

ENERGY PRODUCTION POTENTIAL OF SULEJA MUNICIPAL SOLID WASTE**Ahmad, Umar Muhammad¹, Yola, Isa Aliyu²**

1. Department of Mechanical Engineering, Modibbo Adama University, Yola, Adamawa, Nigeria
2. Department of Mechanical Engineering, Bayero University Kano, Kano, Nigeria

ABSTRACT

Suleja Local Government of Niger State Nigeria is located between 9° 12'N and 7°10' E. Suleja is faced with the twin problem of inadequate electricity and waste management. Although Niger State has not been mentioned prominently as a state with acute waste management problem, there is however a growing evidence that the little that is being generated is not been properly managed. The second of the two principal options for managing MSW in most parts of the world is Waste to Energy (WtE) where the waste is used as a feedstock to produce energy by either thermo-chemical or biochemical means. The MSW of Niger State was characterized using ASTM D5231-92 and sorted into combustibles and non-combustibles, the calorific value was determined using Parr 6310 bomb calorimeter and the energy potential was determined using SZR garbage incinerator with thermal efficiency of 81% at 2.5 bar and 400°C. The daily disposal of Suleja MSW was found to be about 80000 kg out of which 71787 kg are combustibles. The average calorific value was found to be 21.8 MJ/kg. The average energy output in form of steam is between 11.2 - 17.2 MW with an average of 14.7MW of heat.

Keywords: Calorific value, Municipal Solid waste, Waste-to-energy, Bulk density

1. INTRODUCTION

The use of landfills as a method of waste management is widely practiced all over the world; as such, landfill sites must be carefully selected, as it is a critical step in waste disposal. If improperly conducted, the overall efficiency of the waste management system is affected negatively as a result of the generated leachate as well as landfill gas (LFG), which is a powerful greenhouse gas and thus results in a transfer of pollution. Uncontrolled landfill gas migration from the site can not only damage the global environment but can also negatively impact human health and pollute the local environment (Kofoworola, 2007). Leachate from municipality landfills represents a potential health risk to both surrounding ecosystem and human population. The waste sector contributes approximately 5% of the global Greenhouse gases emission and Dumpsites are the emitters of greenhouse gases (World Bank, 2010). In Nigeria like most developing countries, wastes are commonly dumped in open dumps, uncontrolled landfills where a waste collection service is organized (Ogwueleka, 2009).

The Niger State Ministry of Environment is charged with the responsibility of domesticating the Waste Management Policy by ensuring that appropriate programs are drawn up for the handling and disposal of wastes and the supervision of waste management and

sanitation and to mobilize grassroots participation in solid waste management as well as sanitation.. Although Niger State has not yet reached the level of waste management crisis seen in some other parts of the country, there are signs that the situation is deteriorating as the waste is not adequately managed.

This has raised some concern among planners and decision makers. To further consolidate its efforts in getting rid of solid waste in its urban centers, the government of Niger state sought and obtained the assistance of the United Nation Development Programme (UNDP) to facilitate a process that would lead to the development of a sustainable strategy for solid waste management in the main urban centers of the state (Mudiare, 2015)

Despite various efforts, it is becoming clear that present system of waste management has not been able to satisfy community needs for an acceptable clearing level as well as in reducing the general health and environmental impacts of waste. Moreover, national and state efforts have not been able to improve the general aesthetic appearance of city landscape. Evidence of increasing frustration is the indiscriminate and open waste dumping with its attendant high environmental and health risks, and persistent waste accumulation that is evidence in various locations of the main urban centers of the state.

Also available online at <https://www.bayerojet.com>

These locations are consistently liable to various vectors (rodents and insects) and foci to severe environmental pollution, repulsive and very bad smells and disgusting appearance. When burnt on dump locations, these accumulations have negative environmental and health impacts and implications. Effort were made by the past administrators in the state, in launching war against indiscriminate dumping of waste and giving priority to solid waste management. Adequate funds and logistics were made available. However, problem of waste began when the regime elapsed, which result to non-funding of the appropriate organization. This resulted to indiscriminate dumping wastes in every nook and crannies of the state (Mudiare, 2015).

