International Journal of Modern Studies in Mechanical Engineering (IJMSME)
Volume 9, Issue 1, PP 11-24
ISSN 2454-9711 (Online)
DOI: http://dx.doi.org/10.20431/2454-9711.0901002
www.arcjournals.org

Development of an Integrated Model for Effective Waste Management (A Case Study of the Federal Polytechnic, Ado-Ekiti)

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Abstract: *Environmental pollution is a major challenge bedeviling our communities, institutions, states and nation at large. The management of waste in our institutions is of paramount importance, hence the need to develop an integrated model system for holistic capturing of various waste type, recycling possibilities, and entrepreneurship investment for optimal profitability. The Federal Polytechnic Ado-Ekiti was taken as the case study. The wastes were characterized to determine the quantity and quality in terms of bio-degradable and degradable. The bio-degradable was considered for biogas production in power generation while recycling, buy-back and combustion process were considered for the degradable waste. The comprehensive data as gathered in each process where utilized to develop an integrated model known as Integrated Solid Waste Management (ISWM) model. In a year ₦1,233,488 is expected to be generated by buy-back method, where over 10,000 kg of Biogas could be generated and two staffers will be gainfully employed with monthly income of ₦25,000.*

Keywords: *Degradable, Generation, Integrated, Model, Recycle, Waste*

1. Introduction

The massive growth of populace in different institutions across the nation, has far outstripped the various institution's municipal effort to provide basic services to the academic populace. This has resulted in an extremely uneven provision of basic sanitation services, facilities and other urban amenities required which may not be up to western standards in academic, residential and commercial areas in the school. The increased rate of admission, which is now a common feature in many institutions in Nigeria, has created serious environment problems, notably among which are solid wastes. Solid waste in the broadcast sense includes all discarded materials from municipal, industrial and agricultural activities. However for the discussion to follow, solid waste will refer to only that solid waste which are the responsibility of and usually collected by a municipality, residential and commercials area together with some industrial operations are sources of these non-hazardous solid wastes (Henry & Heinke.1989). According to Clark (2002), solid waste management is defined as the branch of solid waste Engineering associated with waste control of generation, storage, collection and transfer, transportation, processing and disposal of solid waste in a manner that is in accordance with the best principle of Public Health Economics, Engineering Conservation, aesthetics and other environmental consideration.

In Federal Polytechnic Ado-Ekiti as also the case in many institutions in Nigeria, there exists imbalance between the production of solid waste and efficient waste disposal. This is because clear priority has often been given to issues of populace increment and commercial development without paying attention to solid waste disposal facilities. This in turn puts the health of the populace at a great risk. The waste generated in our institution comprises of both biodegradable materials such as leaves, husks peels, worn clothes and rags. The non-biodegradable materials include plastics, polythene bags, bottle and metal containers (Adeyeye, 2014).

1.1. Background of Study

Our environment is a very important part of our life. There is therefore need to guide it with all diligence. Pollution is the introduction of contaminants into the environment that cause adverse change in its different forms, including water pollution, air pollution, and land pollution amongst others has however posed treats to our health and environment. Where there is pollution, then, there are pollutants. Pollutants are waste materials that contaminate our environment (air, water or soil). Wastes in a lay man's definition can be everything that no more has a use and needs to be discarded or got rid of. Waste could be liquid or solid form, however, we would be considering solid types of waste in this research, and also a viable waste management strategy. In view of this, an integrated model would be designed for effective waste management. Integrated Model of solid waste management refers to a strategic management approach to effectively manage solid waste with reference to different solid waste generation sources, characterization, transfer, sorting, treatment, recycling, conversion and disposal in an integrated manner, to give good serenity to the academic environment while improving her standard of health.

This institution under study has a population of over 15,000 students and over 1000 staff. Presently, the Institution does appear to have an efficient waste management model which can be used to deal with different waste types. Through her sanitation staff, wastes from different sources (laboratories, metal workshops and repair workshops agricultural areas) located within the premises are collected and transported to dump sites within the premises. The improper disposal of food cans, bottles and plastic wrappings pose grave threats to human health and the environment when it is not properly done. Rapid development of the institutions academic community is a great improvement in terms of however, it also contributes to an environmental challenge – overrun of solid waste material due to rapid population increase. As an advantage, this rapid development has allowed many new innovations to improve their quality of life and for learning institutions it can be said. This therefore implies that learning institutions cannot be excluded from waste management strategies which have been on-going for several number of decades. For this reason, our learning Institution has a big role to play in terms of waste management, as this has a great impact on the society and the country at large. Every student attends a learning institutions to acquire knowledge and skills and if they are met with poor waste management practices, this will negatively affect their approach to waste management.

