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Research Article

Evaluation of Impact of Solid Wastes and Its Potential as A Source of Renewable Energy. A Case Study from Minna and his Environs, Nigeria

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Abstract

The evaluation of impact of solid wastes was carried out around Minna Metropolis, Niger state. This is aimed to evaluate the heating values and its potential as a source of renewable energy within the environs. Integrated approaches (Ultimate and Proximate analyses) was used to carried out the studies. The selected solid waste includes; Polyethene (Nylon), Paper and Plastic bottles. Samples were obtained randomly from five different dump sites. It was observed from the result obtained that the ultimate analysis of the solid waste contains 50% of carbon and 5% of Hydrogen which is within the range of values from literature which can be utilized for waste–to–energy recovery and also it reduces emission during combustion. The proximate analysis shows that the low ash content which can be utilized for energy. The elemental components of the solid waste were used to estimate the Calorific Value from Regression analysis. These data points considered for correlation by regression analysis ranges in carbon content from (27.80 to 92.70)%, hydrogen content (0.10to 8.80)%, oxygen content (0.20 to 49.50)%, nitrogen content (0.00 to 5.95)% and sulphur (0.00 to 1.05)% on dry basis. The derived correlation can be inferred as a 'general correlation' for the estimation of calorific value of solid waste from its elemental components within the above specified ranges.

Keywords: Hydrogen; Oxygen; Nitrogen; Renewable Energy

Introduction

Wastes are substances which are discarded of or intended to be discarded by a community. The waste could be solid or semi-solid materials disposed in land or ocean. Solid waste disposal is placed highly so as not to impact the society or environment negatively. This waste could be assimilated in such a way that they are not visible in the environment either by reusing, recycling or recovery of the wastes. The attributes and amount of the waste created in a region is not just a capacity of the expectation for everyday comforts and way of life of the locale's surroundings, yet relies on upon the accessibility and sorts of the assets and commercial ventures [1].

The waste can be classified into biodegradable waste such as food waste, paper, recyclable materials such as nylon, plastics, inert waste, construction such as rocks, debris, hazardous waste including most chemicals, light bulbs, spray cans, fluorescent tubes, toxic waste including pesticide, herbicides, fungicides and electrical and electronics waste such as computers, electrical appliances, screen etc [2].

Satisfying energy demand through the use of renewable energy sources is the main aim nowadays because of reduction of fossil fuel and environmental issues. Due to the increase in generation of municipal solid waste, it can be utilized as a means of source of energy for power generation or industrial purpose. Recovery of energy can be achieved from the non-recyclable constituents of municipal solid waste as they can decrease the utilization of fossil fuels thus assisting in minimizing global warming. The emission of CO2 coming from biogenic combustion of solid waste is renewable and reduce the global warming because it completes the carbon cycle as it does in biomass. Studies show that the energy recovered from solid waste can be a better way of managing environment from pollution caused by solid waste disposal Technologies [3].

The principal aim of this research is to evaluate the impact of solid waste and its potential as a source of renewable energy to the environment. The analysis of generation capacity and composition of solid waste will be main focus to establish the amount of energy that can be recovered from solid waste.

The energy from waste can be directly derived. Waste can be converted into biogas, syngas or heat. The innovative techniques in changing heat and energy from waste can be physical, thermal or biological. The energy created from waste, consolidated heat and power is a decent alternative for expanding overall energy efficiency in developed country like United States and United Kingdom. A common technique for management of waste is waste to energy recovery. One of alternative way of energy generation from waste which is the change of non-recyclable waste materials into useable heat power or fuel through different techniques including gasification, pyrolization, anaerobic digestion, combustion and landfill gas (LFG) recovery [4].

Materials and Methods

- **Samples Collection and Sorting:** Waste samples was collected from different five dumpsites within Minna and its environs; Kpakungu, Barkinsaleh, Maitumbi, Tunga and Chanchanga. The waste was segregated into non- biodegradable and biodegradable.
- **Sample preparation:** The samples were shredded into smaller quantities of approximately 30mm size and grounded using small mortal to less than 1mm size, this is in order to increases surface area of the sample that will allow easier penetration of heat [5].

Characterization of municipal solid waste

The characterization of municipal solid waste was done by evaluating the elemental composition of the MSW, the proximate analysis, the leachate composition and the calorific value of the MSW samples.

