Feasibility of using Sewage Sludge Bio char in Treating Municipal Sewage

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Abstract

In this study, activated biochar from municipal sewage sludge was used for the treatment of sewage wastewater. The sewage physicochemical parameters were measured before and after bio filtration with biochar applying the principle of adsorption using the standard methods. Bio char with 500 m^2/g surface area and particle size of 0.5-1.0 mm was used at a loading rate of 2.5 g/L and treatment time of 40 hours. The changes in the sewage physicochemical parameters which included biological oxygen demand (BOD), chemical oxygen demand (COD), total phosphates (TP), total solids (TS) and total Kjeldahl nitrogen (TKN) and were measured using standard methods. Upon subjecting the sewage water to the bio char, a reduction of 94%, 90%, 80%, 83% and 82% were observed for the BOD, COD, TP, TS and TKN respectively. The sewage pH also changed from alkaline to neutral. The observed results indicated that sewage sludge bio char can effectively treat sewage wastewater.

Keywords: Bio char, bio contaminants, wastewater treatment, sewage sludge

1. Introduction

Water is a scarce resource and its management for reuse is critical. Sewage wastewater is generated every second and this results in the accumulation of sewage sludge in municipal sewage treatment plants, which if not managed properly will result in environmental contamination (Li *et al.*, 2014). This sewage sludge has potential to be converted to bio char, which can be applied as a good bio filter in wastewater treatment (Liu *et al.*, 2014; Ghezzehei *et al.*, 2014). Biochar is produced by carbonizing (pyrolysis) biomass at high temperatures under anaerobic conditions and a highly porous char like material is produced (Mohan *et al.*, 2014; Nguyen, 2015). The bio char pores have high surface areas as high as 400 square meters per gram (m^2/g) making them usable as bio adsorbents in wastewater treatment (Marschner *et al.*, 2013; Nguyen, 2015; Foereid, 2015). The bio char characteristics make them an attractive option for use in waste water treatment. In this study, the potential to use bio char from sewage sludge in sewage wastewater treatment was assessed in a bid to explore alternative technologies for wastewater treatment as well as a sewage sludge waste management initiative.

2. Materials and methods

2.1 Materials

Sewage sludge and sewage was obtained from a local sewage treatment plant. Filtered sewage water was used for determining the effect of biochar on bio contaminants removal whilst the sewage sludge was used for bio char production. The pH in bio char and sewage was measured using a Hanna Instrument ph meter from Sigma Aldrich South Africa. A 1L lab scale pyrolysis reactor from Borui, China was used for the conversion of the sewage sludge to bio char. Bio char particle size analysis was done through sieve analysis. A Strohlein Area meter II (CIS Ingenieurburo Seifert, Dresden, Germany) was used for the bio char Brunauer–Emmett–Teller (BET) surface area measurements. A Mermet oven from Sigma Aldrich, South Africa was used for characterization of the sewage sludge moisture content, total solids (TS) and volatile solids (VS).

2.2 Methods

2.2.1 Sewage sludge characteristics

The sewage sludge moisture content, total solids and volatile solids were measured using a Memmert oven according to standard procedures. The TS was determined when a 5g well mixed sample was filtered through a filter with a known mass and the residue that remained was dried at 105±0.5 °C in the oven for 1 hour. The net increase in mass was determined as the TS as a percentage. The moisture content of the same sample was expressed at the net weight change as a percentage. The VS were measured by heating a 5g sample at 550 ±0.5°C for 1 hour in the oven.

2.2.2 Bio char preparation

Biochar was made by slow pyrolysis of sewage sludge at 200-600 °C at a maximum heating rate of 1.0 °C/s. The bio char particle size was determined through sieve analysis. The bio char had a surface area was determined in accordance to methodology described by Jindo *et al*. (2014) whereby the Brunauer–Emmett–Teller (BET) surface area of the bio chars were calculated by determining the nitrogen ,gas adsorption at -196 °C using a Strohlein Area meter II (CIS Ingenieurbu ro Seifert, Dresden, Germany). During the process, samples were degassed under continuous nitrogen flow for 24 hours at 100 °C.

