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ADDRESSING POLLUTION FROM DEVELOPED COMPOSITE SOLID FUELS (CHARCOAL) FOR HOUSEHOLD AND INDUSTRIAL PURPOSE

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Abstract

This paper presents the results of emission measurements made on formulated composite solid fuels with the use of kaolinite for minimizing gaseous emissions and for pollution control. The composite solid fuels have been primarily developed to immensely minimize pollution from solid fuels used as alternative fuels to electricity, petrol and diesel on daily basis.

The results show that the addition of the clay content has immensely contributed in channelling the routes of release of some of the compounds in the fuels to accompany the ash residue rather than as gaseous emissions. Therefore, the advantages include high emission reduction. The charcoal- based composite fuels which were produced from a mixture of the solid fuels and clay solution yield its minimum emission for a formulation of 1:1 of saw dust: clay solution (1:2 of clay: water) by mass fraction. Clay incorporated in charcoal for indoor heating has been shown to demonstrate considerable advantages over pure charcoal. The negative impact of the use of pure biomass energy on the daily lives of populations (especially women and children) in the poorest parts of the developing world cannot be underestimated.

Keywords: Composite Solid Fuels; Charcoal, Clay; Kaolinite; Coal; Emission Analysis; Beaker; Sieve; formulation;pdt-Crowcon Gasman single trace gas (CO) analyzer.

1. Introduction

In developing countries, especially in rural areas, 2.5 billion people rely on biomass, such as fuel wood, charcoal, agricultural waste and animal dung, to meet their energy needs for cooking [1]. In many countries, these resources account for over 90% of household energy consumption. In the absence of new policies, the number of people relying on biomass will increase to over 2.6 billion by 2015 and to 2.7 billion by 2030 because of population growth [1]. That is, one-third of the world’s population will still be relying on these fuels. There is evidence that, in areas where local prices have adjusted to recent high international energy prices, the shift to cleaner, more efficient use of energy for cooking has actually slowed and even reversed [1]. Use of biomass is not in itself a cause for concern. However, when resources are harvested unsustainably and energy conversion technologies are inefficient, there are serious adverse consequences for health, the environment and economic development. About 1.3 million people mostly women and children die prematurely every year because of exposure to indoor air pollution from biomass [1]. This necessitates the need to immensely reduce the gaseous emissions, and as well minimize pollution from these sources.

More than half of the world's population still depends on fuel sources that are inefficient, highly polluting and unhealthy. These fuels which are referred to as solid fuels include biomass (wood, animal dung and crop wastes) and coal. People who use these fuel sources burn them in open fires or simple stoves that release most of the smoke into their home, resulting in indoor air pollution that threatens the health of household members, especially women and young children [2]. These pollutants, called solid-fuel "smoke" include respirable particles, carbon monoxide, oxides of nitrogen and sulfur, benzene, formaldehyde, 1,3-butadiene and polyaromatic compounds such as benzo(a)pyrene [3]. In households with limited ventilation (as is common in many developing countries), exposures experienced by household members, particularly women and young children who spend a large proportion of their time indoors, have been measured to be many times higher than World Health Organization (WHO) guidelines and national standards [3-4].

Based on research, it's been noted that valuable time and effort are devoted to fuel collection and income generation instead of education on safe application of the solid fuels. Environmental damage can also result, such as land degradation and regional air pollution. Two complementary approaches can improve this situation [1]: promoting more efficient and sustainable use of traditional biomass as objectified in this present research; and encouraging people to switch to modern cooking fuels and technologies which is relatively more costly and hazardous to health. The appropriate mix depends on local circumstances such as per-capita incomes and the availability of a sustainable biomass supply [1].

Halving the number of households using traditional biomass for cooking by 2015, a recommendation of the United Nations Millennium Project would involve 1.3 billion people switching to other fuels. Alternative fuels and technologies are already available but not at more attractive cost. Providing LPG stoves and cylinders, for example, would cost approximately $1.5 billion per year to 2015. Switching to oil-based fuels might have a significant impact on world oil demand. It's also worth noting that when fuel costs and emissions are considered, the household energy choices of developing countries might be limited by economic, climate-change or energy-security concerns [1].

