# Design of Solid Waste Management System for Faculty of Engineering, Nnamdi Azikiwe University, Awka

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***Abstract -- The study seeks to identify the methods for storage of solid wastes, ascertain the waste disposal systems, and determine the effective waste management system. The study was carried out primarily through survey method and interview of the faculty cleaners in engineering faculty in Nnamdi Azikiwe University, Awka; and a random sampling technique was employed in the collection of the data. Observations were also carried out to view the engineering student's activities in the halls and empirical works of other scholars were consulted. Secondary data were consulted from books, journals, annual reports and internet. The study population of engineering faculty in Nnamdi Azikiwe University (NAU) is 2966. A mathematical model for predicting solid waste generation was developed using multi linear regression technique. A system for efficient management of generated solid waste was modeled. The faculty generates an average of 326.73kg of waste per week at a generation rate of 0.011kg/person/day. The highest volume of solid waste generation is at the engineering workshop accounting for 13.30% of the solid waste stream. Recyclable solid waste accounts for 45.30% of the total solid waste stream. Through some observations we noticed that financial constraints and lack of appropriate technologies are major challenges to wastes management in the faculty of Engineering Unizik.***

***Indexed Terms: Design, Solid Waste, Management System, Faculty of Engineering, Nnamdi Azikiwe University***

## I. INTRODUCTION

### *A. Background to the study*

Engineering as a profession is devoted to designing, constructing, and operating the structures, machines, and other devices of industry and everyday life. Today an engineer is described as someone who has acquired and is applying their scientific and technical knowledge to designing, analyzing, building useful and functional works to satisfy human wants. This would involve structures, machines and apparatus, manufacturing processes as well as forecasting their behavior in particular environmental conditions. This is all accomplished with functionality, operational economics and safety to life and property in mind. Engineering is a broad discipline with many sub-disciplines dedicated to various fields of study with regards to particular types of technologies. Nnamdi Azikiwe University, Awka which is a federal university, started in 1991 and also one of twenty-five federal universities which are overseen and accredited by the National Universities Commission.

Therefore imagine that garbage is left uncollected at different corners of the faculty buildings and areas. Imagine too how high these wastes will build up and stench that results throughout the community. The odour that results is unimaginable. Beyond the odour that results is the destruction of the aesthetics of the engineering faculty.

Tchobanoglous et al (2013) reported that "solid waste comprises all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted". The term solid waste is all-inclusive, encompassing the heterogeneous mass of throwaways from the urban community as well as the more homogeneous accumulations of agricultural, industrial, and mineral wastes.

This report is concerned with the development of a mathematical model that will aid the faculty in predicting the quantity of waste that will be generated over a given time if the population is known. It will be important to point out at the outset that this work is also intended to provide the faculty with the basic information it will require in effectively managing its waste, particularly the solid waste generated.

### *B. Statement of the Problem*

Waste generation and its disposal have become major problems in the faculty of Engineering, Nnamdi

Azikiwe University, hence the need to develop means, even efficient ways to address the situations.

Therefore, the reason of this study is to develop an algorithm that will be an effective tool in determining the amount of solid waste generated in faculty of Engineering, Nnamdi Azikiwe University within a specified period of time and at the same time provides a method of projecting future growth. The work will also suggest an efficient management system. Objectives of the Study to determine the quantity and quality of waste generated in the Faculty, to model for solid waste generation within Faculty of Engineering, NAU, to suggest a waste management system ideal for the Faculty.

## II. DESIGN OF THE SOLAR VEHICLE

### *A. Pollution*

Pollution is the introduction of contaminants that causes instability, disorder, harm or discomfort to the physical systems or living organisms in an environment. Pollution can take the form of chemical substances, or energy, such as noise, heat or light energy. Pollutants, the elements of pollution, can be foreign substances or energies, or naturally occurring, they are considered contaminants when they exceed natural levels. Pollution is often classified as point source or nonpoint source pollution. Point source is a single identifiable source of pollution such as a pipe or a drain. Where by industrial wastes are commonly discharged to rivers and the sea in the way.

The work of Ozor (2010), on the waste management systems in Nnamdi Azikiwe University revealed that no standardized waste disposal and he endeavored to model an ideal waste management system suitable for the environment, but it could not address the issue properly especially as it affects the faculty of engineering. Therefore this noble research targeted towards alleviating the problem of waste management systems to the faculty of engineering, Nnamdi Azikiwe University.Awka.

### *B. Sources and Classification of wastes*

Waste is a general term covering all types of refuse resulting from living activities of humans and other animals. The methods for handling and disposing of waste differ considerably. The different types of solid waste are subdivided as follows:

a. Garbage. Garbage is the solid or semi-solid waste incidental to preparing, cooking, and serving food, and cleaning of food service items. It does not include rubbish. Garbage is classified as edible or non-edible. Edible garbage is that part of the garbage which is suitable for animal food such as scrap meat and vegetables. Non-edible garbage is that garbage which cannot be used for animal food, such as tea leaves, bones, and egg shells.
b. Rubbish. Rubbish consists of wastes which originate in food service facilities, barracks, wards, quarters, and offices. It includes items such as wastepaper, plastics, wood, metal, glass, ashes, and broken or damaged crockery. Rubbish may be classified as combustible or non-combustible depending upon whether or not it can be burned.
c. Pathological Waste. These consist of dead animals, human waste etc. The moisture content is 85% and there are 5% non-combustible particles. The heating value is around $2.5 \times 10^6$J/Kg.