2.2.3 Sewage treatment by adsorption using biochar

In order to study the bio contaminants removal efficiencies, batch experiments were conducted thrice. In each experiment, 100 mL of the sewage water was poured into 250 mL glass beaker. 2.5 g/L bio char loaded with sodium chloride as an activation procedure in order to increase the adsorption efficiency and porosity of the sewage sludge biochar. The activation was conducted in accordance to methodology described by Ahinduzzaman and Islam (2016). The sewage was allowed to settle in the flasks for up to 40 hours and afterwards the bio char and the effluent were separated by filtration.

2.2.4 Sewage physicochemical properties analyses

The raw sewage and the treated sewage's physicochemical characteristics were determined. The parameters determined included: total phosphates (TP), total Kjeldahl nitrogen (TKN), chemical oxygen demand (COD), biological oxygen demand (BOD_5), total solids (TS) and pH. The physiochemical parameters were determined in accordance to APHA (2005).

3. Results and discussion

3.1 Sewage sludge characteristics

The sewage sludge had a moisture content of 63.7±2.6%, TS content of 24.7±0.8% and VS of 16.1±0.2%. This composition showed a high solid content in the sewage sludge hence its potential for use as a bio char raw material.

3.2 Bio char characteristics

A 40% yield of the bio char from the sewage sludge was observed, the rest of the components were assumed to be volatiles that were available in the sewage sludge. The bio char had a surface area of 500 m^2/g and particle size of 0.5-1.0 mm, organic carbon content of 72% and pH of around 8.

3.3 Effect of bio char on sewage wastewater physicochemical properties

3.3.1 Effect on chemical oxygen demand

The organic matter removal in the sewage wastewater was measured through the behavior of the COD concentration after adding bio char over time. The COD significantly reduced by 90% in the sewage water (Figure 1). The reduction in the sewage COD was attributed to the adsorption of the bio contaminants on the bio char during sewage treatment making the bio char act as a bio filter. Earlier studies by Dalahmeh *et al*. (2012) also reported a 99% efficiency removal in COD after using activated biochar for the treatment of grey water.

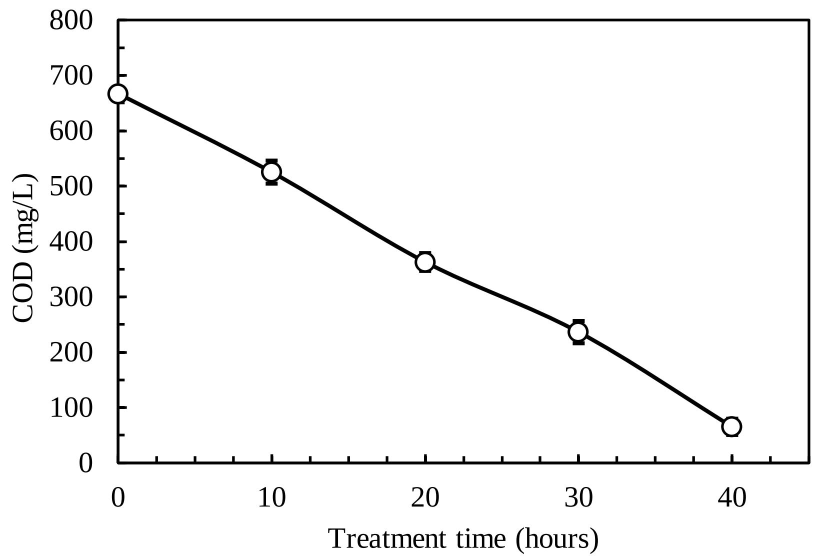

Figure 1. Effect of bio char on sewage COD

3.3.2 Effect on biological oxygen demand

The organic matter removal in the sewage wastewater was also measured through the behavior of the BOD concentration after adding bio char over time. The BOD significantly reduced by 94% in the sewage water over the 40 hours treatment period (Figure 2). The reduction in the sewage BOD was attributed to the adsorption of the bio contaminants onto the bio char surface during bio filtration. The effective removal of bio contaminants as indicated by the BOD reduction can also be attributed to the biological activity due biological action on the biofilm formed on the bio char (Huggins *et al*., 2016).