The outcome of this research project will educate the Institution's general community, her arm in-charge of waste management on adverse effect of improper waste management and thereafter propose a viable model for proper waste management and revenue generation.

2. Literature Review

2.1. Waste

Waste (or wastes) is unwanted or unusable materials. Waste is any substance which is discarded after it has been primarily used, worthless and defective. A waste is different from a by-product, in that, the latter is a joint product of relatively minor economic value. A waste may however become a by-product, joint product or resource through an invention that raises a waste product's value. Wastes are grouped into municipal solid waste (household trash/refuse), hazardous waste, waste-water (such as sewage, which contains bodily wastes (faeces and urine) and surface runoff), radioactive waste, and others. According to UNSD Glossary of Environment Statistics, waste is described as materials that are not prime products (that is, products produced for the market) for which the generator has no further use in terms of his/her own purposes of production, transformation or consumption, and of which he/she wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Residuals recycled or reused at the place of generation are excluded.

2.2. Biomass Potential of the Solid Waste on Campus

In most developing and developed nations of the world, increase in population, prosperity and urbanization has posed more challenges for municipalities in the management of MSW streams especially in a changing climate (Ahmed, 2012). Municipal solid waste (MSW) generation rate has increased globally over the years; due to population growth, changes in lifestyle, technology development and increasing consumerism (Omari *et al*., 2014). It was reported that increase in MSW generation rate is because of the quest Biomass is an energy source which is renewable and it has a limitless supply. The waste generated from FPA has very high biomass content (14.72%). The thermal treatment of MSW generates about 500–600 KWh per ton of electricity (2000lbs or 2204.6lbs) (Kamel*et al*., 2009).

The organic waste decays to produce methane gas which can be used to generate electricity. For safer environments, new regulations have to be enacted so that landfills should be harnessed to collect methane gas. This methane gas is odorless and colorless making it difficult to detect hence, very harmful to living things. Landfills can be harnessed to collect the deadly gas, purify it, and it becomes fit to be used as fuel. Methane can also be produced from agricultural and human wastes through anaerobic composting in digesters.

Waste can be fermented in biogas digesters to produce a methane-rich gas. The gas can be harnessed to produce a reasonable amount of energy for electricity, lighting and a host of other energy consuming needs. Municipal solid waste has the potential to become a valid resource and fuel for the urban sustainable energy mix of tomorrow Nigerian institutions.

2.3. Integrated Solid Waste Management Model

Integrated Solid Waste Management model is a type of model which focuses on life cycle-based solid waste management (Solano et al, 2002). It is a model which seems to meet all the requirements. This (ISWM) model was developed to assist in identifying alternative SWM strategies that meet cost, energy, and environmental emissions objectives. Waste was categorized into 48 items and their generation rates were defined for three types of sectors: single-family dwelling, multifamily dwelling, and commercial. Cost, energy consumption, and environmental emissions associated with waste processing at each unit process were computed in a set of specially implemented unit process models and finally, a life-cycle approach was used to compute energy consumption and emissions of CO, fossil-and biomass-derived CO_2, NO*x*, SO*x*, and greenhouse gases. The biogas is produced using varieties of raw material such as plant material, food waste and animal dung in a reactor. Successful construction of the biogas plant is done in consideration of the setting up and maintenance cost, the government policy and gas handling process, the type of material needed for the construction, the site location for the plant (Amon *et. al.*, 2003). Kerosene and other energy sources produce several gases which are dangerous such as carbon monoxide which is poisonous. Nitrogen dioxide is a throat and lung irritant, and sulphur dioxide can cause difficulty in breathing; this occurs when fumes from a heater are not removed by a chimney, the gases are released into the room (Mukumba *et. al.*, 2015). Waste management is in itself a large and complex system that is difficult to survey. The system grows even more complex as one considers its links to other sectors such as manufacture, energy production, and agriculture. Based on this reviewed model and other models, the author proposes a model that is easy to understand and that will also be easy to convert into abase that can be used by the waste management agents considering the level of technology. The mode designed in this paper gives a broad presentation of the important elements necessary in the management of waste. The major findings of this paper are that the model will enable monitoring of waste types from each location and help set targets for waste minimization.

