Spent bio-slurry from “Adani” rice husk mixed with graded levels of cow dung in bio-gasification: Heavy metals identification and potentials

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Abstract. Heavy metals identification and potentials of spent bio-slurry from “Adani” powdered rice husk (PRH) mixed with graded levels of cow dung (CD) in biogasification process was investigated. The waste supplements include; 90:10, 80:20, 70:30, 60:40 and 50:50 PRH: CD, respectively. The PRH and CD separately served as control. Bio-wastes validation for the anaerobic digestion (AD) process based on physico-chemical properties and calorific values were determined using standard laboratory methods. All the wastes were gasified at ambient conditions using biogas plants of similar volume (48 L) for 30 days. The spent bio-slurry was evaluated for heavy metals (Ni, Cr, Cu, Zn, Mn, Pb, Fe and Ag) and macro elements (Ca, Mg and K) using atomic absorption spectrophotometer. Nutrient contents of undigested wastes showed reliability for the bio-gasification and the waste systems yielded total gas volumes of 123, 127, 125, 141, 127, 246 and 291 liters for 90:10; 80:20; 70:30; 60:40 and 50:50 PRH: CD, PRH and CD, respectively. Onset of flammable gas ignition by digester systems were recorded as 15, 15, 11, 9, 6, 8 and 4 days, for the composite and single wastes, respectively. Concentrations of the heavy metals in the spent bio-slurry composite (90:10, 80:20, 70:30, 60:40 and 50:50 PRH: CD) ranged from 4.28-21.37 (Ni); 0.00-4.86 (Cr); 0.00-2.37 (Ag); 0.00-2.70 (Cu); 0.00-10.42 (Pb); 0.00-9.46 (Mn), 61.14-1,589.65 (Fe) and 1.80-17.32 (Zn) ppm/g of sample, respectively. Concentrations for Ca range from 111.12-333.36; K: 9.67-35.45; Mg: 127.14-238.52 ppm/g of sample. Overall results showed that partially decayed ‘Adani’ powdered rice husk could generate biogas energy in single and co-digested forms for cooking and lighting, among other benefits. Secondly, the co-digested spent slurries contained low amounts of the heavy trace metals identified and have great potentials for application to organic farming and horticultural practices.

Keywords: Anaerobic digestion, bio-gasification, bio-slurry, bio-digester, heavy metals, volume of gas yield

1. Introduction

Rice wastes (husk, straw and powdered rice husk) are always generated from processing of paddy rice into rice grains in various rice mills that are widely spread. Some of the wastes are put into use for agricultural repairs, natural adsorbents, heat and bio-fuel production, among others. However, a great lot is being wasted through burning or allowed to decay naturally where they were dumped. Rice waste contained majorly cellulose in addition to silica and lignin and must be chemically treated, blended with animal manure or allowed to degrade partially by aerobic microorganisms in anaerobic digestion to yield biogas. Aerobic microbes had been found to be stronger than biogas microbes in degrading the fibers before anaerobic digestion takes place successfully [1]. Rice waste has high
heating value (13-16 MJ/kg) but has not been fully utilized for heating, cooking or lighting purposes in many indigenous rice mills and beyond. At the laboratory research levels in Nigeria, biogas fuels had been produced from rice waste after chemical treatment, co-digested with animal manure [2], among other referenced studies. However, application of spent bio-slurry to organic farming (cultivation of oranges, pepper, pineapples, tomatoes, maize, ginger, turmeric, etc.) is limited. This slurry as an organic fertilizer can add humus to the soil which may benefit crop production [3].

The dried slurry could be used as diet supplement for fish, pig, poultry and other animals due to the nutrient rich contents [4]; [3]. However, utilization of the bio-slurry in fish farming will depend on concentration of some heavy metals present based on the type and source of agricultural waste including materials used for the bio-plant construction, among others. Heavy trace metals were found to be useful in the functioning of the methanogens and other biogas microbes but at low concentrations. Hence, verifications on their effects on flammable biogas yields in addition to the composition in the bio-slurry had been determined by [5]; [6] and [7]. Investigation on effect of some heavy metals’ (Zn, Cr, Cu and Pb) concentration between 19 and 80 ppm; on biogas yields reported by [5] showed that the most toxic to the AD (anaerobic digestion) systems was copper (Cu), while Pb was the least. Increase in toxicity of the metals to anaerobic digestion system was related to low biogas yields. Biogas systems are generally temperature and pH dependent including elemental concentration levels for high flammable gas yields and longer retention time.