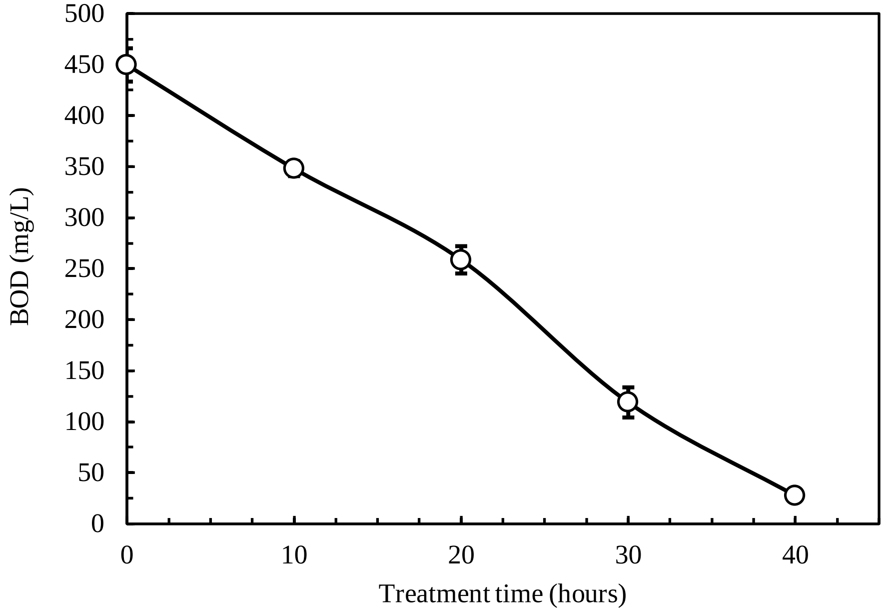

Figure 2. Effect of bio char on sewage BOD

3.3.4 Effect on total phosphorous

The sewage sludge biochar effectively removed total phosphorous from the sewage water by a total reduction of 80% as shown in Figure 3. Previous studies by Dalahmeh *et al*. (2012) also reported an 86% reduction in total phosphates upon treating grey water with activated biochar. This shows that water treatment with biochar as bio filters is effective and must be considered for removal of phosphorous during sewage treatment.