The second of the two principal options for managing MSW in most parts of the world is WtE (Mor *et al.*, 2006) where the waste is used as a feedstock to produce energy by either thermo-chemical or biochemical means (Tsunatu *et al.*, 2015). Waste to energy reduces the amount going to landfill by about 90% (World Energy Council, 2016).

1.1 Study Area

Suleja L.G.A was established by the Local Government reform of 1976 from the defunct Abuja native authority. Suleja lies between Latitude 9°12'1.17" N and Longitude

7°10'20.25" E. It shares boundary with Gurara to the North-West, Tafa to the East in Niger State and Gwagwalada, Zuba to the south, in Federal Capital Territory. Suleja is about 20km North of Abuja the Federal Capital of Nigeria and about 100km North East of Minna the State Capital of Niger State (Aminu *et al.*, 2013). Suleja has about ten (10) Wards within the Local Government Area namely; Bagama 'A', Bagama 'B', Magajiya, Iku South I, Iku South II, Hashimi 'A', Hashimi 'B', Maje, Kurmin Sarki and Wambai. According to 2006 provisional population census, Suleja Local Government has a population of 216,578 and covers a land mass area of 118,910 Sq.km with 2,142 Density/Square Kilometer (NBS, 2012).

Suleja has tropical climate and summers are much rainier than the winters.. The average annual temperature is 26.3 °C and the average rainfall is 1328 mm. The driest month is December. The highest precipitation occurs in September; with an average of 272 mm. March is the warmest month of the year with average temperature of 29.0 °C. The lowest average temperature is in August and is about 24.5 °C (Alfred *et al.*, 2016).

There are three major Dumpsites in Suleja namely; Dikko, Rafin Sanyi and Karfe, however Karfe was declared full and only Dikko and Rafin Sanyi are used (NISEPA, 2018).

2. METHODOLOGY

The method include the determination of the Daily disposal of MSW in Suleja, the Calorific value of Suleja MSW and the electrical energy output of Suleja MSW in kWh/day.

2.1 Daily Disposal of Suleja MSW

A total volume of 336 m³ of waste is disposed daily in Suleja (NISEPA, 2018). The amount of waste disposal rate was determined using the following equation (Bichi and Amotobi, 2013):

$$W_d = \rho V \quad (1)$$

W_d is the mass disposed in kg, ρ is the average bulk density in kg/m³ and V is the volume in m³.

2.1.1 Determination of Bulk density

A wooden container of capacity $V_1 = 0.1\text{m}^3$ was used and its mass was determined as M_1 . Waste collected from Dumpsite was poured into the container until it was over flowing. The contents of the container were settled by dropping it three times from a height of 10cm; and again more waste was added to fill it. The procedure was repeated until the container was completely full. No pressure was applied to the waste in the container to

avoid altering the bulk density. The filled container and its contents were weighed to obtain a mass M_2 . The bulk density (kg/m³) is given by the following equation (Bichi and Amotobi, 2013):

$$\rho_{bulk} = \frac{(M_2 - M_1)}{V_1} \quad (2)$$

Where ρ_{bulk} is the bulk density in kg/m³, M_2 is the mass of filled container and M_1 is the mass of empty container. The daily waste disposal were computed using equation (1).

100 kg of the waste was collected randomly from a truck and it was segregated into combustible and noncombustible waste. The percentage combustible waste P_c was then computed using equation 4 (Conshohocken, 2018).

$$P_c = \frac{W_c}{W} \quad (3)$$

Where; W_c is the mass of combustible component and W is the total mass of sample.

The total mass of combustible waste was computed from the following equation (Conshohocken, 2018)

$$W_{cd} = P_c \times W_d \quad (4)$$

Also available online at <https://www.bayerojet.com>

Where; W_{cd} is the mass of combustible waste disposed in kg/day, P_c is the percentage composition of combustible waste and W_d is the total waste disposed in kg/day. The combustible components considered in this study are plastics, paper, yard, food, wood and other organics.