There have been many programs aimed at developing and disseminating improved stove technologies to reduce the burden, primarily borne by women, of fuel wood collection as well as reducing health risks associated with smoke from burning fuel wood. Technologies have also been introduced to help with the processing of biomass to improve efficiency, allow for easy transportation or to make it more useable. Industrial biomass residues are now widely used in many countries to provide centralized, medium and large-scale production of process heat for electricity production or other commercial end uses. There are several examples in Indonesia of timber processing plants using wood waste-fired boilers to provide heat and electricity for their own needs, and occasionally for sale to other consumers [5].

In America, in the last few decades, South American forests have continued to record large losses of covered area [6]. The rich biodiversity of these tropical forests continues to be in danger of deforestation despite initiatives from Latin American countries, such as the increase of protected areas [7]. In the region of Piura in Peru, there are 389,685 homes of which 55.81% use firewood and charcoal daily as domestic fuel according to the Istituto Nacional de Estadística del Perú - INEI [8]. The Ministry of Environment (1977) states that this material coming from the cutting of dry forest areas characteristic of the region and protected areas such as the Northwest Biosphere Reserve. This situation is compounded by the emission of greenhouse gasses as a result of open indiscriminate burning of wood waste (sawdust, chips and shavings among others) representing approximately 42% of the production from sawmills, which is equivalent to burning 861.84 m3 of wood waste per year in the region according to the INEI [9-12]. Following a premise from United Nations [6], greater efforts and innovative approaches are required to reduce the loss of biodiversity in ecosystems such as forests, and to lower CO emissions to curb climate change [13].

There have been several researches carried out on production of solid fuel for both domestic cooking and industrial applications. One of the major driving forces behind these researches is the need to address the environmental consequences and health hazards associated with the use of solid fuels [14-15]. This has been accomplished in this research. It involves the formulation of composite solid fuels using clay (kaolinite) solution (1:2 of clay: water) and charcoal. The pure sample and a total of three formulations were used. The formulations were in the ratios of 2:1 charcoal: clay solution, 1.5:1 charcoal: clay solution and 1:1 charcoal: clay solution respectively. 200μm sieve, 500ml beaker and pdt-crowcon gasman single trace gas (CO) analyzers were all used in the solution formulation and emission analysis.

The main objective of this research is to devise a means to arrest pollutants from biomass by developing composite solid fuels (charcoal) at immensely reduced gaseous emissions, and as well minimize pollution from such sources.

2. Development of samples and emission analysis

2.1. Materials used

The clay (kaolinite), water, kaolinite solution, charcoal, 200μm sieve, 500mL beaker and pdt-Crowcon Gasman single trace gas (CO) analyzers were all used in the research.

2.2. Sample preparation and formulation

For this study, commonly available charcoal in the rural areas of Nigeria were used. The formulated charcoal fuels were prepared using kaolinite clay solution, and solid pulverized charcoal. Clay-sand mixture was dissolved in water, stirred continuously until the clay components of the mixture were in solution. The solution was decanted through a 200μm sieve into a 500ml beaker to remove suspended particles and kept to allow the fine clay particle settle. After 48 hours clear water was decanted off leaving very fine clay which was dried in an oven maintained at 250℃ for 2 hours. The dried clay was pulverized, measured, mixed with distilled water and made into solutions. Different amounts of the clay solution were mixed with a fixed known amount of pure charcoal to produce the several formulated coal samples [16].

Table 3.1. Shows the values of the concentrations (ppm) and time (m) readings of the samples during combustion

Time, mins	Pure Sample, ppm	2:1 Solution, ppm	Charcoal:Clay sample 1.5:1 Solution, ppm	1:1 Solution, ppm
0.5	28	20	12	12
1.5	49	35	12	18
2.5	55	43	12	18
3.5	63	51	18	28
4.5	80	61	20	12
5.5	55	45	15	9
6.5	50	50	13	10
7.5	45	36	12	9
8.5	39	39	10	7
9.5	42	37	9	6
10.5	37	32	5	7.7
11.5	43	33	7	7
12.5	37	30	6	6
13.5	35	34	7	7
14.5	36	27	7	7
15.5	37	23	5	6
16.5	33	22	7.5	7.5
17.5	30	23	5	7.5
18.5	29	21	7	6
19.5	27	23	6	6
20.5	28	21	7	5
21.5	26	19	5	5
22.5	23	19	5	4
23.5	22	20	3	6
24.5	23	18	4	3
25.5	21	19	5	5
26.5	20	17	4	2.5
27.5	17	17	5	4
28.5	16	16	4	2.5
29.5	16.5	15.5	2.5	2.5