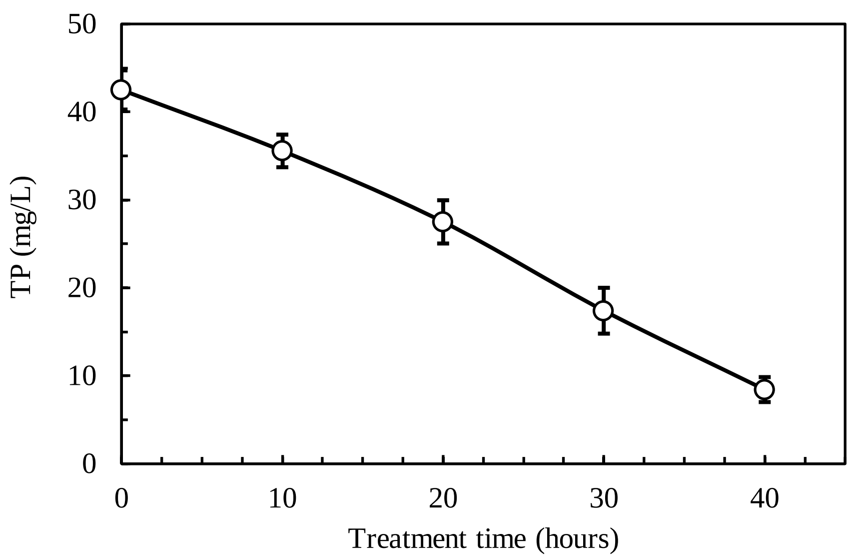

Figure 3. Effect of bio char on sewage water TP

3.3.5 Effect on total Kjeldahl nitrogen

The treatment of sewage water with activated biochar from sewage sludge resulted in a total nitrogen reduction of about 82% as shown in Figure 4. Earlier studies by Dalahmeh *et al*. (2012) reported a 97% decrease for total nitrogen when activated biochar was used in the treatment of greywater.

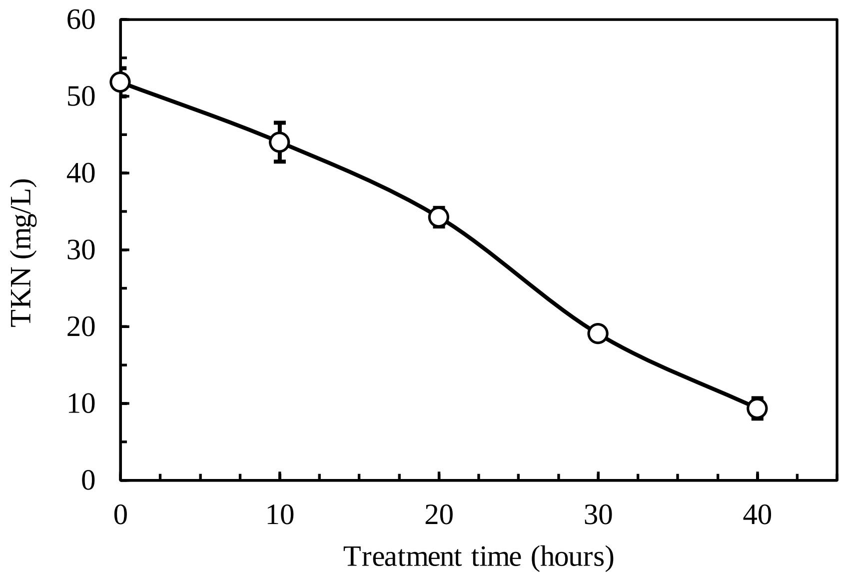

Figure 4. Effect of bio char on sewage TKN

3.3.6 Effect on total solids

The total solids in the sewage wastewater decreased upon bio filtration with bio char from sewage sludge. A reduction rate of 94% was observed over a treatment period of 10 days as shown in Figure 5. The reduction was attributed to the entrapment of solids on the biofilm that would have formed on the biochar during the adsorption process.

