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ABSTRACT

Background: Sand filter backwash water (SFBWW) is an iron containing liquid waste that is generated from borehole groundwater treatment plants. The present study investigated the level of environmental contamination by SFBWW and the effectiveness of recycling SFBWW as a pretreatment for biogas production.

Methods: Randomly selected 1000 locations with borehole water purification facilities in Bayelsa State, Nigeria were surveyed and the level of environmental contamination by SFBWW was visually assessed. Samples of SFBBW were randomly collected from three of the study locations and the physiochemical characteristics of each sample were determined using standard methods. Two liters of SFBWW was taken from each sample and mixed with 20 kg of biowastes (10 kg of cassava mill effluent and 10 kg of sewage). The mixture was fed into a fabricated anaerobic biodigester. A control was set up with purified water replacing SFBWW. Biogas yield and hydraulic retention time were measured in kilograms and days respectively.

Results: Heavy contamination, decolouration and clogging of borehole water facilities with the reddish brown residue of SFBWW was found. Compared with control, a significantly (P <.001) higher level of pH, iron and turbidity was found in SFBWW [pH: control = 6.77 ± .00, versus SFBWW = 8.01 ± .00; iron (mg/l): control = 0.33 ± .00, versus SFBWW = 60.83 ± .01; turbidity (NTU): control = 3.01 ± .01, versus SFBWW = 700.33 ± .33]. Compared with control, a higher biogas and lower hydraulic retention time was found in the group pre-treated with SFBWW.

Conclusion: The novelty of the present study is the combination of SFBWW with anaerobic digestion for the enhancement of biogas production. The present study also found that recycling SFBWW for biogas production served as a safe means of disposing SFBWW. Findings of the present study has implications for environmental sanitation in borehole water treatment plants.

Keywords: Biogas, environment, physiochemical properties, pretreatment, sand filter backwash water

1. Background

Sand filter backwashing refers to the act of pumping purified groundwater backwards into the same sand filter bed that purified it initially [1]. The purified water dislodges the dirt, debris, particles and microorganisms initially trapped in the sand filter bed. Although this process helps to maintain and clean up sand filter bed for reuse, it however generates large quantity of dirty water (10 – 15% of purified water) known as sand filter backwash water (SFBWW), which contaminates and decolourizes water treatment apparatus. This is a problematic liquid waste in groundwater treatment plants [2]. Also, the disposal and management of SFBWW increases the cost of groundwater treatment [2, 3]. A previous study found that the waste water generated from sand filter backwashing contains heavy metals naturally found in groundwater such as iron, manganese, and radium [1].

Another previous study that investigated the microbial safety of recycling sand filter backwash water for drinking purposes in Southern China found the presence of pathogenic *E. coli, Pseudomonas, Novosphingobium, Flavobacterium, Comamonas and Sphingomonas* in SFBWW with *E.coli* and *Pseudomonas* exceeding the WHO limit [4]. In yet another previous study carried out in Egypt, a country suffering water scarcity, the possibility of reducing the amount of treated water used for backwashing was investigated using varied physical conditions [5]. Furthermore, a previous study reported the recovery of a large quantity of quality water from treated sand filter backwash water [1].

Biogas is a renewable and sustainable fuel. It is a gaseous mixture produced through the anaerobic digestion of organic wastes [6]. Aside from biogas, effluent and digestate are also produced during anaerobic digestion [7, 8]. Biowaste pretreatment measures such as the addition of ferric chloride to rice straw followed by 24 hours of mixing under mesothermal temperature (32^0C) has been previously employed as a chemical pretreatment method for biogas production [9]. Biological pretreatment of biowastes with enzymes and microorganisms such as the addition of cellulolytic and hemicellulolytic microbial populations and bacteria consortium that release hemicellulases and cellulases enzymes to biowastes for enhanced biowastes digestion and utilization have also been previously employed as pretreatment for biogas production [10].