And other sources and classification includes.

### *C. Composition of Solid Waste*

The term composition is used to describe the individual components that makes up a solid waste stream and their relative distribution, usually based on percent by weight. The information on composition of solid waste is important in evaluating equipment needs, systems, and management programs and plans.

### *D. Methods of Estimating Waste Quantities*

The waste quantities are usually estimated on the basis of data gathered by conducting a waste characterization study, using previous waste generation data, or some combination of the two approaches. The methods commonly used to assess solid waste quantities are: (a) Load – count analysis (b) weight-volume analysis and (c) materials-balance analysis.

*a. The Load-Count Analysis*: In this method, the number of individual loads and the corresponding waste characterization i.e types of waste, estimated volume are noted over a specified time period. Where scales are available, weight data are also recorded. The unit generation rates are determined by using the field data and, where necessary, published data.

b. Weight-Volume Analysis: Method is used if better and more accurate information on the specific weight of the various forms of solid wastes is needed. This is done by weighing the collection vehicle at the entrance to transfer station platform scales, and then estimating the volume of the truck.

*c. Materials Mass Balance Approach:* Is the only way to determine the generation and movement of solid wastes with any degree of reliability for each generation source, such as an individual home or a industrial activity. The approach to be followed in the preparation of this method is to first draw a system boundary around the unit to be studied. The proper selection of the system boundary is important because, in many cases, it will be possible to simplify the mass balance computation. Next, is to identify all the activities that cross or occur within the boundary and affect the generation of waste. Then, the rate of waste generation associated with each of these activities is defined. Finally, using appropriate mathematical relationships, determine the quantity of waste generated, collected and stored. This is symbolically represented as follows;

$$\frac{dM}{dt} = \sum M_{in} - \sum M_{out} + r_w \quad (2)$$

Where,

$\frac{dM}{dt}$ = rate of change of the weight of material stored within the study unit (kg/d)

$\sum M_{in}$ = sum of all the material flowing into study unit, (kg/d)

$\sum M_{out}$ = sum of the materials flowing out of the study unit. Kg/d

$r_w$= rate of waste generation, kg/d

t = time,

The first step in solid waste characterization given a large solid waste dumpsite is to first divide the entire waste into four parts. Thereafter, one of the quarters is again divided into another four parts (Tchobanoglous et al, 2013). This is often called a quarter of a quarter. The choice of which part of the second quarter that should be chosen as a representative sample for characterization is a matter of experience.

### E. *Sources of Waste in the Faculty of Engineering, Nnamdi Azikiwe University, Awka*

The sources of waste generated in the faculty are:

1. Agricultural waste resulting from the activities of peasant farmers.
2. Constructional waste resulting from the many on-going building projects.
3. Commercial waste emanating from stores, restaurants, and business centers.
4. Gaseous waste from generators, and open air incineration.
5. Sewage sludge in the septic tank in the offices, homes and companies.

### F. *Waste Management in Faculty of Engineering, Nnamdi Azikiwe University, Awka*

The findings we carried out into the waste management system employed by the Engineering faculty reveals that the responsibility of waste management in Unizik, Awka is left in the hands of a contracting firm. However, their job is complemented by the cleaners attached to the department and unit within the faculty. It must be noted that the method of waste management employed by the faculty is ineffective in the light of modern trend in waste management practice, particularly solid waste. Our findings review that the firm simply employs the traditional method of collection and disposals of the waste. Collection is achieved using a waste plastic basket. And for instance, the waste baskets are located along the corridors, stair ways and units, the collection of waste along the corridors and stairs is done daily.
Solid wastes collected are burnt in the open air without sorting. This is often practiced during dry season. In raining seasons, the solid waste, either dumped in the open field or in a shallow composting pit, are left exposed to weathering with its attendant anaerobic or bacterial activities.

Therefore, Njiribeako (2013) reported that “the most popular method of solid waste disposal in many urban cities in Nigeria is open field dumping, followed by open air incineration” This must be corrected!

### G. *Tool for Analysis - Multiple Linear Regressions*

Regression has been defined as the amount of change in the value of one variable associated with a change in the value of variable (Olayiwa 2013). Regression analysis may be simple or multiple, or non-linear. In analyzing problems using regression analysis, some errors usually will occur as a result of mistakes, approximation of functional form, omitted variables, measurements and random behavior of subjects under study.

Multiple regression analysis will be used in the development of the relationship between the variables of interest. The relationship between the dependent variable Y and the independent variables $X_i$ is expressed as:

$$Y = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \beta_3 X_{3i} + e. \quad (3)$$

Where,

$\beta_0$ = Y intercept of the regression line in the X-Y plane

$\beta_1, \beta_2, \beta_3$ = Multiple regression coefficients

$X_1, X_2, X_3$ = independent variables

e = error term

r = Coefficient of correlation

$r^2$ = Coefficient of determination

$R^2$ = Multivariate coefficient of determination

n = the number of input data.