2.2 Calorific Value

1 kg of waste sample from the two designated dumpsites in Suleja namely; Dikko and Rafin Sanyi Dumpsites were collected and sorted manually to remove the inorganic materials (e.g. Glass, metals etc) according to (ASTM D5231-92, 2003), in the months of September, November and January (2017-2018). Each constituent were cut into small pieces or grinded; The samples were then weighed and placed into the bomb calorimeter. The bomb calorimeter was assembled, and the cap was securely tightened. Oxygen pressure was then injected into the bomb calorimeter until the pressure reached 25 atm. The bomb calorimeter was placed into an adiabatic calorimeter bucket containing water with a fuse (ignition) wire of about 7cm long passing through the sample with both ends of the wire attached to two electrodes of the bomb calorimeter. A thermometer was placed inside the water jacket after bomb calorimeter as connected to a power source. The stirrer was then started and allowed to run five minutes before the temperature reading was taken. The fire button was then pressed at the fifth minutes of the experiment. At the end of the fifth minutes, a stop watch was started and the temperature was recorded at one minute interval. Subsequent temperature readings were recorded continuously until the difference between successive

readings became constant for at least three minutes. After the last temperature reading was taken, the calorimeter was stopped, the cover was lifted and components were removed and wiped with a clean cloth.

The results obtained from the experiment were used to calculate the calorific value of the municipal solid waste as described in the manual (Parr 6310 Bomb Calorimeter Manual, 1960).

The gross calorific value was calculated using equation.

$$CV = \frac{\Delta t \times w}{m} \quad (5)$$

Where; CV is the calorific value, Δt is the corrected temperature rise, w is the water value of the bomb calorimeter and m is the mass of the fuel.

2.3 Energy Output

The energy potential was determined using SZR garbage incinerator with thermal efficiency of 81%, the heat energy in form of steam generated at 2.5 bar and 400°C. The energy potential was then calculated using equations 6 and 7 (Lawal & Garba, 2013)

$$\eta = \frac{E_o}{E_i} \quad (6)$$

$$E_o = \frac{E_i \times \eta}{3600} \frac{kWh}{day} \quad (7)$$

Where; E_o is the energy output, E_i is the energy input and η is the conversion efficiency.

$$E_i = \dot{m} \times CV \quad (8)$$

Where; E_i is the energy input, \dot{m} is the mass flow rate of MSW in kg/day and CV is the calorific value in kJ/kg.

3. RESULTS AND DISCUSSION

The results of the average bulk density, percentage combustible component, daily disposal of combustible waste, average calorific values and energy output of Suleja MSW are presented in Figures 1-5 respectively.

The bulk density for Suleja dumpsites were found to be between 240 kg/m³ and 280kg/m³. The highest was recorded in September as shown in Figure 1. The bulk density is in agreement with that of Sabongari in Kano (Bichi and Amotobi, 2013) but higher than of Hiridwar in India (Jain & Sharma, 2011) which indicates the variation in lifestyle. The amount of combustible waste disposed daily takes has a peak value of 83 000 kg/day lowest value of 59 000 kg/day. This is the daily mass flow rate of fuel for energy recovery. The percentage

Also available online at <https://www.bayerojet.com>

combustible components were found to be between 80-90% of the total waste disposed as in Figure 2. The disposal rate was mostly between 70,000 kg/day and 80,000 kg/day. The highest was recorded in November and the lowest was recorded in January as shown in Figure 3. The highest amount of waste disposed was on day 9 in September with about 100 000 kg and the lowest amount was on day 10 both in November and December as shown in Figure 3. In January, low amount of waste disposal is evident with values slightly above 80 000 kg/day as shown in Figure 3. Generally at least about 80 000 kg of waste is disposed daily in Suleja.