Fresh powdered rice husk from ‘Adani’ rice mill had been utilized to generate renewable natural gas (biogas) after soaking in enough water for one week to partially decay [8]. It was then combined with other wastes such as brewery spent grain, cassava wastewater and carbonated soft drink sludge. Also, studies were carried out by different Authors for the purpose of optimization of biogas yields from rice wastes (9); [10]; [11]; [2], among others). Limited information was found on the analysis of the heavy metals concentration of the bio-slurry and its subsequent use in agricultural production including diet supplements for fish and other animals. Cow wastes (dung, abdominal feaces and liquor) had been used as complements with plant residues/biomass due its ability to provide larger population of anaerobic bacteria dominated by cellulolytic bacteria able to biodegrade cellulose from the manure ([12], [13], [14], [2]). Its energy value is also higher than that of rice husk. Hence, the purpose of the study was to: i. generate biogas energy from ‘Adani’ powdered rice husk (obtained from the dumping site) mixed with graded levels of cow dung, ii. Analyze the spent bio-slurry for some heavy trace and macro-elements concentrations; and iii. Consider the suitability of the spent slurry for organic food production.

2. Materials and methods

Cow dung (50 kg) was collected from the slaughter house in ‘Ikpa’ daily market, inNsukka while partially decayed powdered rice husk (100 kg) was procured from ‘Adani’ rice mill at the dumping ground, inUzo Uwani, Udenu local government, Enugu State, respectively. Biogas plants and analar grade chemicals were obtained from National Centre for Energy Research and Development (NECRD), University of Nigeria, Nsukka. All chemical analyses and calorific value determination for the study were done at the Biomass laboratory, NECRD. The AD experiment was carried out at the NECRD exhibition ground. Other materials used include: weighing balance (50 kg “Five Goats,” model no., Z051099), (3 kg metra balance; model no., TL 3000), gas collection accessories, pocket-sized pH meter-RIO2895; Hanna Instruments Italy), bomb calorimeter (XRY-1A, China), Pen Type-Thermo-hygrometer-CE (humidity range: 2 to 98 %), locally fabricated burner and distilled water

2.1. Sample pretreatment

The dung was allowed to be aerated for 2 days before the experimental setup. Rice husk was screened to remove non bio-degradable materials and any other unwanted waste. Samples were taken for chemical analyses and 60 kg of the PRH was soaked in enough water in big plastic bowls for 4 days to allow partial degradation to further take place [15].
2.2. Experimental setup

Experimental design was based on a completely randomized design and samples formulated were according to the ratios: 90:10, 80:20, 70:30, 60:40 and 50:50 PRH: CD, respectively. The PRH and CD separately served as control. Seven prototype metallic bio-plants (48 L capacity each—Figure 1) designed and constructed at NCERD engineering workshop for anaerobic digestion experiments were used to setup the experiment. The digesters were each loaded with the waste diluted with water in the ratio of 1:3 (9:27 kg; waste: water). Only ¾ of the digester volumes was occupied by the slurry leaving out headspace for gas storage during production. Experiment was carried out between May 16th and June 15th, 2018 at ambient temperature range of 22.5-34.5°C (active sun hours-8am to 4pm) for 30 days.

Figure 1: Biogas plant

2.3. Analytical methods for the AD process

2.3.1. Nutrient composition analyses of unfermented wastes

Proximate composition of the waste suspensions such as moisture, ash, crude fibre, fat, nitrogen and protein of the unfermented food wastes were done using [16] method. Organic carbon content was carried out using the method described in [17]. Total and volatile solids content of the wastes were analyzed using the method of [18]. The calorific contents were determined using bomb calorimeter [16].