The coefficient of determination is a measure of the variation of the dependent variable that is explained by the regression line and the independent variable (Bluman, 2004).

It is also a ratio of the explained variation to the total variation. The term $r^2$ is usually expressed as a percentage and is given by the formula.

$$r^2 = \frac{(Y_i - \acute{Y})^2 - (Y_i - y)^2}{(Y_i - \acute{Y})^2} \quad (4)$$

$$R^2 = \left[1 - \frac{(\acute{Y} - y)^2}{(Y_i - y)^2}\right] \quad (5)$$

Where,

Yi = Observed values

Ý = Mean of dependent variable

y = Predicted Values

## III. MATERIALS AND METHODS

The methodology of the research involves survey, sampling, interviews, characterization and mathematical modeling.

### A. Survey

They essence of the survey is to know the types and constituents of the solid waste generated so that it can be effectively characterized. It will also give an idea of the population of the area, so that the quantity of waste generated per household can be determined, hence multiplying such quantity by the number of household gives the total amount of waste generated. In the waste survey, the order is: Waste collection, counting of the waste to know the quantity, and weighing to know the volume.

In the survey exercise, the present development waste in the faculty with respect to departments/units and other services locations were adopted for the research work. So the essence of the zoning is to give an idea of the types, amount and composition of the waste generated depending on population characteristics, social status, life style and living habit.

Therefore, for the purpose of this research, we worked with the faculty cleaners and the secretary of each department for the collection of data to analyze the population. So the faculty has a total of nine departments.

### B. Sampling

The sampling is carried out within certain specific areas in the Engineering faculty. This is so because, when constructing a sampling technique one must always keep in mind that the population from which we wish to draw inference must also be the population from which the data are randomly sampled (Piergorsch and Bailer, 2014).

### C. Interview

The methods of approach adopted here include; Discussion with the Faculty cleaners on how the carry out their daily activities and also the challenges they face during sweeping, Example how students litters the hall during sweeping and no adequate provision of waste bin which causes improper waste management.

Some students reported that the sweepers sometimes don't sweep thoroughly rather the pick papers and nylons only within the halls.

D. Characterization

The wastes are then characterized to determine the composition of the waste generated. The goal of waste characterization study is to identify the sources, characteristics, and quantities of the waste generated. A general characterization of the solid waste was done i.e. it was done irrespective of the social status, Life style and Living habit of the people.

The steps adopted in the waste characterization study include:

a) Gathering existing information
b) Identifying waste generation sources and waste characteristics
c) Develop waste categories
d) Conduct field studies
e) Conduct market survey for recyclable waste
f) Assess factors affecting waste generation rates

E. Determination of the Generation Rate

The overall generation rate, $R_g$ for the entire community is determined using the relationship given below:

$$R_g = \frac{\text{Total Weight Generated}}{\text{Total Population} \times 7d/wk} \quad (6)$$

The generation rates of individual solid waste components are required in the design of a solid waste management system (sincere and sincere, 2013).The weighing of the solid waste is usually done using platform scale.

F. Analytical Tools Employed for Measured Waste Quantities

Mathematical and Software tools are used for various analyses in the study. The type of software used in the analyses is software package for social science (SPSS). The mathematical considers the dynamism of waste management processes.

This is important in determining and developing a solid waste management system. This will enable us to provide container capacity to handle the largest conceivable quantity of solid waste to be generated in a given time. This is often based on generation rates and the characteristics of the collection system (Tchobanoglous et al, 2013).

G. Mathematical Modeling

Population Growth Rate

The population growth of a given area can be either geometric or arithmetic.

$P_{(t)} = f(P_o, t, r)$

Assuming an arithmetic population growth rate for the purpose of the design of the quantity of waste generated, then

$$P_{(t)} = P_o [1 + rt] \quad (7)$$

$$\text{If } t = t - t_o \quad (8)$$

Substituting (8) into (7)

$$P_{(t)} = P_o [1 + r (t - t_o)] \quad (9)$$

Where,

$P_{(t)}$ = Projected population at any given year, t

$P_o$ = Base reference population

t = change in time

r = population growth rate

t = Year of study

$t_o$ = Based reference year of study

Thus, for the growing faculty of engineering population, assume that the population growth rate of r = 2.5% = 0.025.

Hence, equation (9) becomes, if r is constant over the specified range time, t; hence,

$$P_{(t)} = P_o [1 + 0.025 (t - t_o)] \quad (10)$$

H. Determination of Quantity of Solid Waste Generated

The based reference year of study for which this research was carried out is 2014. The design life for the study is 25 years. This is the optimum for a semi urban environment for which Faculty of Engineering is categorized, based on this study.