Analyses and Results

Determination of ultimate analysis (Elemental Composition)

The combustible percentage is shared among nitrogen, carbon, oxygen and hydrogen in standard ultimate analysis (Niessen, 1995).

Nitrogen, hydrogen, Sulphur and carbon (NHSC) are the elemental composition of the solid waste which was carried out at National Geographical Centre, Kaduna in accordance with the procedures of the Association of Official Analytical Chemists (AOAC, 2003). The composition of waste was determined using wet oxidation. 1.0-g of MSW sample was weighed into the digestion tube and 5W of digestion mixture was added to it. The mixture was left overnight in the fume cupboard. Using a tecator, the mixture was digested for 2 hours at 170°C and allowed to cool. To digest the mixture vigorously, 30-ml of distilled water was added to the solution and mixed. 50-ml of distilled water was added to the solution to increase the volume of digested mixture to 80-ml. Atomic Absorption Spectrometer was used to trace the elements under analysis.

Moisture contents determination

To determine the percent moisture of the waste samples weighing, 1-kg of the sample was weighed into a crucible and the sample was dried at 110°C for 1 hour in an oven and dried using a desiccator. The percentage of moisture content (MC) was calculated as a fraction loss in weight of sample before and after drying.

M_1=mass of empty crucible (g)

M_2=mass of empty crucible + sample (g)

M_3=mass of empty crucible + sample after heating (g)

Moisture content=$M_2 - M_3$

$$\% \text{ moisture content} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 \quad (3.1)$$

Volatile matter determination

The volatile matter percentage was carried out by heating the sample at a temperature of 950°C for 7 minutes using a muffle furnace. The crucible was cooled in the desiccator immediately it was removed from the furnace and weighed. The percentage loss of mass of the sample excluding the percentage moisture is the percentage of volatile matter.

M_1=mass of empty crucible (g)

M_2=mass of empty crucible + sample before heating (g)

M_3=mass of empty crucible + sample after heating (g)

M_C=percentage of moisture content

$$\% \text{ Volatile matter} = \frac{M_2 - M_3}{M_2 - M_1} \times 100 - MC$$

Ash content determination

Ash content is the non-combustible residue of the sample gotten after combustion which contains Sulphur and oxides. The process was carried out by burning of the sample at temperature of 750oC for an hour in a muffle furnace without a lid. The sample was cooled in a desiccator and weighed and the process was repeated constantly until a constant weight was attained.

M_1=mass of empty crucible (g)

M_2=mass of empty crucible + sample before heating (g)

M_3=mass of empty crucible + residue (g)

Ash content= $M_3 - M_1$

$$\% \text{ of ash content} = \frac{M_3 - M_1}{M_2 - M_1} \times 100$$

Fixed carbon determination: Mass of fixed carbon is determined by deducting the percentage of ash content, moisture content and volatile content from the total percentage.

% FC=100 – % ASH – % MC - % VM

Calorific value determination

Calorimetric estimation is the general process for measuring the energy content of the solid waste as a source of fuel. Regression analysis was used to estimate the heating value of each samples using the result obtained from the ultimate analysis.

Proximate analysis results

The proximate analysis presents the percentage ash, the percentage moisture, the volatile matter and the percentage fixed carbon of the MSW. The overall proximate analysis results is presented in Appendix A_1.

Characterization of samples in Maitumbi

The proximate analysis of solid waste in Maitumbi shown in figure 1. Waste paper has the highest moisture content of 6.52% due to its organic nature while plastic bottle and polyethene (Nylon) has little or no percentage moisture, because they are already processed material fully dried off moisture and with no pore space for moisture to penetrate through it.

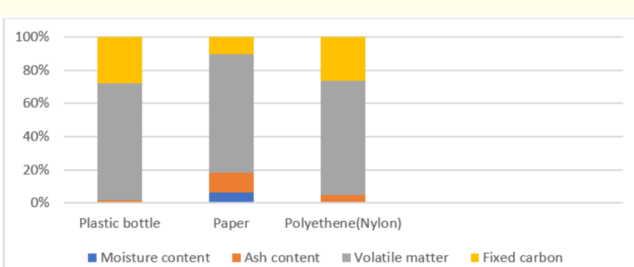

Figure 1 : Characterization of Samples in Maitumbi.

Polyethene (Nylon) has the highest volatile matter of 89. 15% and plastic bottle have with a value of 81.34% closed to polyethene. The percentage ash content of waste paper is higher than that of plastic bottle and polyethene due to their dryness after removal of moisture content.