2.3.2. Monitoring of the AD process stability

pH

The monitoring of the biogas systems for changes in pH was done at the zero day of the period and then two days’ intervals until the study ended using the pocket-sized pH meter.

Ambient temperature
Diurnal temperature changes and relative humidity were recorded using Pen Type-Thermo hygrometer.

2.3.3. Diurnal volume and flammable gas production monitoring

Volume of gas formed per day was determined by collection over water [19]. Flammability/ignition check for digester systems was also carried out on daily basis until the system produced flammable biogas and occasionally till the end of digestion period. Locally fabricated biogas stove was used [20].

2.3.4. Microbial progression analysis

Microbial counts (total viable counts) of the bio-systems to monitor the progress of the biogas microbes were determined by collecting slurry samples from each system using modified surface viable count method [21]. This was done at various stages such as zero day (charging day), flammable, maximum gas yield and end of experimental periods.

A 1g of the waste slurry was weighed and transferred into sterile test tubes and 10 ml sterile saline solution was introduced into each test tube that contained the slurry sample. The mixture was shaken thoroughly to obtain a uniform suspension that was allowed to set and the supernatant served as the inoculums. Various dilutions were obtained from the supernatant using sterile distilled water obtained with a sterile pipette. The aim was to obtain dilutions that contain approximately 30 cells per 0.015ml. Agar plates were prepared and the undersides of the plates were divided into eight segments with an indelible marker. They were inoculated with 0.1ml of each suspension of the sample. The plates were then transferred to an anaerobic jar (containing a gas pack used to evacuate all traces of oxygen thereby creating an environment having only carbon IV oxide), where CO$_2$ was forced to circulate. Incubation took place for 24 hours at 37°C for each stage where counting is involved. After incubation, the number of colonies on each segment was counted.

2.3.5. Analysis of the spent biogas sludge/bio-slurry

Determination of the heavy trace metals and some macro-elements concentration

Heavy metals; Ni, Cu, Zn, Mn, Pb, Fe, Ag, Cr and macro elements (Ca, Mg and K) concentrations were identified from the powdered rice husk spent bio-slurry composite systems using atomic absorption spectrophotometer method [22].Atomic absorption spectrophotometer device, AA-7000, ROM Version 1.01; serial number A30664700709, was used for the analysis from 16-17$^{th}$ July, 2018. The elements were absorbed at various wavelengths. Phosphorus (P) was analyzed using UV-1800 Visible Chimadz spectrophotometer made in Japan, while nitrogen from the spent sludge was evaluated by Kjeldhal method of [16].

2.3.6. Data analysis

Data collected were analyzed using regression and one-way analysis of variance from IBM statistics software package 23.0 versions, Microsoft Excel and Graph Pad Prism software version 6.50. Mean separation was done using Duncan’s new multiple range test and significant difference accepted at p<0.05 [23].

3.0 Results and discussion

3.1. Nutrient composition of the undigested organic wastes

Nutrient composition of the undigested wastes’ slurry is shown in Table 1. The slurry was found to be suitable for the bio-degradation [24] and contained ash that ranged from 0.1-0.56%; moisture: 94.80-96.70%; crude fat: 0.20-0.85%; crude fibre: 0.40-1.10%; crude protein: 0.35-2.28%; carbon content: 1.54-1.60%; volatile solids: 0.77-2.75% and calorific value: 3991.0-4984.0 kJ/kg. Biogas system in biotechnology is a complex biochemical system where organic wastes can be fermented anaerobically in a reactor specially designed for it to produce biogas made up of majorly methane and carbon dioxide. Hence, its main objective was to produce a renewable and green energy option; and soil
nutrients for plant and animal production. For a successful bio-degradation four ingredients are required namely, organic matter, putrefactive bacteria, anaerobic conditions and heat. Organic matter is the food source for methane producing bacteria and should be rich in nutrient to be utilized by the biogas microbes.