Given that:

$Q_{OC}$ = Quantity of offices/classrooms generated solid waste (kg)

$Q_{WL}$ = Quantity of workshop/laboratory generated solid waste (kg)
$Q_{UA}$= Quantity of unaccounted for generated solid waste (kg)
R = Unit rate of solid waste generated (kg/ person. day)
$Q_T$ = Total quantity of solid waste generated (kg)
$\propto$ = rate of generation of workshop/laboratory solid waste
$\beta$ = rate of generation of unaccounted solid waste
The quantity of the offices/classrooms generated solid waste, $Q_{AT}$ is expressed as:
$Q_{OC} = f(P_O, P_{(t)}, t, R)$
But, $Q_{OC} = R \times P_{(t)}$(Tchobanoglous et al, 2013) (11)
Substituting (9) into (11), we obtain that
$Q_{OC} = R\, P_O\, [1 + r\,(t - t_o)]$ (12)
The quantity of workshop/laboratory generated solid waste is expressed as:
$Q_{WL} = f(Q_{OC})$
$Q_{WL} = \alpha\, Q_{OC}$ (Quasim et al, 2011)
(13)
Substituting (12) into (13), we obtain that
$Q_{WL} = \alpha\, R\, P_O\, [1 + r\,(t - t_o)$ (14)
The quantity of unaccounted generated solid waste is expressed as:
$Q_{UA} = f(Q_{OC})$
$Q_{UA} = \beta\, Q_{OC}$ (Quasim et al, 2011) (15)
Substituting (12) into (15), we obtain that
$Q_{UA} = \beta\, R\, P_O\, [1+ r\,(t-t_o)]$ (16)
The total quantity of generated solid waste, $Q_T$ is given by the relation
$Q_T = Q_{OC} + Q_{WL} + Q_{UA}$ (17)
Substituting (12), (14), and (16) into (17), we have that
$Q_T = R\, P_O\, [1 + r(t-t_o)] + \alpha\, R\, P_O[1 + r(t-t_o) ] + \beta\, R\, P_O[1 + r(t-t_o) ]$
$Q_T = R\, P_O\, [1 + r\,(t-t_o) ]\{ 1+ \alpha + \beta \}$ (18)
But $R\, P_O\, [1 + r\,(t-t_o) ] = Q_{OC}$ , hence (18) will then become
$Q_T = Q_{OC}\, \{1 + \alpha + \beta\}$ (19)
Therefore, assuming that:
$Q_{WL}$ = 10% of $Q_{OC} = 0.1Q_{OC}$ , $\alpha$ = 10% (Quasim et al, 2011) (20)
$Q_{UA}$ = 5% of $Q_{OC} = 0.05Q_{OC}$ , $\beta$ = 5% (Quasim et al, 2011) (21)
Substituting (20), (21) into (17), we have that the total quantity of generated solid waste, $Q_T$ is given by the relation
$Q_T = Q_{OC} + 0.1Q_{OC} + 0.05Q_{OC}$
$Q_T = Q_{OC}\, \{1 + 0.1 + 0.05\}$
Thus,
$Q_T = 1.15Q_{OC}$ (22)

I. Multiple Linear Regression Applications

Since number of variables involved in the determination of the quantity of solid waste generated in the university is more than one, a multiple linear regression model method was adopted in the determination of the mathematical model.
The basic assumption in employing this method is that the dependent variable, $Q_T$ and independent variables $Q_{OC}$, $Q_{WL}$ and $Q_{UA}$ is linearly correlated. Thus, equation (3) can be rewritten as:
$Q_T = aQ_{OC} + bQ_{WL} + cQ_{UA} + k$
(23)
Where a, b, c, and k are constants.
STATISTICA, software was employed in determining the regression equation. Further analysis of the data was done on the STATISTICA application software using the Forward Stepwise Regression. The forward stepwise regression technique involves the re-examination at every stage of the regression of the variables incorporated into the model in previous stages. Any variable which provides a non-significant contribution is removed from the model. This approach is continued until no more variable will be admitted to the equation and no more are rejected.

J. Determination of Solid Waste Composition

The composition of each material type is computed as:
$$\%\ \text{Composition} = \frac{Wi}{\sum_{i=1}^{j} Wi} \times 100$$
(24)
Where,
w = weight of component
i and j = the number of waste component of samples

## IV. RESULTS AND DISCUSSIONS

Results

A. Data Collected in the Faculty on the Existing Population

The faculty has nine department in which we got the population of the staff and students as shown in the table Appendix-I.

B. Population of Students Using the Halls

The Total Population of Engineering students using the halls in the Faculty are as follows, as shown in appendix -II

C. Results on the Rate of Solid Waste Generation in the Faculty

The solid waste generation rate, R for the various departments, units and others is shown in Table of Appendix III.

However, the total solid waste generation rate for the faculty as determined from the values obtained in Table 6 and using equation (5) is:

$$R = \frac{326.73}{4346 \times 7} = 0.011 \text{ kg/person. day} \quad \text{Or}$$

$$11 \text{ g/person. day}$$

The result shows that 0.011kg or 11g of solid waste is generated per person per day within the faculty.

D. Analysis of Composition

The Percentage compositions of each of the component solid waste were obtained as in equation (24). The results are obtained and from the results of the analysis, it is shown that 13.30% of the solid waste is generated, which represents the highest solid waste generated within the faculty is at the 'Engineering Workshop' it's clearly expected given the large scale metals disposed from the workshop, This is followed by the 'FEG Hall' contributing 7.33% of the total solid waste generated. The Least amount of waste is generated at the 'Metallurgy & Material' with 1.92% of the total waste. Dirt's & Ashes, Polythene waste and paper waste contribute 49.60%, 16.16% and 13.19% respectively of the total solid waste. Being an academic environment with small student population, the result definitely is a reflection of the peculiarity of the environment. The percentage of dirt's reflects the amount of sand carried by the student on their foot wears. Glass waste (0.91%) is the least quality of solid waste generated within the faculty.