2.4. Waste Management in Learning Institutions

Educational institutions represent the main components of sustainability promotion in our society. Waste management is one of the challenges that educational institutions have to face in accomplishing sustainability goals. From the research that has been conducted most of educational institutions have deficiencies regarding waste management. Waste quantities generated in educational institutions do not depend on the number of students and the total built surface, but is influenced by the educational institution type. The challenge faced by these institutions is the difficulty to promote realistic sustainable development actions plans without major changes in public educational institutions. It is widely encouraged to adopt sustainable practice, in which institutions need to be pro-active and develop a range of suitable programmes for students at all levels including the design of waste management models in these institutions where the students can be incorporated into it.

2.5. Challenges in Waste Management Service Delivery in Nigerian Institutions

Some of the challenges include;

- Little or no investment in infrastructure for waste management.
- Lack of human capacity for administrative and technical issues on waste management.
- Wrong attitude of Students towards solid waste disposal.

- Poor planning for waste management within the campus.
- Few or no academic research focused on waste management.

3. METHODOLOGY

In achieving the specific objectives, extensive literature review was carried out to establish the basic parameters required in the development of and effective model. Having carried out an extensive review, the flow chart of operation as shown in Figure3.1 below was adopted. An investigation into the types and quantity of waste produced on daily basis was carried out as shown in figure 3.1 below. The wastes were characterized based on degradable and, non-degradable. The bio degradable wastes were considered for biogas production while the non-degradable were considered under recycling or combustible. The model was developed based on the type, quantity, cost, and output in terms of profit and power supply (its equivalent).

3.1. Materials and Methods

3.1.1. The Study Area

The research was conducted at the Federal Polytechnic Ado-Ekiti, located at longitude of 5^{o} 13' 17.0004"E and latitude 7^{o} 37' 15.9996" N with elevation of 380.5^{o}. Its main relief feature is low land with tropical rainfall of western region of Nigeria. The topography and location factors are prevalence of the tropical rainy climate.

Figure1. *Map of Ado-Ekiti and its Environs (Ejiko et. al. 2020)*

The Federal Polytechnic, Ado Ekiti, is located on the outskirt of the state capital, Ado-Ekiti, Nigeria. The institution, has 04 faculties, several administrative, academic and commercial buildings, 3 students' hostels (each having several blocks), Centre of Innovation Centre, Maintenance building and staff quarters. As gathered from the Information and Communication Technology (ICT) Department of the institution, It also has about 15689 students, with 3 hostel blocks, having several hundred rooms within campus, 506 Academic staffs and over 1000 Non-Academic staff for the 2019/2020 academic session and about 500–1,000 estimated visitors' population daily. Community services, teaching and research are the major activities in the campus and these amounted to an estimated 18000 daily populations. The campus comprises the School of Business Studies, Engineering, Environmental Studies, and Sciences & Computer Studies, Vocational Technical Education.

3.1.2. Data Collection

The purpose of this research was to design a waste management model for The Federal Polytechnic, Ado-Ekiti and information that was necessary for the design of the model was collected. The method employed for data collection is as follows:

- Visitation to dump sites
- Sample (waste) collection.
- Waste classification
- Sorting and characterisation
- Weighing and data collection

3.1.3. The Waste Collections System

The Institution waste is handled by the waste management unit of the school. However, there was no recorded document regarding the quantity, rate and the trend of solid waste generated. The solid wastes are often disposed at strategic locations within the campus which is burnt subsequently after being collected. Waste containers are distributed at some strategic positions on campus across all faculties. The Institution has no solid waste prevention, reduction, recovery, recycling nor composting measures neither does it have a proper mechanism for disposal. Rather, the Institution has only been collecting the solid wastes from their sources and transporting them to specific location behind the area of collection and burnt in open air.