Furthermore, a previous study showed that pretreatment of biowastes with ultrasonication, microwave and weak alkali-acid increased biogas yield, while thermal and strong acid-alkali pretreatment reduced biogas yield [11]. Also, grinding and dilute acid pretreatments were the physical and chemical pretreatment employed to enhance biogas production from potato peel wastes in a previous study [12]. In yet another previous study, lipase and xylanase enzymes were added to palm oil mill effluent (POME) to improve biogas production [13]. However, all these pretreatments increased the cost of biogas production [14]. Thus, a low cost biowastes pretreatments for the production of upgraded biogas is needed.

The aim of the present study was to investigate the level of environmental contamination by sand filter back wash water sediment (SFBWW) and the effectiveness of recycling SFBWW as a biowaste pretreatment for biogas production.

2.0 Methods

2.1 Study location and field survey

The study location was Bayelsa State, Nigeria. The State lies on latitude 4.664030 N, and longitude 6.036987 E [15]. Bayelsa State houses the national forest at Sagbama Local Government Area very close to Forcados River [16, 17]. Field survey to randomly selected 1000 borehole water purification facilities in Bayelsa State, Nigeria was carried to ascertain the level of environmental pollution caused by SFBWW. Boreholes were selected using multistage random sampling technique [18].

2.2 Experimental design

The experimental design involved two groups: Group one (control): 20 kg of biowastes mixed with 2 L of clean treated water. Group 2: 20 kg of biowastes mixed with 2 L of SFBWW [19].

2.3 Determination of the concentration of iron

The concentration of iron in SFBWW was determined using atomic absorption spectrometry method as previously described [20].

2.4 Determination of pH, temperature and turbidity

The pH, temperature and turbidity of SFBWW were evaluated using a pH meter, thermometer and turbidity meter respectively [21].

2.5 Collection of biowastes

Cassava mill effluent was collected from a cassava processing mill on the concave bank of Forcados River in Toru – Orua, the same community where the University of Africa is situated, while sewage was collected from a septic tank in the University of Africa, Toru – Orua, Sagbama LGA, Bayelsa State, Nigeria.

2.6 Moisture content determination

Thermogravimetric method was used for moisture content determination of cassava mill effluent and sewage [22]. Briefly, 1 litre of SFBWW was evapourated to dryness and the weight loss due to evaporation of moisture was calculated. Results were expressed as percentage [23].

2.7 Pretreatment of biowastes

Ten kilogram of cassava mill effluent was mixed with 10 kg of sewage and the biowaste mixture was pretreated with 2 L of SFBWW. A control was set up without pretreatment.

2.8 Anaerobic digestion

Two biodigesters were fabricated and labelled group 1 and 2 respectively. Control biowastes mixture was fed into biodigester 1, while SFBWW-pretreated biowastes mixture was fed into biodigester 2 as previously described [6]. Two replicate set-ups were made for each group.

2.9 Hydraulic retention time and biogas yield determination

The hydraulic retention time for biogas production was measured in days while the cumulative biogas yield was measured in kilograms using a weighing scale [6].

2.10 Statistical analysis

SPSS version 24 was used for data analysis. Results were presented in graphs and tables. T-test was used to determine significant difference between means and results were expressed as mean ± standard error of mean [24, 25].

3.0 Results

3.1 Environmental impact of SFBWW

As presented in Table 1, SFBWW was found to be discharged directly into the environment without prior treatment in both urban and rural households. Figure 1 shows the negative impact of SFBWW on the environment and surfaces of borehole water purification facilities surveyed in the present study. As showed in Figure 1a, the SFBWW found in the present study was reddish brown. The most noticeable negative impact of SFBWW on the environment found in the present study was the decolourization of the environment, pipes, water treatment and storage facilities with the reddish brown colouration of SFBWW as showed in Figure 1b – g.