From the analysis presented above, Polythene waste and plastics are the highest and least of the organic waste. Similarly, dirt's/ashes and Glass waste are the highest and least of the inorganic waste.

The component and composition of recyclable solid waste in the faculty show the quality of recyclable solid waste in the faculty and is 45.30% of the total solid waste stream. Polythene and paper waste contributes the highest of the recyclable solid waste. According to Chidubem (2012), "recycling of papers saves−60% (raw material), 40% energy, 60% water and 40% cut in $SO_2$ emissions. Each tone of paper recycled saves−2.5m$^3$ of landfill space, 17 trees, and 1.7 tones of lumber, 24,000 gallons of water and 3 barrels of oil".

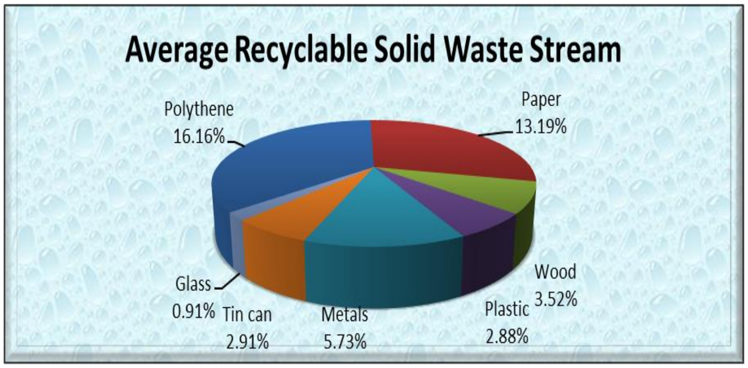


*Fig 1: Average Composition of Recyclable Solid Waste Stream in the Faculty*

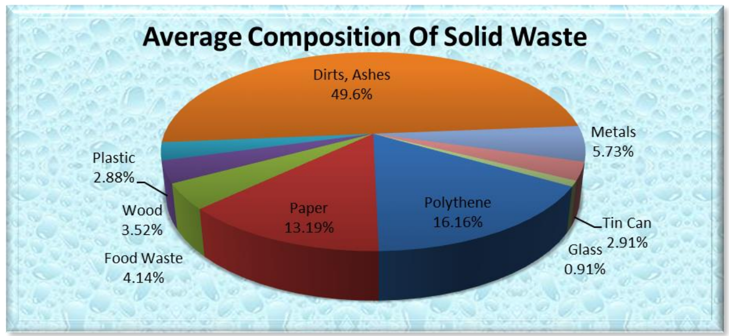


*Fig 2: Average Composition of Solid Waste Stream in the faculty*

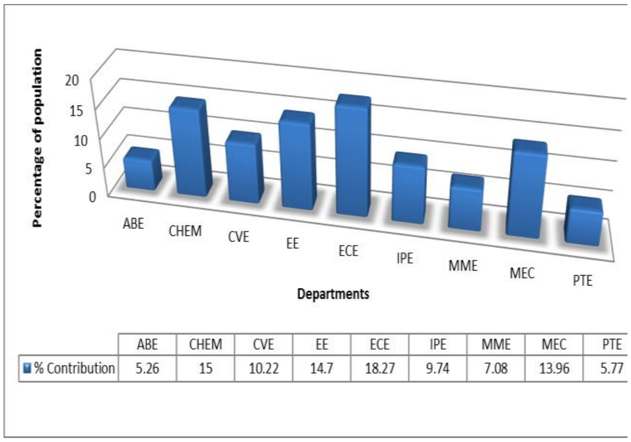


*Fig 3: Relative Contribution of Waste in the Departments*

The bar chart displayed in Figure 3 above shows that the department of Electrical and Computer Engineering generates the largest quantity of solid waste, accounting for 18.27% of the total solid waste stream in the faculty. Agriculture and Bio-resource Engineering generates the least, only accounting for 5.26% of the solid waste.

E. Determination of the Regression Models

The factors that are significant in the determination of the quantity of solid waste generated are the population and the quantity of domestic generated waste (which on its part depends on the generation rate, R). The Projected population, $P_t$ obtained using equation (8) over the projected 25 years period is given in Table 1.