Below are pictures taken from some of the waste dump sites visited:

3.1.4. Sorting

Plate3.1. *Waste Dumping Site in School of Engineering*

There are several methods which are employable in the sorting of solid wastes. However, in this study the, hand sorting method was employed in sorting of the wastes at the dump sites.

Other techniques often used for sorting of solid waste into their components includes mechanical sorting, magnetic separation, electrostatic separation, screening, gravity separation, floatation, drying method and inertia separation.

3.1.5. Waste Quantification and Characterization

Quantification at the point of waste collection was employed as there are no well-structured collection/disposal mechanisms and records in FPA presently. Sorting was carried out at the various locations. Mass of each sorted composition was measured by measuring the physical volume of the waste, multiplied by its density and thereafter recorded. At the end of each sorting, summation of the individual weights was done to give the average of total weight of MSW (Municipal Solid Waste) at that location, daily. The percentage composition of each of the components was then calculated. The solid wastes were identified as recyclable or non-recyclable after having obtained the weight percentage of each individual component. The potential of each solid component to be recycled was determined by categorizing them as wastes which exists in market for the recycling such as metals, polythene bags, paper and plastic, for recyclable in which no market exists such as glass, leather, organic waste and textile and for non-recyclable wastes like sanitary waste and inert materials.

Plat 3.4. *The equipment used for weighing the solid waste samples.*

3.2. Process of Operation of the Designed Model

Table 3.1: Process of Operation of the designed Model

STAGES	Determine Expected Revenue/ Biogas per Session			
	Plastic	**Nylon**	**Paper**	**Food Waste**
Stage 1	Insert Population			
Stage 2	Calculate likely waste to be generated on weekly basis using regression equation			
Stage 3	Multiply result for each waste by "buy-back" rate per kg = Revenue per week for each waste type			Divide result by 3.34kg = Biogas per week
Stage 4	Multiply Results in stage 3 by 32 weeks of a session = Revenue per session			Multiply Result by 32 week = Biogas per Session
Stage 5	Calculate Salary of Workers			
Stage 6	Calculate allowable fund for Miscellaneous and Transportation			
Stage 7	Determine Profit			