Table 1. Proportion of urban and rural households discharging SFBWW into the environment

Households	Boreholes with Sand filtration N (%)	SFBWW discharged directly into the environment N (%)
Rural	**100 (10)**	**100 (10)**
Urban	**900 (90)**	**900 (90)**

SFBWW: Sand filter backwash water

Figure 1. Environmental impact of SFBWW (A) A sample of SFBWW collected in the present study from a borehole water treatment plant (B) Underground water purification facilities found to be contaminated with SFBWW in the present study in Bayelsa State, Nigeria.

3.2 Physiochemical characteristics of SFBWW

As shown in Table 2, compared with control, SFBWW had a significantly (p<.001) higher concentration of iron and turbidity [(iron (mg/l): control, 0.34 ± .00 versus SFBWW, 60.84 ± .01); (turbidity (NTU): control: 3 ± .01 versus SFBWW: 700 ± .02)]. Also, compared with control, SFBWW had a significantly (p < .001) higher pH.

Table 2. Physiochemical characteristics of SFBWW

	Control	SFBWW	*P* value
pH	**6.77 ± .00**	**8.01 ± .00**	**<.001**
Iron concentration (mg/l)	**0.33 ± .00**	**60.83 ± .01**	**<.001**
Temperature (°C)	**25.00 ± .00**	**24.98 ± .02**	**.31**
Turbidity (NTU)	**3.01 ± .01**	**700.33 ± .33**	**<.001**
Colour	**colourless**	**reddish-brown**	

Results presented as mean ± standard error of mean. NTU: nephelometric turbidity units

3.3 Moisture content of biowastes

As shown in Table 3, the two biowastes used in the present study (cassava mill effluent and sewage) had a very high moisture content.

Table 3. Moisture content of biowastes

	Moisture content	*p* value
Cassava mill effluent	**97.17 ± .29**	**0.003**
Sewage	**95.07 ± .11**	

Results presented as mean ± standard error of mean

3.4 Effect of SFBWW pretreatment on biogas yield

As shown in Figure 2, the biogas yield of biowastes pretreated with SFBWW was significantly higher than that of control ($p < 0.03$).