*Table 1: Projected population for the faculty*

| S/No | $t_0$ (Base Year) | t(Year of Study) | t (change in time) year | $P_t$(Persons) |
|---|---|---|---|---|
| 1 | 2014 | 2014 | 1 | 4346.00 |
| 2 | 2014 | 2015 | 2 | 4454.65 |
| 3 | 2014 | 2016 | 3 | 4563.30 |
| 4 | 2014 | 2017 | 4 | 4671.95 |
| 5 | 2014 | 2018 | 5 | 4780.60 |
| 6 | 2014 | 2019 | 6 | 4889.25 |
| 7 | 2014 | 2020 | 7 | 4997.90 |
| 8 | 2014 | 2021 | 8 | 5106.55 |
| 9 | 2014 | 2022 | 9 | 5215.20 |
| 10 | 2014 | 2023 | 10 | 5323.85 |
| 11 | 2014 | 2024 | 11 | 5432.50 |
| 12 | 2014 | 2025 | 12 | 5541.15 |
| 13 | 2014 | 2026 | 13 | 5649.80 |
| 14 | 2014 | 2027 | 14 | 5758.45 |
| 15 | 2014 | 2028 | 15 | 5867.10 |
| 16 | 2014 | 2029 | 16 | 5975.75 |
| 17 | 2014 | 2030 | 17 | 6084.40 |
| 18 | 2014 | 2031 | 18 | 6193.05 |
| 19 | 2014 | 2032 | 19 | 6301.70 |
| 20 | 2014 | 2033 | 20 | 6410.35 |
| 21 | 2014 | 2034 | 21 | 6519.00 |
| 22 | 2014 | 2035 | 22 | 6627.65 |
| 23 | 2014 | 2036 | 23 | 6736.30 |
| 24 | 2014 | 2037 | 24 | 6844.95 |
| 25 | 2014 | 2038 | 25 | 6953.60 |

The Value for the domestically generated waste $Q_{OC}$ was obtained using equation (12). $Q_{WL}$, $Q_{UA}$ and $Q_T$ were obtained using equations (14), (16) and (19) respectively to get values in the table 2 below.

Where;

$Q_{OC}$ = Quantity of Office/Classroom generated solid waste (kg/year)

$Q_{WL}$ = Quantity of Workshop/Laboratory generated solid waste (kg/year)

$Q_{UA}$ = Quantity of unaccounted for generated solid waste (kg/year)

$Q_T$ = Total quantity of solid waste generated (kg/year)

Table 2: Data for the determination of the regression model

| $Q_{OC}$(Kg/year) | $Q_{WL}$(Kg/year) | $Q_{UA}$(Kg/year) | $Q_T$(Kg/year) |
|---|---|---|---|
| 17449.19 | 1745.10 | 872.54 | 20068.31 |
| 17885.42 | 1788.50 | 894.25 | 20567.75 |
| 18321.65 | 1832.17 | 916.09 | 21069.96 |
| 18757.88 | 1875.80 | 937.90 | 21571.59 |
| 19194.11 | 1919.40 | 959.71 | 22075.22 |
| 19630.34 | 1963.00 | 981.52 | 22574.85 |
| 20066.57 | 2006.70 | 1003.33 | 23076.59 |
| 20502.80 | 2050.30 | 1025.10 | 23578.22 |
| 20939.03 | 2093.90 | 1046.10 | 24079.85 |
| 21375.26 | 2137.53 | 1068.77 | 24581.60 |
| 21811.49 | 2181.20 | 1090.58 | 25083.23 |
| 22247.72 | 2224.80 | 1112.39 | 25584.86 |
| 22683.95 | 2268.40 | 1134.20 | 26086.49 |
| 23120.18 | 2312.00 | 1156.01 | 26588.21 |
| 23556.41 | 2355.60 | 1177.82 | 27089.86 |
| 23992.64 | 2399.30 | 1199.63 | 27591.49 |
| 24428.87 | 2442.90 | 1221.45 | 28093.24 |
| 24865.10 | 2486.50 | 1243.26 | 28594.87 |
| 25301.33 | 2530.13 | 1265.07 | 29096.50 |
| 25737.56 | 2573.76 | 1286.88 | 29598.24 |
| 26173.79 | 2617.40 | 1308.69 | 30099.87 |
| 26610.01 | 2661.00 | 1330.50 | 30601.50 |
| 27046.24 | 2704.60 | 1375.13 | 31103.13 |
| 27482.47 | 2748.30 | 1374.13 | 31604.88 |
| 27918.70 | 2791.87 | 1395.94 | 32106.51 |
| $\Sigma Q_{OC}$ =567098.7 | $\Sigma Q_{WL}$ =56710.16 | $\Sigma Q_{UA}$ =28376.99 | $\Sigma Q_T$ =652166.8 |

F. Result of the Multiple Regression Analysis

| | Mean | Std. Deviation | N |
|---|---|---|---|
| $Q_T$ | 26086.6728 | 3691.96594 | 25 |
| $Q_{OC}$ | 22683.9484 | 3210.56349 | 25 |
| $Q_{WL}$ | 2268.4064 | 321.04781 | 25 |
| $Q_{UA}$ | 1135.0796 | 161.89545 | 25 |

Table 4: Model Summary for the Analysis

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate | Change Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | R Square Change | F Change | df1 | df2 | Sig. F Change |
| 1 | 1.000[a] | 1.000 | 1.000 | 0.52561 | 1.000 | 5.921E8 | 2 | 22 | 0.000 |

a. Predictors: (Constant), $Q_{UA}$, $Q_{CT}$

Table 5: Result on ANOVA

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 3.271E8 | 2 | 1.636E8 | 5.921E8 | 0.000[a] |
| | Residual | 6.078 | 22 | 0.276 | | |
| | Total | 3.271E8 | 24 | | | |