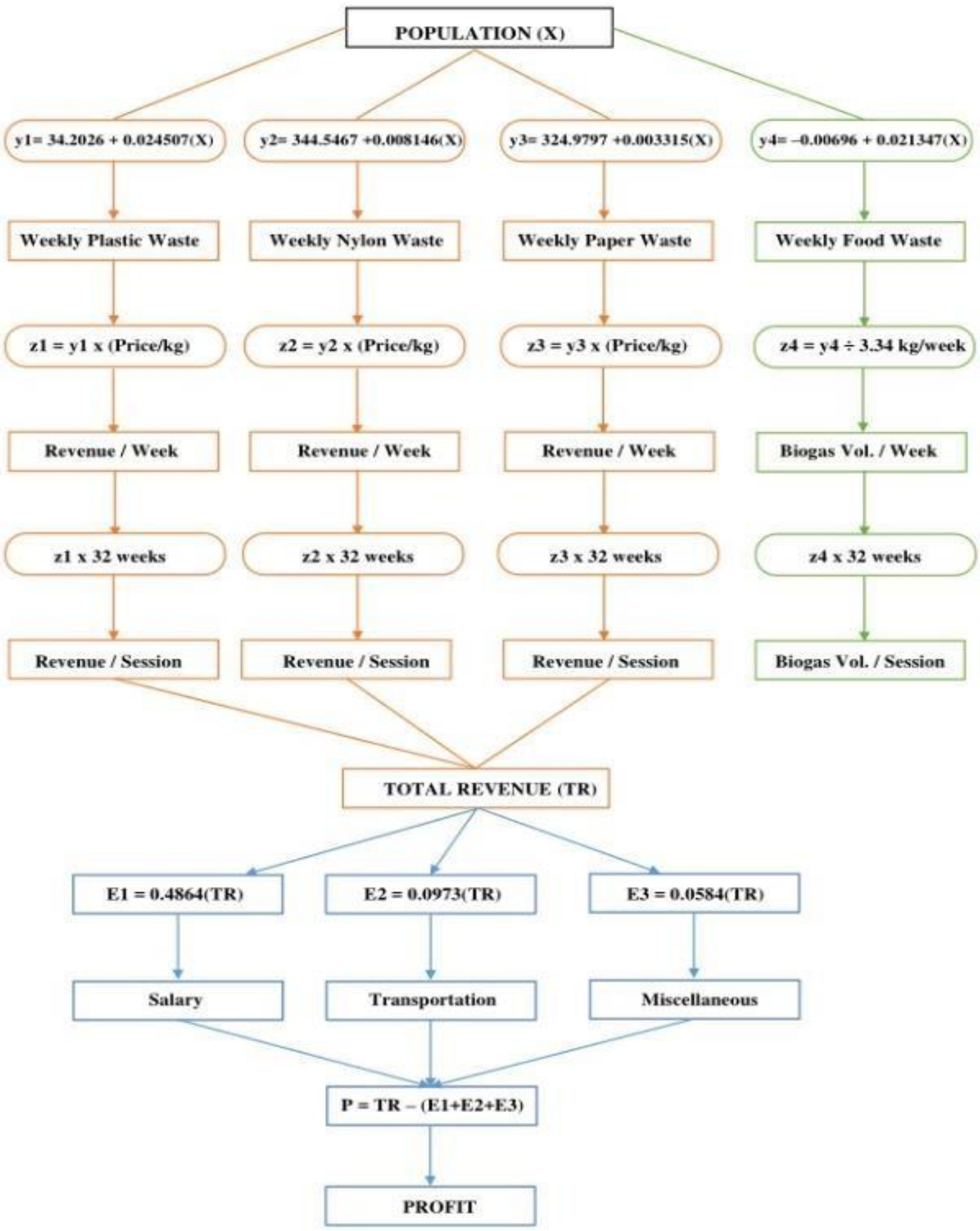

Figure3.3. *Process Diagram for Model Development*

4. Results and Discussion

4.1. Case Study Results

The results that were obtained from the study conducted at The Federal Polytechnic, Ado-Ekiti to determine the waste generation rate is as shown in Table 4.1 was further decentralized into Table 4.1.1 – 4.1.11 based on schools, centers and different locations. In this study, waste was collected from different locations sorted and weighed across the institution as shown in Table 4.1 and Table 4.2. The waste components found in The Federal Polytechnic, Ado-Ekiti included food residues, paper, plastics, metals, glass, textiles, rubber, nylon, and wood. However, the study at The Federal Polytechnic, Ado-Ekiti focused on food residues, paper, plastics and nylon only. The factors that influence the amount of waste generated are;

- The time of the year: mainly holidays of the year, that is, Christmas and New Year holidays. When holidays come up, students often travel home hence, reduce the amount of waste generated.
- Time already spent on campus by students. Waste generation is higher at early resumption period and reduces as towards the end of the semester due to reduced funds.

Table4.1.1. *Waste Composition Obtained from the School of Engineering*.

		A	School Of Engineering					
S/n	**Waste type**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	8.9	8.5	8.5	8.8	8.5	43.2	8.64
2.	Plastic	6.6	7.0	4.7	7.2	7.6	33.1	6.62
3.	Peels	1.0	1.3	0.9	1.2	1.0	5.4	1.08
4.	Nylon	4.7	5.3	3.5	2.5	3.0	19	3.8
5.	Food Waste	2.3	2.6	1.8	1.4	2.6	10.7	2.04
	TOTAL(KG)	23.5	24.7	19.4	21.1	22.7	111.4	22.18

Table4.1.2. *Waste Composition Obtained from the School of Science & Computer Studies.*

		B	School of Science & Computer Studies					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	10.6	10.7	9.0	5.2	6.4	41.9	8.38
2.	Plastic	6.5	7.6	6.4	7.6	6.0	34.1	6.82
3.	Peels	0	0	0	0	0	0	0
4.	Nylon	5.2	4.0	4.8	5.2	4.9	24.1	4.82
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	22.3	22.3	20.2	18.0	17.3	100.1	20.20