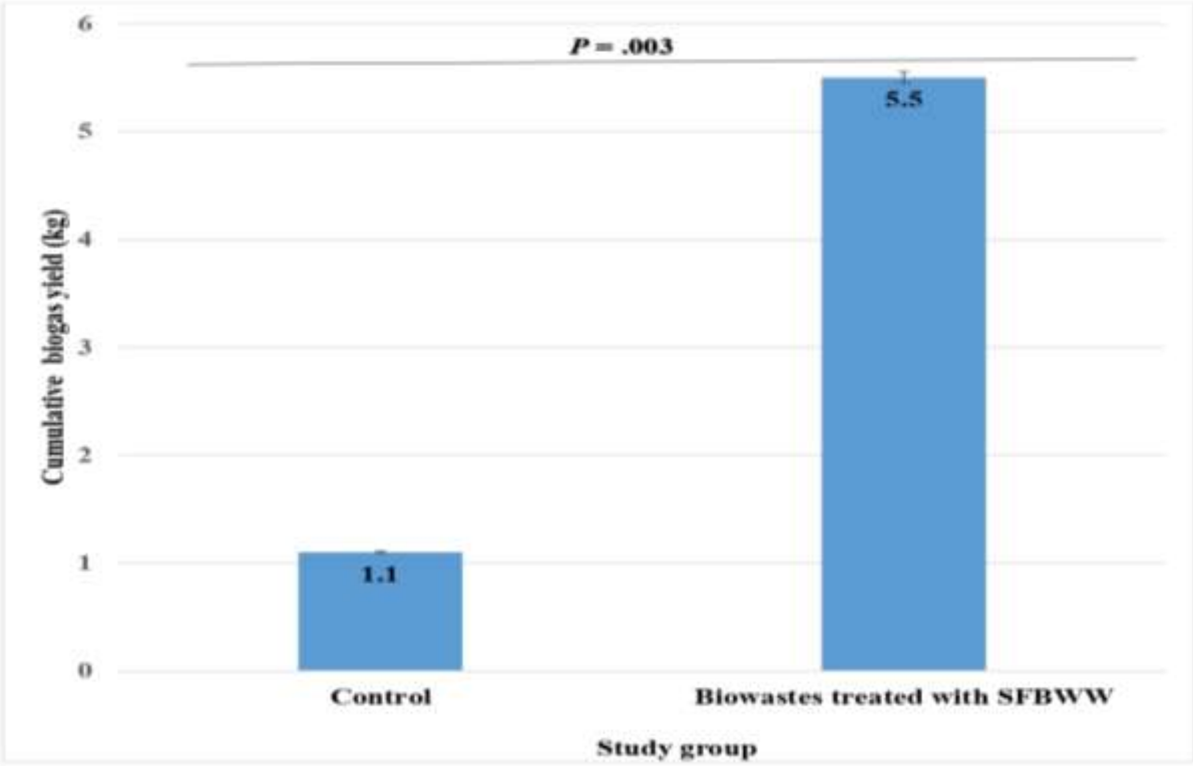

Figure 2 Cumulative biogas yield over a period of seven days. Results presented as mean ± standard error of mean.

3.5 Effect of SFBWW pretreatment on hydraulic retention time

Figure 3 shows that the hydraulic retention time of biowastes pretreated with SFBWW was significantly ($p < 0.001$) lower than that of control.