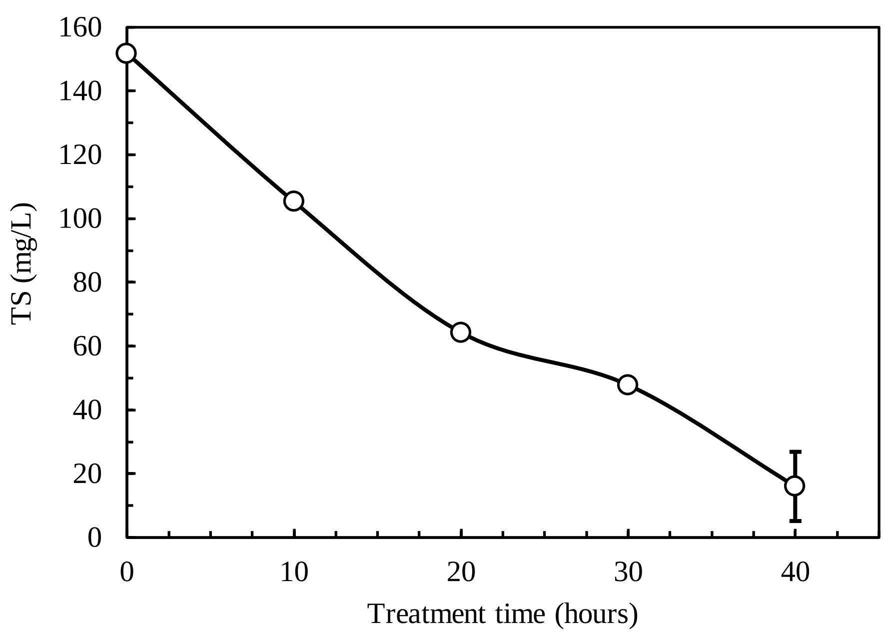

Figure 5: Effect of bio char on sewage total solids removal

3.3.7 Effect of bio char on pH

During the treatment of sewage water using activated sewage sludge biochar, the Ph changed from alkaline to neutral as shown in Figure 8. Liu and Zhang (2012) also reported that biochar has potential to neutralize the pH when 4-16g/kg of biochar was added for soil amendment.

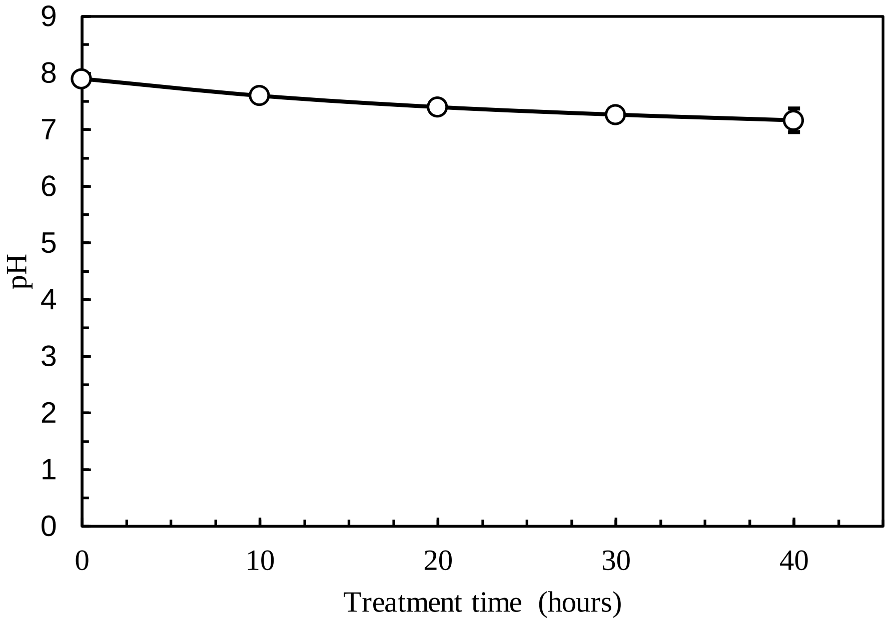

Figure 8: Effect on bio char on sewage wastewater pH

Table 1. Sewage physicochemical properties before and after bio char adsorption

Parameter	Raw sewage	Sewage effluent	%Reduction
pH	7.9±0.1	7.0±0.2	-
BOD	449.7±16.3	27.5±3.9	94
COD	667.0±10.9	65.2±14.7	90
TP	42.5±2.2	8.4±1.4	80
TKN	51.8±1.8	9.4±1.3	82
TS	155.2±5.5	526.0±4	82

4. Conclusion

Biochar effectively treats wastewater through possible adsorption of bio contaminants onto the bio char surface with an average reduction efficiency of >80% for BOD, COD, TKN, TP and TS. Production of biochar from sewage sludge can be adopted as a waste management strategy by local sewage treatment plants. The spent biochar can be utilized as a source of bio fertilizer due to the enrichment of the nitrogen accumulated from the wastewater.

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