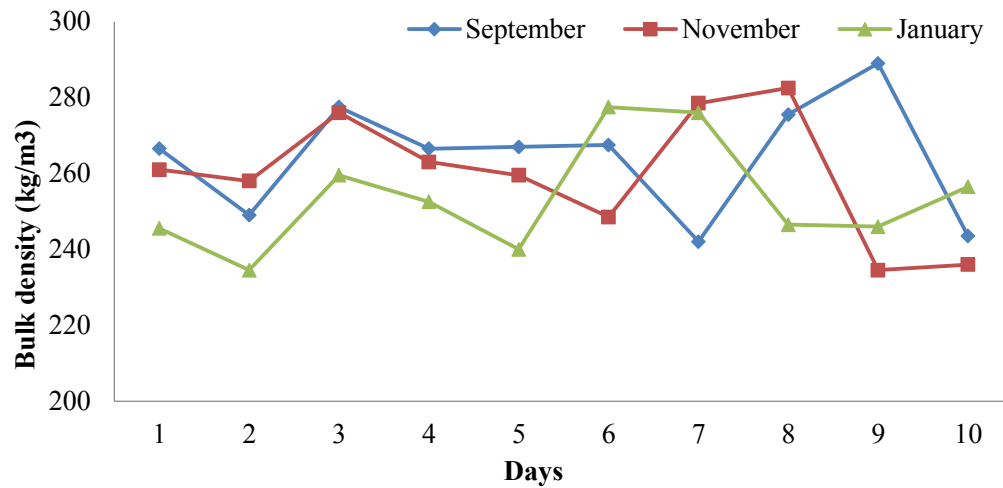


Figure 1 : Average bulk density of Suleja MSW

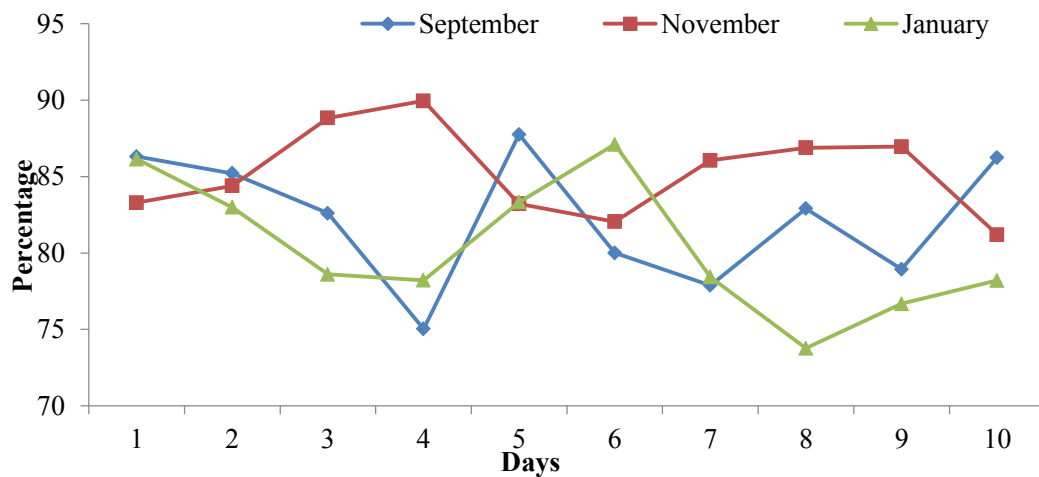


Fig 2: Percentage of combustible components

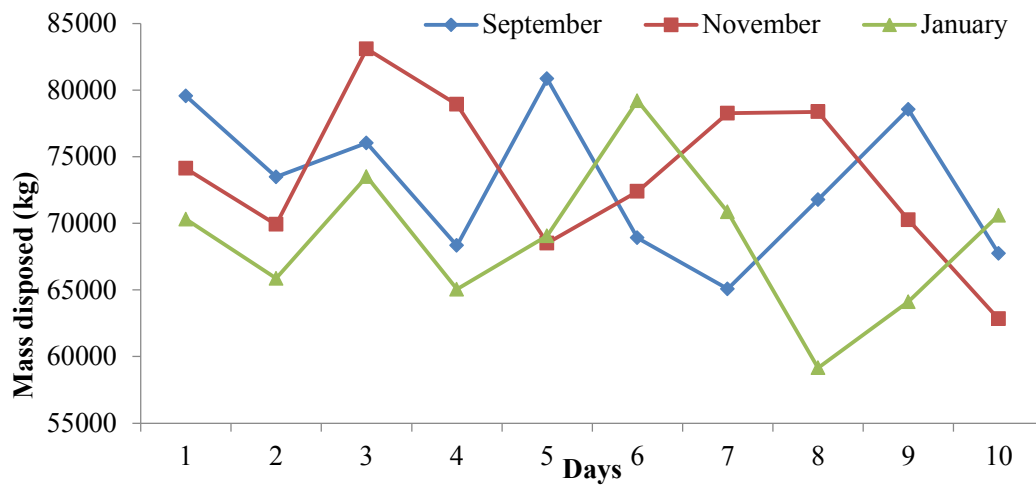


Figure 3: Daily disposal of combustible waste

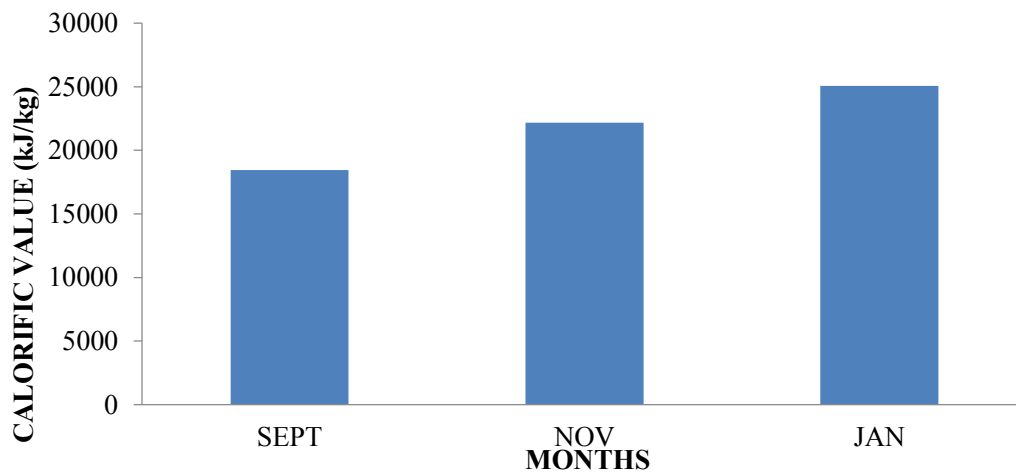


Figure 4: Average Calorific Value of Suleja MSW

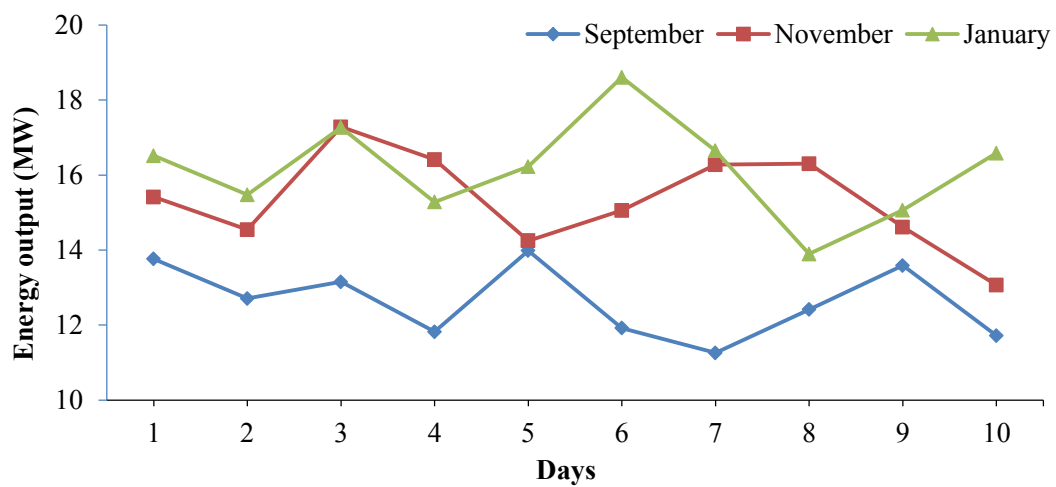


Figure 5: Energy output

Also available online at <https://www.bayerojet.com>

The amount of combustible waste disposed was recorded in November with over 80 000 kg/day and the lowest was in January with about 60 000 kg/day as shown in Fig 3. The daily waste disposal shows no consistency. However, in September more amount of combustible wastes are disposed predominantly above 70 000 kg/day. The lowest amount were recorded mostly in January with values around 70 000 kg/day or even less.