Three formulations of the composite charcoal were performed using the clay-water mixtures. The clay-water mixtures was of ratio 1:2 and the mixtures or simply clay solutions were then added to the varying amounts of charcoal to form 3 samples of different compositions. The different charcoal to clay formulated produced were 1:1, 1.5:1 and 2:1 designated as samples C_1, C_2 and C_3 respectively. The mixtures of charcoal and clay solution formed pastes which were then placed in crucibles lined with filter paper and kept in an oven at 250ºC for 2 hours until the mixture was dry. The lumps were then left to cool.

2.3. Emission measurement

In this research, carbon monoxide was examined from the burning of the pure and the formulated charcoal-clay fuel samples. The instrument applied for sampling was the model pdt-Crowcon Gasman single trace gas analyzers. The instrument began with testing all the batteries to ensure good power supply, the red and blue alarm LEDs, sounder and internal vibrator alert. The analyzers were calibrated for ranges, zero and span checks, temperature and pressure correction factors before sampling began to rectify drifts in measurements. A detailed description of the CO analyzer operation is given by the pdt-Crowcon Gasman instruments user's manual.

Sampling was conducted from the stack of the furnace where the samples were burnt. An inlet probe fitted to about the middle of the length of the smoke stack was connected to a manifold of equal internal diameter. The outlet was connected to the sample inlet of the trace gas analyzer. During sampling, a particular temperature and burning period were maintained.

2.4. Procedure

Following the assembly set-up, combustion for emission analysis began. Starting with the pure samples followed by the formulated composite charcoal samples.

For each sample run, 5 grams of the crushed solid fuel sample was placed in a crucible and kept in the furnace set to a temperature of 400℃ to burn. This was performed for 20 minutes to allow for complete burning of each sample. During the combustion, emitted gases were measured continuously by the gas analyzers and the concentration was being recorded every 60 seconds.

3. Results and discussion

This section presents the results of the research in both tabular and graphical form. Table 3.1 depicts temporal variation of CO emission levels from the pure and the formulated charcoal samples while Figure 3.1 shows the results interpretation.

Figure 3.1 shows temporal variation of CO emission levels from the pure and the formulated charcoal samples. The CO emitted during the combustion of charcoal and the formulated samples show several erratic peaks throughout the burning but towards the last minutes of the combustion time, the concentrations of the pure charcoal and the sample, C_3, eventually become approximately equivalent. A similar situation is observed for the other two samples but a lower concentration. This study has shown a consistent pattern of emission reduction exhibited by the composite charcoal based fuels.

Charcoal burning in domestic heaters usually operates at elevated temperature of about 400ºC and above, however, combustion at 400ºC is most efficient as less emission is released over the same burning duration [16] and as a result the combustion, tests were conducted at 400℃. All the formulated solid fuel samples follow the same emission distribution growth behavior. The test results show that sample burning generates an initially high pollutant concentration followed by a sudden drop, then a rise and fall in a sinusoidal form but with decreasing intensity of the wave peak. The pattern occurs until the wave peaks generated flattens out. There is a sudden initial rise in the gas concentration reaching its peak within 5 minutes of start time. Thereafter, the concentration declines steadily and stabilizes on a particular value for the operating condition.