Table 6: Result on the Coefficients

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. | Correlations | | | Co linearity Statistics | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Zero-order | Partial | Part | Tolerance | VIF |
| | (Constant) | 0.738 | 0.792 | | .932 | 0.362 | | | | | |
| | $Q_{WL}$ | 11.491 | 0.012 | .0999 | 931.265 | 0.000 | 1.000 | 1.000 | .027 | 0.001 | 1363.297 |
| | $Q_{UA}$ | 0.017 | 0.024 | 0.001 | 0.710 | 0.485 | 1.000 | 0.150 | .000 | 0.001 | 1363.297 |

a. Dependent Variable: $Q_T$

Table 7: Result on Excluded Variables

| Model | | Beta In | T | Sig. | Partial Correlation | Co linearity Statistics | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Tolerance | VIF | Minimum Tolerance |
| | $Q_{OC}$ | 0.505[a] | 2.576 | 0.018 | 0.490 | 1.753E-8 | 5.705E7 | 1.753E-8 |

a. Predictors in the Model: (Constant), $Q_{UA}$, $Q_{UA}$

b. Dependent Variable: $Q_T$

The result returned from the standard regression analysis of table 2 above using the SPSS STATISTICA application software, with the projected 25 years data a simple linear regression model with three (3) independent variables was obtained for solid waste generation as:

From the result below we can get values of the analysis;

Here, the result shows that;

Multiple Regression Coefficient of Determination = 1.000

F = 5.921E8 is the value at which to evaluate function

$R^2$ = 1.000

Adjusted $R^2$ = 1.000

Standard error of estimate: 0.52

Degree of Freedom (df) = From the result we have that $df_1$ numerator degree of freedom to be 2, $df_2$ the denominator degree of freedom is 22. This shows that it is equal to 19.45.

When the projected 25 years data in Table 2 were analyzed using the STATISTICA procedure on the MS Excel platform, a simple linear regression model with three independent variables was obtained for solid waste generation as:

For the variance, the model coefficients obtained is,

($Q_{OC}$) beta = 0.505

($Q_{WL}$) beta = 11.491

($Q_{UA}$) beta = 0.017

Constant = 0.738

$Q_T = Q_{OC} + Q_{WL} + Q_{UA}$ + Constant

$= 0.505Q_{OC} + 11.491Q_{WL} + 0.017Q_{UA} + 0.738$ (25)

This was obtained by multiplying the Office/Classroom waste distribution coefficient (0.505), Workshop/Laboratory waste distribution coefficient (11.491) and Unaccounted waste distribution coefficient (0.017) obtained with the independent variables $Q_{OC}$, $Q_{WL}$ and $Q_{UA}$ respectively.

The observed relationship between total solid waste generation and the independent parameters (offices/classrooms, workshop/laboratory and unaccounted waste) is highly significant given an observed variance ratio of $F = 5.921 \times 10^8$ as shown in (Table 5).

When further analysis were run on the model using the forward stepwise linear multiple regression procedure, on the STATISTICA application software platform, all the three parameters, that is $Q_{OC}$, $Q_{WL}$ and $Q_{UA}$ were returned as important model parameters.

Following the results obtained in the final regression summary for dependent variable, $Q_T$ using the stepwise regression technique on STATISTICA platform, it shows that the model is reliable, returning all the independent variables as significant shown which the predicted model is now for solid waste generation within the faculty.

G. Solution by Least Square Estimator

Using the data in Table 2, the method of least square estimators was used to solve the multiple linear regression problems.

The solution of the augmented matrix is given below:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \beta_0 \\ \beta_1 \\ \beta_2 \\ \beta_3 \end{bmatrix} = \begin{bmatrix} 0.738 \\ 0.505 \\ 11.491 \\ 0.017 \end{bmatrix}$$

Hence, $\beta_0 = 0.738$ $\beta_1 = 0.505$ $\beta_2 = 11.491$ and $\beta_3 = 0.017$

By substituting this result into the regression equation (22) we have that:

$Q_T = 0.505Q_{OC} + 11.491Q_{WL} + 0.017Q_{UA} + 0.738$ (26)

H. Discussion of Results

The results of the regression model in using the method of the least square estimators confirms the result obtained using the STATISTICA application platform for both the standard regression procedure and the forward-stepwise regression analysis procedure.

Hence, using the least square regression model, the coefficient of multiple determinations, $r^2$ was

determined to compare the value obtained with that obtained from the result returned from the STATISTICA application platform. The formula determining the coefficient of determination $r^2$ is given in equation (4).