Fixed carbon is the residue gotten after the percentage of moisture, ash and volatile matter has been deducted. The highest percentage of 17.2% was found in plastic bottle and waste paper with a percentage of 10.39%.

Characterization of samples in Chanchaga

The proximate analysis of MSW in Chanchaga shown in figure 2. Waste paper has the highest moisture content of 6.13% due to its organic nature while plastic bottle and polyethene (Nylon) has little or no percentage moisture. Polyethene (Nylon) has the highest volatile matter of 85. 66% and plastic bottle have a percentage of 81.34% closed to polyethene. Fixed carbon is the residue gotten after the percentage of moisture, ash and volatile matter has been deducted. The highest percentage of 19.39% was found in plastic bottle and the lowest fixed carbon percentage of 8.76% in polyethene (Nylon).

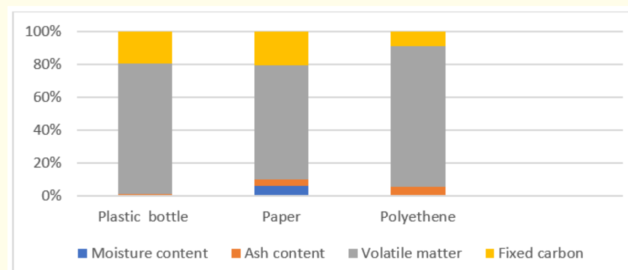

Figure 2 : Characterization of Samples in Chanchaga.

Characterization of samples in Tunga

The proximate analysis of MSW in Tunga presented in figure 3. Polyethene (Nylon) and plastic bottle has the lowest percentage moisture of 0.57% and waste paper has the highest percentage moisture of 7.48% due to its high absorption of moisture in nature. Highest volatile matter of 85.01% was found in polyethene (Nylon) and plastic bottle has a percentage of 75.46% closed to that of polyethene. The percentage of fixed carbon in polyetheneis 8.24% which lower compare to that of plastic bottle which has the highest percentage of 23.49%.

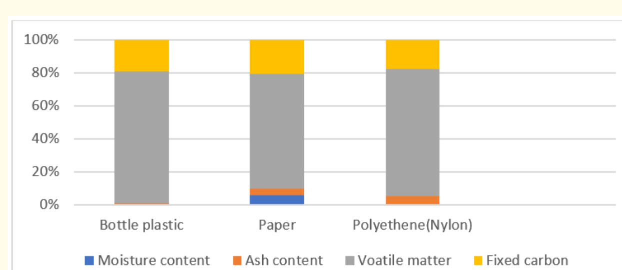

Figure 3 : Characterization of Samples in Tunga.

Characterization of samples in Kpakungu

The proximate analysis of MSW in Kpakungu shown in figure 4. Polyethene has the lowest percentage moisture of 0.65% and waste paper has the highest moisture content of 6.52%. Polyethene (Nylon) has the highest volatile matter of 89. 15% and plastic bottle have with a value of 81.34% closed to polyethene. Plastic bottle has the highest fixed carbon percentage of 16.52% compare to that polyethene with 5.81%.

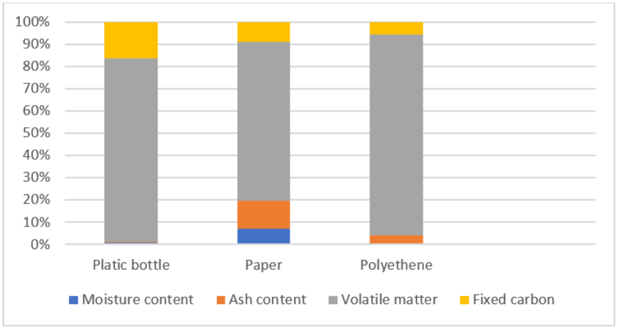

Figure 4 : Characterization of Samples in Kpakungu.

Characterization of samples in Barkin Saleh

The proximate analysis of MSW in Barkin Saleh shown in figure 5. Waste paper has the highest moisture content of 7.81% plastic bottle and polyethene (Nylon) has little or no percentage moisture. Polyethene (Nylon) has the highest volatile matter of 83.16% and plastic bottle with a percentage of 83.58% closed to polyethene.