Table 1: Nutrient composition of undigested waste suspensions

| Parameter               | 100PRH | 100CD | 90:10 | 80:20 | 70:30 | 60:40 | 50:50 |
|-------------------------|--------|-------|-------|-------|-------|-------|-------|
| Ash content (%)         | 0.29±0.02 | 0.56±0.03 | 0.40±0.03 | 0.10±0.02 | 0.30±0.03 | 0.14±0.01 | 0.31±0.02 |
| Moisture (%)            | 96.70b±20 | 94.80a±14 | 96.90b±21 | 96.70b±07 | 96.70b±14 | 96.70b±28 | 96.70b±21 |
| Fat (%)                 | 0.20±0.03 | 0.85±0.03 | 0.25±0.02 | 0.30±0.04 | 0.40±0.01 | 0.45±0.03 | 0.55±0.02 |
| Crude fibre (%)         | 1.10±0.21 | 0.40±0.14 | 0.90±0.21 | 0.90±0.07 | 0.90±0.03 | 0.80±0.04 | 0.80±0.07 |
| Protein (%)             | 0.35±0.02 | 2.28±0.23 | 0.53±0.02 | 0.70±0.06 | 0.96±0.03 | 1.14±0.01 | 1.31±0.02 |
| Carbon (%)              | 1.60±0.28 | 1.54±0.01 | 1.60±0.28 | 1.60±0.07 | 1.60±0.14 | 1.60±0.14 | 1.57±0.02 |
| V- solids (%)           | 0.89±0.02 | 2.75±0.02 | 0.77±0.01 | 0.85±0.03 | 1.53±0.02 | 1.00±0.14 | 1.00±0.03 |
| Calorific-value (kJ/kg) | 3991±0.71 | 4984±1.40 | 4030±1.41 | 4186±1.41 | 4355±1.41 | 4576±1.41 | 4811±1.71 |

Values are means ± standard deviation of three replications. Means with the same superscript within rows were not significantly (p>0.05) different. PRH- powdered rice husk; CD-cow dung

3.2. Biogas systems’ characteristics

3.2.1 Diurnal volume of gas production

Bio-plant systems’ performances are shown in Figures 2 and 3 (i-iv). Biogas energy production was cumulatively observed to be significantly (p<0.05) higher for the single wastes systems (PRH and CD) than co-digested wastes. Average daily gas volumes for the waste systems ranged from 4.10-9.70 L/day for 90:10 to CD. Cow dung system had highest cumulative volume of gas yield and shortest onset of flammable gas production (early digester ignition time-Figure 2) among all the biogas plant systems. Hence, the order of cumulative volume of gas production is as follows: CD>PRH>60:40>50:50&80:20>70:30>90:10, while for early digester ignition time; CD<50:50<PRH<60:40<70:30<80:20; 90:10. The scenario exhibited by the products of the gasification pointed out superiority of cow dung in quality and quantitative biogas production among other biogenic wastes and has been noted by many authors [25], [26]; [8]; [2]. It also highlighted that when powdered rice husk is well pretreated it will generate higher amount of biogas energy close to that of cow dung within the period. The PRH utilized for the study had partially decayed in the dumping site before being soaked for the AD process. However, fresh powdered rice from the factory plant collected and pretreated in the previous studies of [8] produced less total volume of gas with longer onset of flammable gas production.
Figure 2: Cumulative volume of gas yield [L] and bio-digester systems’ onset of ignition time [days].

Figure 3 (i): Daily gas production for 90:10 and 80:20 bio-systems.
Figure 3 (ii): Daily gas production for 70:30 bio-systems.

\[ y = -0.0078x^2 + 0.5267x - 1.5825 \]
\[ R^2 = 0.9684 \]

Figure 3 (iii): Daily gas production for 50:50 and 60:40 bio-systems

\[ y = -0.0106x^2 + 0.5492x - 1.4163 \]
\[ R^2 = 0.9287 \] for 60:40

\[ y = -0.0106x^2 + 0.5492x - 1.4731 \]
\[ R^2 = 0.9287 \] for 50:50
3.2.2. Microbial progression in the biogas systems