Let $Q_T = Y_i$, $Q_{PV} = y$, $\acute{Y} = Q_{MD}$

$Q_{MD}$ = Mean of the dependent variable

$Q_{PV}$ = Predicted Value

$(Q_T - Q_{MD})^2$ = Sum of square of regression

$(Q_T - Q_{PV})^2$ = Sum of squares of residuals

Hence, the coefficient of multiple determination $r^2$ is:

$$r^2 = \frac{(Y_i - \acute{Y})^2 - (Y_i - y)^2}{(Y_i - \acute{Y})^2} \quad \text{Or}$$

$$r^2 = \frac{\{(Q_T) - (Q_{MD})\}^2 - \{(Q_T) - (Q_{PV})\}^2}{\{(Q_T) - (Q_{MD})\}^2}$$

$$r^2 = \frac{17339716117 - 6.077927}{17339716117}$$

$$r^2 = \frac{17339716111}{17339716117}$$

$$r^2 = 0.999$$

From the result obtained above, the coefficient of determination ($r^2$ = 0.9999) can also be expressed in percentage as 99.99%. This value agrees with that obtained from the STATISTICA application platform for analysis of multiple regression problems.

The coefficient of determination, r is given as:

$$r = \sqrt{r^2} = \sqrt{0.9999}$$

Coefficient of Correlation, $r = 0.99995$

Since the value of the correlation coefficient is significant, valid predictions can be achieved from this model. There is a high degree of positive correlation (since r =1) between the predicted raw values and each of the independent variables. This is an indicative of the acceptance of the model as a useful tool in predicting solid waste generation within the faculty of engineering, Nnamdi Azikiwe University, Awka..

There is also a strong positive correlation between the observed value and the predicted value. The strength of the correlation also affirms that the generated model is a good predictor of the solid waste generation within the faculty.

## V. CONCLUSION AND RECOMMENDATIONS

### A. Conclusion

A survey was conducted to determine the rates of solid waste generation at the various units of the faculty. Generated wastes were subsequently characterized and peak period waste generation was taken for the worst case scenario. Quantities of waste generated were estimated as a function of population generation rates, with considerations for office/classroom, workshop/laboratory and unaccounted wastes. Solid waste generation was estimated for a 25 year population data in accordance with internationally acceptable standard. Initial solid waste generation capacity of the faculty was determined to be 326.70 kg/wk. 39.89% of generated waste is organic while 59.15% accounts for inorganic.

A model for predicting solid waste generation within the faculty was determined based on the solid waste generation data obtained during the survey and projected to account for 25 growth period, using standard multifactor regression techniques. Total solid waste generation was obtained as a function of offices/classrooms solid waste ($Q_{OC}$), workshop/laboratory solid waste ($Q_{WL}$), and unaccounted solid waste ($Q_{UA}$). Further analysis of the residuals shows that the model predicted values are strongly correlated with the actual waste generation scenario within the faculty. Diagnostic analysis using the forward stepwise regression analysis technique confirmed that model obtained in equation (25) is an appropriate model for predicting solid waste generation within the faculty. The high coefficient of determination ($r^2$ =0.9999) obtained from the analysis of the observed data is a strong indication of the reliability of the generated model.

Therefore, the analysis provided in this work is a useful tool that will guide the faculty in making decisions as they affect the management of solid waste. The composition of solid waste generated within the faculty has also been brought to the knowledge of the management. Such knowledge will guide the management in public enlightenment campaign for the reduction of waste generation through consciously designed program. The time is long past when engineers, municipal waste managers, and waste management companies treat municipal solid waste as a relatively uniform material that need only be collected and disposed of. Solid waste management now involves decisions regarding the disposition of wide range of waste products. The process begins with the identification of waste for recovery (recycling or composting). The evaluations of these decisions require thorough understanding of collection needs, scale of recovery facilities, and such disposal needs as landfill volume.

Perhaps, it will be important to look at waste minimization as an important management strategy as it helps in resource conservation, economic efficiency and environmental protection and cleanliness. This strategy would save the faculty, private enterprise within the faculty and individual huge financial waste, especially with the international cry over financial crisis rocking the developed and developing countries.

The result of this research work has also revealed the potential income generating source available to the faculty through the implementation of recovery program, especially with 45.30% of the waste being recoverable which is been ensured that wastes are properly stored before collection by the relevant body (offices, departmental classrooms, workshops/laboratories and business centers).

B. Recommendations

There is a need for the provision of production data (by weight) for the materials and products in the solid waste stream by the waste managers. This will help in constant estimation of the generation data.

a) Since 45.30% of the solid waste generated within the faculty is recyclable, studies to develop economically recycling techniques and equipment for the means of solid waste control and revenue generation for the faculty is suggested.

b) The Faculty should come up with a policy statement on the management of solid waste within the faculty, especially given the fact that the model obtained to predict solid waste generated is reliable at a coefficient of multiple determination of 0.9999.

c) Further studies should be done to determine the time of filling each of the existing waste bins at the various departments/units, using the per capita generation rate obtained in this research work as a guide.

d) In order that the goals outlined above may be achieved, the faculty must endeavor to provide the resources required to achieve its waste management targets through designing, implementing, and evaluating solid waste management programs and procedures, and through developing educational awareness programs for every staff and students in engineering.

e) Achieving a waste management program that works requires the involvement of all members of Engineering. All members must be responsible for reducing their individual contribution to solid waste through reuse, reduction and appropriate recycling practices.

f) Procedures for waste management must be developed in the following areas:

i. Reduction
ii. Reuse
iii. Procurement
iv. Composting
v. Recycling
vi. Residual waste
vii. Waste audits
viii. Educational awareness program.

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