Table4.1.3. *Waste Composition Obtained from the School of Business*

		C	School of Business Studies					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	9.2	9.0	8.5	9.4	8.5	44.6	8.92
2.	Plastic	7.7	5.8	6.4	6.0	5.2	31.1	6.22
3.	Peels	0	0	0	0	0	0	0
4.	Nylon	5.1	4.7	3.8	4.2	2.9	20.7	4.14
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	22.0	19.5	18.7	19.6	16.6	96.4	19.28

Table4.1.4. *Waste Composition Obtained from the School of Environmental Studies.*

		D	School of Environmental Studies					
S/N	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (Kg)**	**Aver. (Kg)**
1.	Paper	10.5	12.3	12.6	9.0	8.7	44.1	10.62
2.	Plastic	5.5	6.0	4.7	6.8	6.2	29.2	5.84
3.	Peels	0	0	0	0	0	0	0

4.	Nylon	4.4	4.3	4.7	4.0	3.8	21.2	4.24
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	20.4	22.6	22	19.8	18.7	103.5	20.7

Table4.1.5. *Waste Composition Obtained from Olusegun Obasanjo Centre for engineering Innovation.*

		E	Olusegun Obasanjo Centre for Eng. Innovation					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	1.0	0.6	0.4	1.0	0.5	3.5	0.7
2.	Plastic	0.2	0.4	0.3	0.2	0.1	1.2	0.24
3.	Peels	0	0	0	0	0	0	0
4.	Nylon	0.5	0.2	0.4	0.1	1.2	2.4	0.48
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	1.7	1.2	1.1	1.3	1.8	7.1	1.42

Table4.1.6. *Waste Composition Obtained from Maintenance Services*

		F	Maintenance Services					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	0.01	0.01	0.01	0.01	0.01	0.01	0.01
2.	Plastic	1.0	0.8	0.9	1.0	0.6	4.3	0.86
3.	Peels	0.5	0.4	0.2	0.3	0.1	1.5	0.5
4.	Nylon	0.8	0.4	0.5	0.3	0.1	2.1	0.42
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	2.31	1.61	1.61	1.61	0.81	7.95	1.79

Table4.1.7. *Waste Composition Obtained from Staff Quarters*

		G	Staff Quarters					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	0.38	0.5	0.39	0.3	0.4	1.97	0.394
2.	Plastic	0.5	0.1	0.09	0.08	0	0.77	0.154
3.	Peels	1.0	0.7	0.9	0.8	0.8	4.2	0.84
4.	Nylon	0.2	0.18	0.18	0.2	0.8	1.56	0.312
5.	Food Waste	5.0	1.0	1.1	1.2	3.0	11.3	2.26
	TOTAL(KG)	7.08	2.48	2.66	2.58	5.0	19.8	3.96

Table4.1.8. *Waste Composition Obtained from Abuja Hostel*

		H	Abuja Hostel					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	9.6	16.4	2.1	6.1	9.5	43.7	8.74
2.	Plastic	9.9	8.5	6.3	6.2	5.5	36.4	7.28
3.	Peels	9.0	40.0	36.0	27.5	34.1	146.6	29.32
4.	Nylon	15.0	17.5	14.6	17.5	14.5	79.1	15.82
5.	Food Waste	15.0	17.5	14.6	17.5	14.5	79.1	15.82
	TOTAL(KG)	58.5	99.9	73.6	74.8	78.1	351.3	76.98

Table4.1.9. *Waste Composition Obtained from Lagos Hostel*

		I	Lagos Hostel					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	37.0	14.5	10	8.5	8.9	78.9	15.78
2.	Plastic	50.0	40.0	38.5	18.5	9.0	156	31.2
3.	Peels	70.0	51.0	42.0	49.0	38.5	250.5	50.1
4.	Nylon	30.0	32.2	40.0	25.5	20.3	148	29.6
5.	Food Waste	38.5	30.5	25.7	19.5	20.5	134.7	26.94
	TOTAL(KG)	225.5	168.2	156.2	121	97.2	768.1	153.62

Table4.1.10. *Waste Composition Obtained from Annex Hostel*

		J	Annex Hostel					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	27.5	17.5	12	13.0	10	80	16
2.	Plastic	42	13	12.2	7	10	84.2	16.84
3.	Peels	90	65	53.0	43.0	40	291	58.2
4.	Nylon	60	35.5	40	35.6	25	196.1	39.22
5.	Food Waste	20.1	22.5	23.5	14.5	18.5	99.1	19.82
	TOTAL(KG)	239.6	153.5	140.7	113.1	103.5	750.4	150.08