The activities of scavengers who picks plastics, papers and other materials will drastically reduce the amount of waste to be taken as fuel for energy production as such the scavengers who resides at the landfill where employed in taking samples to avoid skewed results.

The calorific value of Suleja MSW can be seen from Fig 4 to be highest in January for combustible waste. There is a gradual increase in the calorific values from September to January. The lowest average calorific value was found to be in September with a value of about 18 MJ/kg was lowest in September with 18 MJ/kg and the highest in January with about 25 MJ/kg as shown in Figure 4. The calorific value was found to be increasing from September through January and might be connected with the relative increase in the proportion of high calorie organic content such as corn cob with 19.5 MJ/kg, groundnut shell 16.5 MJ/kg etc. in the waste stream during the harvest period (Maton *et al.*, 2016).

The average heating (calorific) value of Suleja MSW is 21.8 MJ/kg which is in agreement with Ibikunle *et al.* (2019). The calorific value is 9% higher than the 20 MJ/kg obtained by Igbinomwanhia *et al.* (2016) for Benin metropolis, 11% lower than 24.51 MJ/kg for Numan (Abubakar *et al.*, 2018) and 27% higher than the 17.1 MJ/kg average heating value for Nigeria (Amber *et al.*, 2012). Moreover the calorific value is 320% and 118% higher compared to 5.6 MJ/kg and 10.1 MJ/kg obtained for Kano by Oumarou *et al.* (2012) and Daura *et al.* (2014)). The large disparity may be due to the different methodologies employed by the two previous researchers.

The steam energy output in MW for Suleja MSW is shown in Fig 5. It can be observed that the lowest energy output was in September, with energy values less than 12 MW of heat in some days and the highest was greater than 18.5 MW. However, most frequent values were within the range of 14-17 MW with an average of 14.7MW. It can also be observed that the energy output were higher in November and most notably January.

The above result indicates that 1000 kg (1 ton) of Suleja MSW has an energy value equivalent to 1200 kg (1.2 ton) of sub bituminous coal, 1360 kg of firewood 470-520 kg of diesel, 420 -520 kg of oil, 470-490 kg of petrol, 430-470 kg of liquefied petroleum gas (LPG), 400-520 kg of natural gas, 150-180 kg of hydrogen and 390-430 kg of methane.

4. CONCLUSION

- i. The MSW of Suleja metropolis was assessed to determine its suitability for energy production. The maximum disposal rate recorded was 100 000 kg and 82% of the waste were combustibles.
- ii. The calorific value of the waste was found to be 21.8 MJ/kg which was found to be higher than the minimum 7 MJ/kg required to setup incineration plant (Rand *et al.*, 2000).
- iii. The average energy production potential in form of steam is 11.2-17.2 MW with an average of 14.7MW of heat.

5. REFERENCES

- Abubakar, A., Barnabas, M. H., & Tanko, B. M. (2018). The Physico-Chemical Composition and Energy Recovery Potentials of Municipal Solid Waste Generated in Numan Town, North-Eastern Nigeria. *Energy and Power Engineering*, 10(11), 475–485. <https://doi.org/10.4236/Epe.2018.1011030>
- Alfred, B. Y., Gillian, M. U., Mike, O., Ofonedum, O. L., & Justina, A. (2016). Urban Growth and