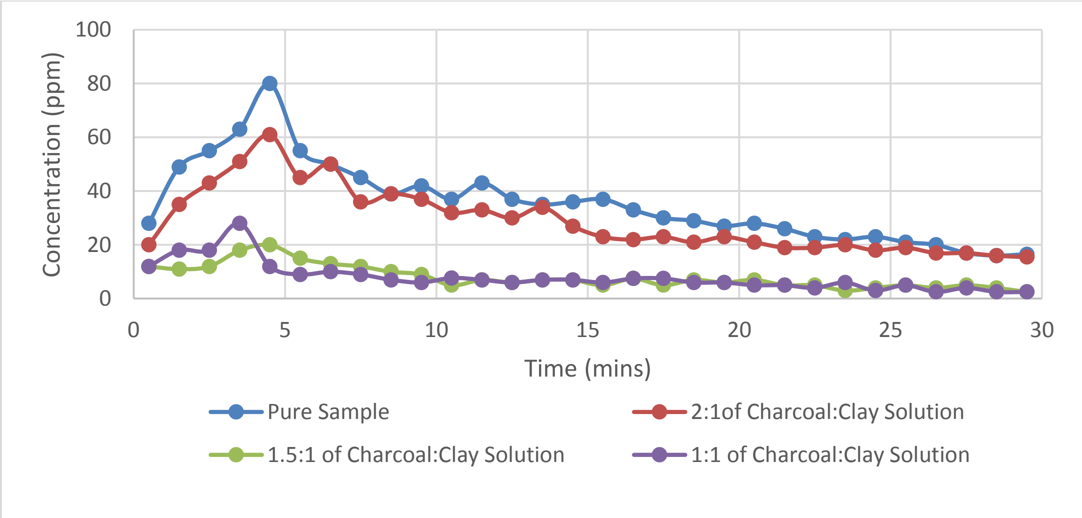

Figure 3.1. The temporal variation of CO emission levels from the pure and the formulated charcoal samples

The contribution of clay incorporated in charcoal for indoor heating has some considerable advantages over pure charcoal as seen on Figure 3.1 The advantages include high emission reduction and a highly deadly pollutant emission is to a significant extent reduced in the rate during burning. In as much as the addition of clay to pure charcoal has an effect on the reduction of emissions, a proportional solid fuel: clay solution trend indicates a limit to the addition of clay. The decrease in emissions of the various gases may be attributed to a repression of some particular minerals within the composite coal that might have possibly been transformed into solid which are embedded in the ash during combustion. The suspension of the minerals from being oxidized maybe attributed to the less release of the pollutant gases. The solution of 1:2. of clay: water, formulated into a composite solid fuels of 1:1 of pure charcoal: clay solution produces the solid fuel-type with the best pollutants emission rates reduction. The addition of the clay content has only contributed in channeling the routes of release of some of the compounds in the fuels to accompany the ash residue rather than as gaseous emissions.

The health of the public can be adversely affected by the smoke created from wood burning which can easily be inferred from gaseous emission analysis of solid fuel combustion in Figure 3.1 The pollutants include carbon monoxide, fine particles and other chemical compounds such as oxides of nitrogen and a range of organic compound. These pollutants can cause breathing difficulties even at relatively low levels, especially for young children, the elderly and people who are already suffering from respiratory conditions such as asthma [17]. The gaseous emission results of the formulated composite charcoal samples designated C_1 have shown that the pollutants (carbon monoxide) from these sources can be significantly reduced by the use of clay (kaolinite).

This study has shown that the negative impact of biomass energy on the daily lives of populations (especially women and children) in the poorest parts of the developing world cannot be underestimated. Furthermore, evidence would strongly suggest that the persistent widespread use of biomass energy largely depends on the factors of access in Africa, affordability and pricing policies in Indonesia, coal in China and LPG in some countries.

4. Conclusion

In line with the World Health Organization (WHO) guidelines, an attempt to enhance the environment through the development of less harmful and environmentally tolerable fossil fuel types has been made. Based on the experimental procedure and the research results, the following inferences have been drawn:

1. Clay (kaolinite) can significantly reduce gaseous emissions from solid fuels (charcoal).
2. The solution of 1:2 of clay: water, formulated into a composite solid fuels of 1:1 of pure charcoal: clay solution produces the solid fuel-type with the best pollutants emission rates reduction.
3. The addition of the clay content has only contributed in channeling the routes of release of some of the compounds in the fuels to accompany the ash residue rather than as gaseous emissions.
4. Clay incorporated in charcoal for indoor heating has been shown to demonstrate considerable advantages over pure charcoal.
5. The decrease in emissions of the various gases may be attributed to a repression of some particular minerals within the composite coal that might have possibly been transformed into solid which are embedded in the ash during combustion.
6. The negative impact of the use of pure biomass energy on the daily lives of populations (especially women and children) in the poorest parts of the developing world cannot be underestimated.
7. A means to arrest pollutants from biomass by developing composite solid fuels (charcoal) at immensely reduced gaseous emissions has been devised.

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