Proliferations of the biogas microbes during experimental periods are shown in Figure 4(i-vii) for the different waste systems. Higher values were obtained and relatively maintained when conditions were favourable for the microbes. Coefficient of determination ($r^2$) for CD and PRH indicated that 99 and 70%, respectively, of the data plotted agreed to microbial progression in the biogas systems. Log TVC values (6.60 and 6.0) at the end of study were still high and might indicate the ability of the systems to produce for a longer period. This value was also higher for 50:50 ratio systems whose Log TVC was 7.30 and $r^2$ was 0.84 approximately. The lowest value (3.20) was found in 70:30 systems with $r^2$ as 0.97. The 90:10 systems had poorest value (0.22) for $r^2$. Only 22% of the data agreed to the pattern of the progression.

Figure 3 (iv): Daily gas production for single waste systems.
Figure 4 (i): Log TVC against test periods for cow dung system.

Figure 4 (ii): Log TVC against test periods for PRH system.

Figure 4 (iii): Log TVC against test periods for 90:10 blends.
Figure 4 (iv): Log TVC against test periods for 80:20 blends.

\[ y = -0.0275x^2 + 0.1425x + 4.3275 \]
\[ R^2 = 0.7368 \]

Figure 4(v): Log TVC against test periods for 70:30 blends.

\[ y = -0.1025x^2 + 0.3015x + 3.6325 \]
\[ R^2 = 0.9748 \]
3.2.3. Bio-gasification stability parameters

(i) pH

Figure 5(i-vii) shows relationship between changes in pH of the bio-digester systems and volume of gas yield within the experimental period. The pH is one of the process parameters that can affect...
biogas microbes and consequently volume of gas yield in AD process. The slow growing methanogens are highly sensitive to pH changes and can only operate optimally within slightly acidic (6.5) to slightly alkaline (8.0) pH range [27]. Hence, improper range in pH values of a biogas system can result in collapse of the system with subsequent reduction in the volume of gas yield. Figures presented showed that each of the system produced maximally in the range of slightly acidic (almost 6.5) and 8.0 pH level. Hence, the pH range at the flammable gas production and to the end of study was recommendable and indicated that the spent sludge could be useful as soil conditioner for crop production.

Figure 5 (i): Relationship between volume of gas yield [L] and pH at two days’ intervals for cow dung system.
Figure 5 (ii): Relationship between volume of gas yield [L] and pH at two days’ intervals for powdered rice husk system.

Figure 5 (iii): Relationship between volume of gas yield [L] and pH at two days’ intervals for 90:10 systems.

Figure 5 (iv): Relationship between volume of gas yield [L] and pH at two days’ intervals for 80:20 systems.
Figure 5 (v): Relationship between volume of gas yield [L] and pH at two days’ intervals for 70:30 systems.

Figure 5 (vi): Relationship between volume of gas yield [L] and pH at two days’ intervals for 60:40 systems.
(ii) Ambient temperature during experimental period

Figure 6 presents changes in daily ambient temperature during study period. Diurnal ambient temperature variation affects biogas production. Weather conditions such as wind speed, rain, sunshine (solar radiation), relative humidity, and cloud cover, etc., affect biogas production throughout the seasons of the year [28]. Findings of [29] discovered in bio-gasification of some organic wastes that insolation, wind speed and relative humidity and volume of gas yield, were highly correlated with ambient temperature, which varied between 22 and 29°C.
3.3. Heavy metals and some macro-elements concentration in spent bio-slurry mixture systems

