Research Article

Assessment of Sludge Sample as a Feedstock for Power Generation

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Abstract

Treatment and disposal of sewage sludge has become an economically and environmentally sensitive problem. This necessitates cost-effective and innovative solutions whilst responding to environmental regulation and public pressures. This study examines the characteristics of a typical sludge samples as received following standard analytical procedures and its suitability for power generation. The results of the analysis revealed that the sample has good proximal and ultimate attributes. The higher heating value of the sample on dry basis was found to be 21.21 MJ/kg. These characteristics are similar to qualities of standard coal used as fuel in power stations.

Keywords: Sewage sludge, characterisation, proximal, ultimate, HHV

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1. Introduction

Most rural areas in Africa are confronted with challenges of solid waste disposal. Majority of the solid wastes are disposed in an uncontrollable manner that affects the environment and threatens the health of residents, making it one of the most serious public hazards in the rural society. It has been demonstrated that wastes such as municipal solid waste, plastics and agricultural residue can be transformed to energy or valuable chemicals [1,2]. This is normally achieved by several routes including bioconversion, incineration or thermochemical conversion processes [3-4]. Sewage sludge constitute another solid waste that has become an economically and environmentally sensitive problem today. It has been reported that the amount of sewage sludge generated increases proportionally with the industrial development in most countries [5-7]. The sludge normally contains undesirable components such as organic, inorganic, toxic substances as well as pathogenic or disease-caused microorganisms. The traditional disposal of sewage sludge includes depositing in the ground, utilization in agricultural works, dumping into the sea and incineration. With the future of disposal through the first three methods facing a ban, a growing interest is now being directed towards incineration and other thermal processes [7]. These methods are found to benefit the concept of waste-to-energy. For such thermal applications, the crucial property of material to be met is its energy content or heating value. This is used as the priority for evaluating the potential of sewage sludge. The objective of this study is to evaluate physicochemical properties of a typical sludge sample and its suitability as a feedstock for power generation.

2. Materials and Method

Three sewage samples as received were oven dried at 105 °C to a constant weight for moisture content determination according to the BS EN 14774-1 standard [8]. The dried materials were then milled in a Retsch® rotor beater mill to particle sizes between 0.2 mm and 1 mm and stored in air-tight plastic bags for further studies [9]. Volatile matter and ash content on dry basis were determined according to BS EN 15148 [10] and BS EN 14775 [11] respectively. Fixed carbon was computed by subtracting the percentage compositions of ash and volatile matter from the bone dry sample mass. Higher heating value (HHV) was determined using a Parr 6100 oxygen bomb calorimeter following BS EN 14918 [12]. The ash/inorganic composition was determined using energy dispersive x-ray-scanning electron microscope (EDX-SEM). Elemental compositions were determined using a CHNS/O analyser.

3. Results and Discussion

The three sludge samples as received were dried to a constant weight at 105 °C in an electrical oven. The total moisture present in the samples is shown in Figure 1. Sample 1 without any pre-drying had only less than 15 wt% solid matter presents in it while sample 2 and 3, after first and second round pre-drying contains about 42 and 71 wt% solid matter respectively. This suggests that in order to achieve less than 30 wt% moisture content, the fresh sludge sample need two cycle drying. Proximate analysis on dry basis (Figure 2) shows that the pre-dried samples (2&3) have similar physicochemical characteristics both in volatile matter, fixed carbon and higher heating value. These properties are also comparable to the coal samples used as fuel in a standard power station. On the other hand, sample 1 has ash content of about 24 wt%, which is about 31% higher relative to sample 2 and 3. Similarly, the volatile matter content of the

sample 1 is about 38% higher compared to that of the sample 2 and 3. This means that in the pre-drying, some ash forming materials and volatile components were lost during the process.

Figure 1: Moisture content in the samples

Figure 2: Proximal attributes of the samples

Further investigation of the ash content of the sample was carried out using EDX analysis to ascertain the nature of inorganic minerals present. Elemental scanning results (Figure 3) revealed the presence of alkaline and alkaline earth metals such as sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca) in all the samples. Silica (Si), aluminium (Al), iron (Fe), titanium (Ti), zinc (Zn) and phosphorus were also detected. In order to understand the dynamics of these mineral during the thermochemical conversion and their resulting impacts on the process, ash indices analysis such as fouling/slagging and aerosol emissions were carried out. Fouling/slagging tendency, which is the ratio of [basic oxides/acidic oxide] $\times$ (Na+K) refers to deposit formation from adhering of sticky, melted or softened ash particles on heat transfer surfaces exposed to radiant heat while the aerosol emission index of a solid fuel is derived from the amount of K, Na, Zn, and Pb present all together in the fuel. Fouling index below 0.4 is said to qualify the fuel as having low-medium fouling tendency while 0.4-0.7 are high-severe fouling characteristics [13]. According to this aerosol index, fuels may be categorized as (1) low PM1 emission range, index <1 wt% (db), (2) medium PM1 emission range, index 1–10 wt% db, (3) high PM1 emission range, index >10 wt% db tendency. Figure 4 shows the amount of individual mineral element present in the samples, which suggests that all the samples have severe fouling characteristics and may emit medium PM1 during thermochemical conversion.

Figure 3: SEM-EDX elemental scanning of the ash

Figure 4: Ash indeces analysis

The elemental composition of the samples from the ultimate analysis shows that the alternal attributes of the samples such as carbon, hydrogen Sulphur and oxygen contents are similar to that of the coal (Figure 5). However, the nitrogen content of the samples is between 4.2-5.5 wt%. Generally, the N concentrations in the fuels are categorized into (1) Low-N fuels (<0.4 wt %, db), (2) Medium-N fuels (0.4–1 wt %, db) and (3) High-N fuels (1–10 wt %, db). From the N-content recorded in this investigation, the sample can be characterized as high N-fuel. Further evaluation of the alternal attributes of the samples also suggests that the molar ratio of hydrogen/carbon (Figure 6) of sample 1 is similar to that of coal-1 while sample 2 and 3 have ratio similar to coal-2. This characteristic further indicates that the samples have high combustibility tendencies since a high H/C ratio of the fuel is an indication of its combustibility.

Figure 5: Ultanal attributes of the samples

Figure 6: Hydrogen/carbon ratio versus Oxygen/carbon ratio of the samples

4. Conclusion

Characteristics of a typical sludge samples as received was analysed following standard analytical procedures. The sludge samples possessed good physicochemical properties comparable to that of coal. However, the nitrogen content of the sample is between 4-5.5 wt% and aerosol emissions index analysis of 1-10 wt%, which classified the samples as high N-fuel and medium PM1 fuel. Utilisation of the sludge sample as feed stock for power generation via thermochemical conversion pathway may require post-treatment of product streams and decontamination of tar and ash (bottom and fly) due to the presence of heavy metals in order to conform with standard environmental regulations.

5. References

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