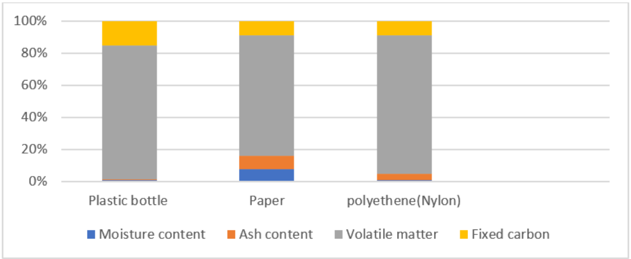

Figure 5 : Characterization of MSW samples in Barkin Saleh.

Fixed carbon is the residue gotten after the percentage of moisture, ash and volatile matter has been deducted. The highest percentage of 17.26% was found in plastic bottle and waste paper with a percentage of 10.39%.

Moisture content

Based on the proximate analysis carried out on the MSW collected at five different dumpsites in Minna, it can be deducted that waste paper has the highest percentage moisture of 7.81% from the MSW taken from Barkin Saleh which has negative effect on chemical conversion and energy content level, while the lowest moisture content is polyethene (Nylon) of 0.41% from the waste taken from Chanchaga.

Among all the samples taken from each dumpsite, polyethene (Nylon) has the lowest percentage moisture which can give high energy value. In Barkin Saleh it has 0.61%, Maitumbi 0.64%, Chanchaga 0.41%, Tunga 0.57% and Kpakungu 0.65% with an average moisture content of 0.58%.

Plastic bottles and polyethene (Nylon) contains little or no percentage moisture. Plastic bottles have it lowest moisture of 0.57% in Tunga and its highest percentage moisture of 0.88% in Maitumbi. The low percentage moisture in both plastics and polyethene is because they are already processed materials fully dried off moisture and with no pore space for moisture to penetrate it before and after use by consumers.

Paper is an organic product and moisture loving, it can easily absorb moisture which constitute their high moisture content than nylon and plastics with and average percentage moisture of 7.01% from the five dumpsites with a range of 6.13 – 7.81%. This high moisture content is prohibitive for combustion process as it rises the ignition temperature, also its contents reduces the calorific value of the fuel [6].

Volatile matter

The next process after moisture content is the percentage volatile matter. The volatile matter for all the waste possesses high percentage of volatile matter ranging from 69.57- 90.07%. Polyethene (Nylon) has the highest volatile matter with an average value of 87.21%, the lowest is 85.01% in Tunga and highest of 90.07% in Kpakungu while plastic bottles has an average percentage volatile matter of 80.35% closed to polyethene (nylon).

Waste paper has the least percentage of 71.75%, the highest percentage volatile matter in Barkin- Saleh is 75.17% and the lowest is 69.57% in Chanchaga.

The percentage of volatile matter affects the chemistry of solid fuels because it takes a long duration for a volatile matter material to burn out. High percentage of volatile matter shows that MSW possesses large amount of useful gases, such as methane which can be easily removed from the waste when subjected to heat.

Ash content

Based on the results obtained, plastic bottles has the lowest ash content with a range of 0.49 - 0.62%, the highest percentage of 0.62% in Maitumbi and the lowest in Barkin- Saleh with a percentage of 0.49%. polyethene (Nylon) and plastic bottles can be used for utilization of energy due to their low ash content because higher percentage of ash affects the carbonization effect.

Waste papers has the highest percentage ash content with a range of 5.07 - 12.58%, the sample taken from Tunga has the lowest ash content while the waste papers taken from Kpakungu has the highest percentage ash. The highest percentage of ash exhibited by waste paper than plastics and nylon is due to their dryness after removal of moisture and affinity for combustion.

The ash range between 0.49 - 12.58%, which is small, the possibility of having small quantity of salts, heavy metals, chlorine and organic pollutant is small which is advantageous to waste management and environment [7].

Fixed carbon

The residue obtained after the percentage of moisture, volatile matter and ash has been deducted is the fixed carbon content. The highest percentage of fixed carbon were found in plastic bottle with an average value of 18.37% and waste paper with an average of 11.60% and the lowest percentage of 7.61% in polyethene (Nylon).

The higher the MSW charcoal generated, the higher the corresponding energy content for a waste with high percentage of fixed carbon (FAO, 1998).