Some heavy metals and macro-elements of the spent sludge mixture systems identified are presented in Table 2. Concentrations of the heavy metals in the mixture (90:10, 80:20, 70:30, 60:40 and 50:50 PRH: CD) ranged from 4.28-21.37 (Ni); 0.00-4.86 (Cr); 0.00-2.37 (Ag); 0.00-2.70 (Cu); 0.00-10.42 (Pb); 0.00-9.46 (Mn), 61.14-1,589.65 (Fe) and 1.80-17.32 (Zn) ppm/g slurry, respectively. Concentrations for Ca range from 111.12-333.36; K: 9.67-35.45; Mg: 127.14-238.52 ppm/g of sample, while P: 4.17-9.58% and N: 0.09-0.21%. Values in Table 2 were obtained after multiplying all the data in ppm (actual concentrations of Table 3) with dilution factor (41.667). The 50:50 bio-slurry mixture did not contain Ag and Cu, 60:40 had no Ag, 70:30 had no Cr, Pb and Mn, and 80:20 had no Cr and Ag, while 90:10 contained no Cr and Pb but had highest amount of Fe among other complements. Presence of heavy trace metals and other elements have been verified to be very useful to biogas microbes by helping enzymes to function properly. However, this has to be at low concentrations. Results obtained from powdered rice-cow dung systems showed the low level concentrations of the metals in each digester after the AD process. However, only Fe was of higher values in 90:10, 80:20, 70:30 and 50:50 systems than others.

The 90:10 and 80:20 systems became lighted on the fifteenth day of the retention period which might task the patience of the user especially in terms of cooking, lighting and electricity application. Concentrations of Ni and Zn were also higher in 90:10 and 80:20, respectively, than others. For the macronutrients, potassium and magnesium were higher in concentration for 90:10 systems than others, while 80:20 had highest amount of calcium among others. Research reports of [7] noted that heavy metals from plant and livestock residues could affect quantity of biogas in AD process. Consequently, such metals with level of concentration that can assist in the health maintenance and performance of methanogens are: Cu-0.00 to 100; Fe$^{2+}$-50 to 4000; Ni-0.1 to 0.8; Cd$^{2+}$-0.1 to 0.3 and Zn-0.00 to 5.0 mg/L. Also, findings of [6] indicated that higher concentrations (80.0 ppm) of heavy metals (Cu, Zn, Cr, and Pb) reduced biogas yield by 36.30, 31.64, 31.64 and 30.62% in the various biogas systems. Studies of [30] highlighted that the heaviest metals that might toxify aquatic life at high concentrations, such as fish, include; Hg, Pb, Cd, Cu and Zn. These results showed that heavy metals concentration in AD systems should be monitored for higher yields of renewable natural gas (bio-methane) required for cooking and other purposes including application of the spent sludge to the soil for crop production, agric- and horticultural practices.

The benefits of the spent bio-slurry had been shown to be numerous. For instance: i. It is odourless and would not attract flies wherever applied since it has been fully digested; ii. It can enhance the soil ability to retain water and add digested rich nutrients from dead bacteria and the solid sludge; iii. The slurry after separation and stored for few days could be diluted with water on equal ratio and apply directly to fruit crops and vegetables in the garden or crops cultivated in farms around households without any reactions that could kill the plants; major plant nutrients- NPK-nitrogen-phosphorus-potassium are also made available in addition to other macronutrients required for plant growth such as calcium and magnesium, among others,[31]; [3] and [32]. The NPK values in the study were relatively low and might be due to delay in the analysis (one week after end of the study). The powdered rice spent bio-slurry systems indicated that the spent slurries could be used for organic farming, rearing of domestic animals such as pig, goat, snail, poultry and others. As an advantage, pH range of the composite slurry systems varied from slightly acidic (6.5) to slightly alkaline (8.0) level at end of study.
Table 2: Some heavy trace metals (ppm/g of sample) and macro-elements identified from spent bio-slurry systems

| Heavy trace metal & macro-elements (ppm/g sample) | 90:10 | 80:20 | 70:30 | 60:40 | 50:50 |
|-------------------------------------------------|-------|-------|-------|-------|-------|
| Ni                                              | 21.37 | 8.55  | 8.55  | 4.28  | 12.82 |
| Cr                                              | 0.00  | 0.00  | 0.00  | 4.86  | 2.43  |
| Ag                                              | 1.19  | 0.00  | 2.37  | 0.00  | 0.00  |
| Cu                                              | 1.35  | 1.35  | 2.70  | 1.35  | 0.00  |
| Pb                                              | 0.00  | 10.42 | 0.00  | 10.42 | 10.42 |
| Mn                                              | 6.75  | 9.46  | 0.00  | 4.05  | 1.35  |
| Fe                                              | 1,589.65 | 509.50 | 183.92 | 61.14 | 163.04 |
| Zn                                              | 12.63 | 17.32 | 3.25  | 1.80  | 5.41  |
| K                                               | 35.45 | 29.01 | 305.58 | 138.90 | 203.74 |
| Ca                                              | 228.82 | 152.13 | 127.14 | 138.90 | 111.12 |
| Mg                                              | 238.82 | 152.13 | 127.14 | 138.90 | 203.74 |
| N (%)                                           | 0.09  | 0.11  | 0.15  | 0.18  | 0.21  |
| P (%)                                           | 4.17  | 5.0   | 6.67  | 7.10  | 9.58  |