Also available online at <https://www.bayerojet.com>

- Landuse Cover Change in Nigeria Using GIS and Remote Sensing Applications. Case Study of Suleja L.G.A., Niger State. *International Journal of Engineering Research & Technology (IJERT)*, 5(08), 124–138.
- Amber, I., Kulla, D. M., & Gukop, N. (2012). Generation, Characteristics and Energy Potential of Solid Municipal Waste in Nigeria. *Journal of Energy in Southern Africa*, 23(3), 47–51.
- Aminu, Z., Yakubu, M., Mohammed, A. A., & Kumar, N. (2013). Impact of Landuse on Soil Quality in Suleja, Niger State, Nigeria, 2(2), 1–7.
- ASTM D5231-92. (2003). Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste. ASTM International. <https://doi.org/10.1520/D5231-92R08>. Copyright
- Bichi, M.H. and Amotobi, D. A. (2013). Characterization of Household Solid Wastes Generated in Sabon-Gari Area of Kano in Northern Nigeria. *American Journal of Research Communication*, 1(2009), 165–171.
- Conshohocken, W. (2018). Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste 1, 92(Reapproved 2016), 1–6. <https://doi.org/10.1520/D5231-92R16>. Copyright
- Daura, L. A., Enaburekhan, P. J., & Rufai, A. I. (2014). Characteristics and Composition Analysis of Municipal Solid Waste in Kano, Nigeria, 5(9), 972–975.
- Ibikunle, R. A., Titiladunayo, I. F., Akinnuli, B. O., Dahunsi, S. O., & Olayanju, T. M. A. (2019). Estimation of Power Generation From Municipal Solid Wastes: A Case Study of Ilorin Metropolis, Nigeria. *Energy Reports*, 5, 126–135. <https://doi.org/10.1016/j.egy.2019.01.005>
- Igbinomwanhia, D., Obonor, A., Olisa, Y., & Akhator, P. (2016). Evaluation of Waste-To-Energy Potential of Domestic Solid Wastes in Benin Metropolis. *J. Appl. Sci. Environ. Manage.* Dec, 20(4), 1089–1092. <https://doi.org/10.4314/Jasem.V20i4.23>
- Jain, S., & Sharma, M. P. (2011). Power Generation From MSW of Haridwar City: A Feasibility Study. *Renewable and Sustainable Energy Reviews*, 15(1), 69–90. <https://doi.org/10.1016/j.rser.2010.09.007>
- Kofoworola, O. F. (2007). Recovery and Recycling Practices in Municipal Solid Waste Management in Lagos, Nigeria. *Waste Management*, 27(9), 1139–1143. <https://doi.org/10.1016/j.wasman.2006.05.006>
- Lawal, A. M., & Garba, I. (2013). Study of The Energy Potential of Solid Waste in Bauchi Town, (2001), 1–7.
- Maton, S. M., Dabi, D. D., Dodo, J. D., & Nesla, R. A. (2016). Environmental Hazards of Continued Solid Waste Generation and Poor Disposal in Municipal Areas of Nigeria, 6(3), 1–10. <https://doi.org/10.9734/JGEEI/2016/26469>
- Mor, S., Ravindra, K., De Visscher, A., Dahiya, R. P., & Chandra, A. (2006). Municipal Solid Waste Characterization and Its Assessment for Potential Methane Generation: A Case Study. *Science of the Total Environment*, 371(1–3), 1–10. <https://doi.org/10.1016/j.scitotenv.2006.04.014>
- Mudiare, M. O. (2015). Analysis of Domestic Solid Waste Management Strategies in Tunga, Chanchaga Local Government Area, Niger State, Nigeria. Ahmadu Bello University Zaria.
- NBS. (2012). Facts and Figures About Niger State.
- NISEPA. (2018). Niger State Environmental Protection Agency.
- Ogwueleka, T. (2009). Municipal Solid Waste Characteristics and Management in Nigeria. *Iranian Journal of Environmental Health Science & Engineering*, 6(3), 173–180. <https://doi.org/10.1016/j.wasman.2007.09.039>
- Oumarou, M. B., Dauda, M., Abdulrahim, A. T., & Abubakar, A. B. (2012). Characterization and Generation of Municipal Solid Waste In, 2(5), 3669–3672.
- Parr 6310 Bomb Calorimeter Manual. (N.D.).
- Rand, T., Haukohl, J., & Marxen, U. (2000). Incineration of Solid Waste: A Decision Makers Guide. Washington DC.
- Tsunatu, D.Y; Tickson T.S; Sam, K.D; and Namo, J. . (2015). Municipal Solid Waste As A Source of Energy. *International Journal of Engineering and Technology*, 5(3), 1–6. <https://doi.org/10.1109/INDICON.2015.7443789>
- World Bank. (2010). Waste Generation. *Urban Development Series-Knowledge Papers*, 3(1), 8–12.
- World Energy Council. (2016). World Energy Resources Waste To Energy | 2016.