Ultimate analysis results

The ultimate analysis specifies the percentage of each elemental chemical compositions of the solid waste. It includes carbon, oxygen, hydrogen, nitrogen and sulphur. It is essential in evaluating the composition, amount of air required for combustion, and volume of the combustible gases (Raju., *et al*. 2014)

Hydrogen content

The percentage content of hydrogen was obtained from elemental analysis in selected MSW, present in figure 6 and results in appendix A2. The percentage hydrogen content ranges within 2.31 – 4.37%.the waste paper has the highest percentage of Hydrogen and low percentage of 2.31% in polyethene (Nylon).

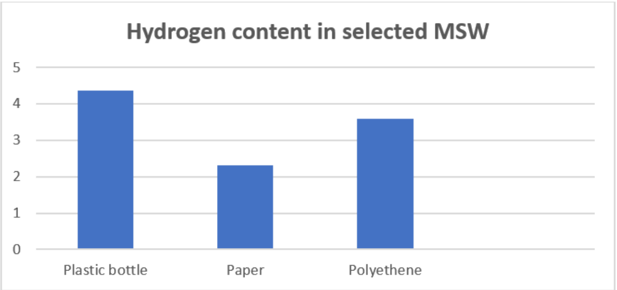

Figure 6 : Hydrogen content in MSW.

Oxygen content in MSW

The percentage content of oxygen was obtained from elemental analysis in selected MSW, results in appendix A2 and present in figure 7. The percentage content of oxygen was within the ranges of 43.55 – 45.13%. The result was slightly above the observations made by (Chaney, 2005), who reported that percentage oxygen was within range of 30 - 40%.

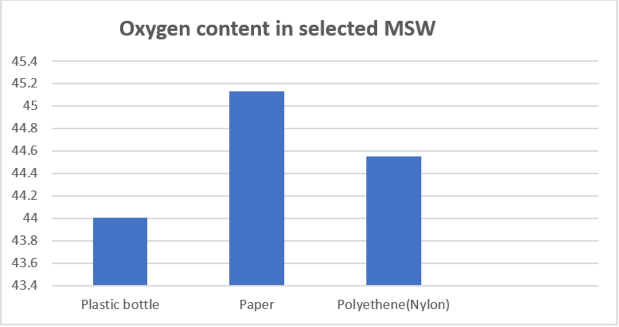

Figure 7 : Oxygen content in MSW.

Nitrogen content in MSW

The percentage content of nitrogen was obtained from elemental analysisin selected MSW, present in figure 8 and results in appendixA2. The percentage content of nitrogen was within the range of 1.79 – 2.47%. The percentage content of nitrogen was higher in plastic bottles with percentage of 2.47% and lower in polyethene (Nylon) with percentage of 1.79%. In the formation of harmful emission, nitrogen is important and it does partakes in the combustion process (Kassileu., *et al*. 2010).

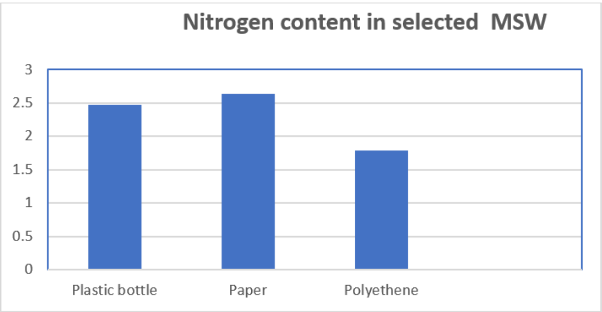

Figure 8 : Nitrogen content in selected MSW.

Carbon content in MSW

The percentage content of carbon was obtained from elemental analysis in selected MSW, present in figure 9 and results in appendix A2. The percentage of carbon calculated was within the ranges 48.17 – 50.91%. The highest percentage is 50.91% for polyethene (Nylon) and lowest percentage of 48.17% in plastic bottles. The high percentage of carbon content in a sample shows that they will add to the combustibility of a fuel briquette [8].

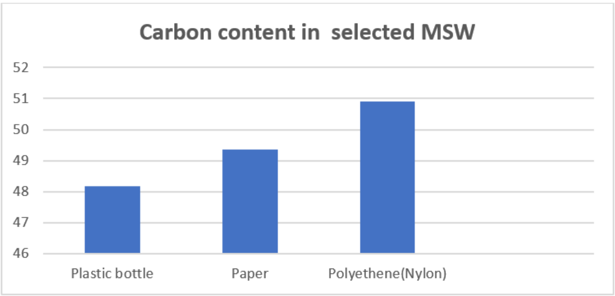

Figure 9 : Carbon content in selected MSW.