Ni-nickel; Cr-chromium; Ag-silver; Cu-copper; Pb-lead; Mn-manganese; Fe-iron and Zn-zinc [Heavy trace metals]; N-nitrogen; P-phosphorous; K-potassium; Ca-calcium and Mg-magnesium [macro-elements]

ppm = parts per million; 1ppm = 0.001g/kg = mg/kg; Dilution factor = 41.667/1 g of sample

Table 3: Actual concentrations (ppm) of the heavy trace metals and the macro-elements

| Spent sludge mixture | Ni (232.0 nm) | Cr (357.9 nm) | Ag (328.1 nm) | Cu (324.8 nm) | Pb (283.3 nm) | Mn (279.5 nm) | Fe (248.30 nm) | Zn (213.9 nm) | K (766.5 nm) | Ca (422.7 nm) | Mg (285.2 nm) |
|----------------------|---------------|---------------|---------------|---------------|---------------|---------------|----------------|---------------|--------------|---------------|---------------|
| 90:10                | 0.512 8       | 0.00 0.0285   | 0.0323        | 0.00 0.1620   | 38.148        | 0.3030        | 0.8508         | 5.3333        | 5.7239       |               |               |
| 80:20                | 0.205 1       | 0.00 0.00    | 0.0323        | 0.2500        | 12.227 9      | 0.4156        | 0.6961         | 8.000        | 3.6508       |               |               |
| 70:30                | 0.205 1       | 0.00 0.0569  | 0.0647        | 0.00 0.00     | 4.4017        | 0.0779        | 0.6961         | 7.3333        | 3.0510       |               |               |
| 60:40                | 0.102 6       | 0.1167        | 0.00 0.0323   | 0.2500        | 1.4672        | 0.0433        | 0.6188         | 3.333         | 3.3704       |               |               |
| 50:50                | 0.307 7       | 0.0583        | 0.00 0.00     | 0.2500        | 3.9127        | 0.1299        | 0.2320         | 2.6667        | 4.8894       |               |               |

nm = nanometer (wavelength); ppm = parts per million; dilution factor = 41.667/1 g of sample; date of analysis = 16 and 17th July, 2018.

4.0 Conclusions

Partially decayed powdered rice husk from Adani rice mill dumping ground generated higher volume of biogas that could be compared to the yield from cow dung in an AD batch process. Cumulative volume of gas production order is as follows: CD>PRH>60:40>50:50&80:20>70:30>90:10, while for early digester ignition time; CD<50:50<PRH<60:40<70:30<80:20<90:10. Presence of higher concentrations of heavy metals in biogas systems as a factor can affect quality and quantity of the natural gas generated including spent bio-slurry applications. Hence, effort should be made to monitor their concentrations before the AD process. Spent sludge from the powdered rice husk could be used for organic farming, rearing of domestic animals such as pig, goat, snail, poultry and others. As an
added advantage, pH range of the composite slurry systems varied between slightly acidic (6.5) to slightly alkaline (8.0) level at end of the experiment. The study strongly supports installation of functional concrete fixed dome bio-gas plants at Adani rice mills for the generation of renewable natural gas, methane, and spent slurries that can be separated for bio-fertilizer and animal feed. This will also reduce liberation of free methane from partially decayed powdered rice husk at the dumping ground which might contribute to global warming.

5.0 References

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