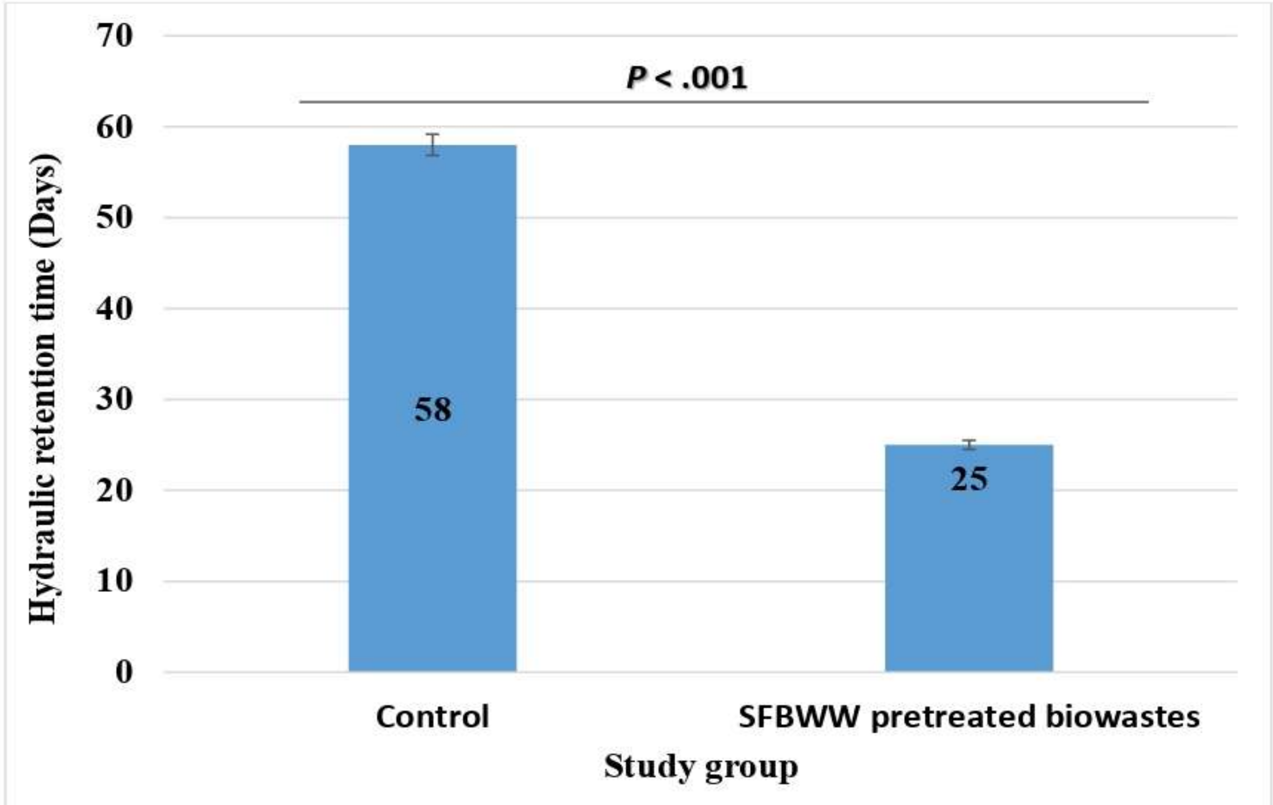

Figure 3. Hydraulic retention time for SFBWW-pretreated biowastes versus control. Results presented as mean ± standard error of mean**.**

4. Discussion

The present study investigated the level of environmental contamination with SFBWW and the effectiveness of recycling SFBWW as for biogas production. Physiochemical characteristics of SFBWW as well as biowaste hydraulic retention time and biogas yield were also evaluated. Contrary to previous reports on the treatment of sand filter backwash water before disposal or reuse in Saudi Arabia [1] and India [2], the present study found that the heavily contaminated SFBWW generated from borehole water purification facilities in Bayelsa State was not treated before disposal rather, it was discharged directly into the surrounding environment without treatment. This led to the contamination and decolouration of the environment and borehole facilities with reddish brown sediments from SFBWW sediments. Clogging of borehole water purification and storage facilities with SFBWW was also found in the present study contrary to the findings of previous studies [1, 2]. The buildup of the heavily contaminated SFBWW residues on the surfaces of water storage tanks and facilities makes such storage tanks disease reservoirs. According to World Health Organization (WHO), borehole and its component should be free from contamination in order to ensure clean water supply [26].

Also, the present study found a very high iron concentration in the SFBWW analyzed compared with control. Other physiochemical properties of SFBWW analyzed in the present study were also found to be significantly different from that of control. Although the presence of iron and other physiochemical properties found in the present study have been reported in previous studies [1, 27 - 29], however, the iron concentration of SFBWW found in the present study was higher than the iron concentration found in previous studies [1, 28] and lower than the iron concentration found in another previous study [29]. This shows that variation in the iron concentration of SFBWW exist from one geographical location to another. Therefore an evaluation of the physiochemical characteristics of SFBWW before disposal into a given environment is recommended. This may provide useful information on the nature of contaminants released in to the environment in a given geographical location.

Furthermore, the present study found a reduction in the hydraulic retention time of biowastes pre-treated with SFBWW and an increase in their biogas yield compared with control. Compared with other previously reported pretreatments for biowastes, the use of SFBWW as a low cost pretreatment and catalyst for hydraulic retention time reduction and increase in biogas yield is novel. It has not been previously reported. Thus the present study has filled a major gap in research and has added to the body of research on biogas production. Although several pretreatments have been previously reported to enhance biogas production, however these previously reported pretreatments have also been reported to increase the cost of biogas production [30, 31]. Mechanical pretreatment for example, aside from been energy intensive is also very costly [30], while chemical pretreatment aside from been expensive might contaminate downstream biogas product [31]. However, the use of SFBWW, a discarded waste for biogas production occurs at little or no cost. This also serves as an alternative strategy and technology for the disposal of SFBWW and maintenance of a clean and healthy environment within borehole water treatment facilities.

The high moisture content found for the biowastes used in the present study agrees with previous findings [32]. Further studies on ways to dewater these wastes in order to increase their valorization is highly recommended.

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