Sulphur content in MSW

The percentage content of sulphur was obtained from elemental analysis in selected MSW, present in figure 10 and results in appendix A2. The percentage of Sulphur calculated was within the ranges 0.16 – 0.98%. The highest percentage of 0.98% was in plastic bottles compare to waste paper 0.98%. The percentage of Sulphur in the MSW were all acceptable due to their low Sulphur content below 1%. The effect of air pollution will be reduced due to low percentage of Sulphur contents found which will reduce the emission of sulphur oxide (SO_2).

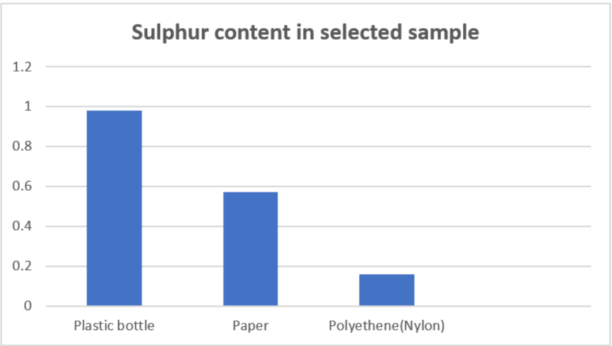

Figure 10 : Sulphur content in selected MS.

Heating values of MSW

The heating value determines the energy content of a MSW. Net Heating Value or Gross Heating Value, Lower Calorific Value (LHV) and High Heat Value (HHV) are the terms usually used to describe the energy content of MSW. It is property of MSW fuel that depends on its elemental composition and proximate analysis. It is measured as a unit of energy per unit mass of substance (MJ/kg). The heating value (HV) was obtained by equation 15, result in appendix B and present in figure 11.

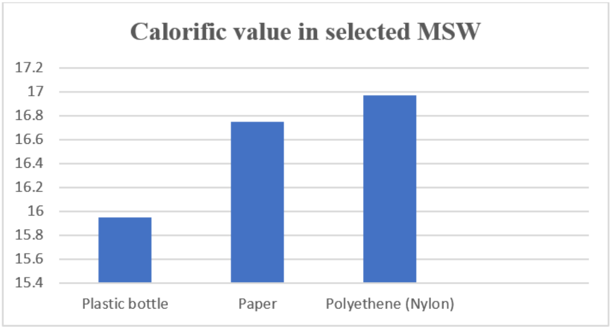

Figure 11 : Calorific value in selected MSW.

The calorific value of each waste obtained is shown in figure 11. Plastic bottle has a calorific value of 15.94MJ/Kg, paper (16.75MJ/Kg) and nylon (16.97MJ/Kg). The calorific value in polyethene is due to the high carbon content and low ash content. The calorific value of the MSW is closed to the literature value of 19.87MJ/Kg [10-52].

Discussion and Conclusions

This research work presents the evaluation of impact of solid waste characterization in Minna Metropolis. The proximate analysis of municipal solid waste show that, the highest percentage moisture content was in waste papers due to their high absorption of water and being an organic product, which reduced the energy content. Polyethene (Nylon) and plastic bottles have low percentage moisture which can generate high energy value and low drying rate. Polyethene (nylon) which has the highest volatile matter takes longer time to burn out and it presence shows useful gases such as methane. Plastic bottles and Polyethene (Nylon) has the potential of utilizing them for energy due to their low ash content because higher percentage of ash affects the carbonization effect. The lower percentage fixed carbon generated lower heat value and extend the heating as calculated for polyethene (Nylon) and higher fixed carbon in plastic bottles and waste paper.

The elemental composition shows that average amount of nitrogen and sulfur are small which reduces emissions during combustion. The waste contains almost 50% of carbon and 5% hydrogen respectively which may contribute to high heating value of the municipal solid waste.

The heating values of the MSW could be estimated from Regression analysis using the elemental compositions. The data points considered for correlation by regression analysis ranges in oxygen content (0.20 to 49.50)%, hydrogen content (0.10 to 8.80)%, carbon content from (27.80 to 92.70)%, nitrogen content (0.00 to 5.95)% and sulphur (0.00 to 1.05)% on dry basis,the derived correlation can be accepted as 'general correlation' for the estimation of calorific value. The average calorific value (16.55MJ/Kg) is in accordance with the literature value 19.87 MJ/Kg which has high potential for energy generation.

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