Table4.1.11. *Waste Composition Obtained from the Health Centre*

		K	Health Centre					
S/n	**Types of waste**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Total (kg)**	**Aver. (kg)**
1.	Paper	1.2	1.3	0.8	1.2	0.9	5.4	1.08
2.	Plastic	2.2	1.3	2.7	1.8	1.4	9.4	1.88
3.	Peels	0	0	0	0	0	0	0
4.	Nylon	0.8	0.4	0.5	0.3	0.6	2.6	0.52
5.	Food Waste	0	0	0	0	0	0	0
	TOTAL(KG)	4.2	3.0	4.0	3.3	2.9	17.4	3.48

Table 4.3 represents the methods with which waste samples were collected in the institution at the various locations and the disposal method often applied.

4.2. Waste Generation Rate

The Federal Polytechnic, Ado-Ekiti generated a weekly average of 2274.405 kg by weight of solid waste daily during the 5-months study period in 2019/20 academic session. Waste generated in FPA varied by months, seasons and locations (whether academic/administrative, commercial, or residential). Solid Waste generation was often high during academic periods and lowest during breaks and vacation periods, (the Covid-19 lockdown period being at the rock bottom). Waste generation got spiked by the presence students after the vacation period. A total of 2,274.405kg/week was generated during full academic periods.

4.3. Waste Characterization

Table 4.2 provides the percentage of waste composition by weight of the MSW generated in the Institution. Inorganic waste forms the biggest component of the MSW generated in the campus which is about as polythene is about 21.24%, with paper and plastics at 17.02% and 18.45% respectively.

Table4.2. *Summary of Wastes Composition in the Federal Polytechnic Ado-Ekiti*

S/N		**SOE**	**SSCS**	**SBS**	**SES**	**OOC EI**	**Maintenance Services**	**Staff Quarters**	**Abuja Hostel**	**Lagos Hostel**	**Annex Hostel**	**Health Centre**	**Total (Kg)**
1	Paper	43.2	41.9	44.6	44.1	3.5	0.05	1.97	43.7	78.9	80	5.4	387.275
2	Plastic	33.1	34.1	31.1	29.2	1.2	4.3	0.77	36.4	156	84.2	9.4	419.77
3	Peels	5.4	0	0	0	0	1.5	4.2	146.6	250.5	241	0	649.2
4	Nylon	19	24.1	20.7	21.2	2.4	2.1	1.56	45.5	148	196.1	2.6	483.26
5	Food Waste	10.7	0	0	0	0	0	11.3	79.1	134.7	99.1	0	334.9
	Total	111.4	100.1	96.4	94.5	7.1	7.95	19.8	351.3	768.1	700.4	17.4	2274.405
	Percent (%)	4.29	4.40	4.24	4.16	0.31	0.34	0.88	15.45	33.77	30.79	0.77	100

Table4.3. *Methods of Waste Collection, Processing, Re-Use and Disposal In The Federal Polytechnic, Ado-Ekiti*

S/No	**Unit**	**Collection Method**	**Processing Method**	**Re-Use**	**Disposal Method**
1	School of Engineering	Manual (waste basket)	Nil	nil	open dump/ burning

2	School Science & Computer Studies	Manual (waste basket)	Nil	nil	open dump/ burning
3	School of Environment Studies	Manual (waste basket)	Nil	nil	open dump/ burning
4	School of Business Studies	Manual (waste basket)	Nil	nil	open dump /burning
5	Olusegun Obasanjo Centre for Engineering Innovation	Manual (waste basket)	Nil	nil	open dump /burning
6	Maintenance Services/ Physical Planning	Manual (waste basket)	Nil	nil	open dump/ burning
7	Staff Quarters	Sack (waste basket)	Nil	nil	open dump/ burning
8	Health Centre	Sack (waste basket)	Nil	nil	open dump/ burning
9	Hostels	Sack (waste basket)	Nil	nil	open dump/burning

Figure 4.1 provides the classification of waste generated in the institution by type and it reveals peels are the most generated type of waste. Also, Figure 4.2 represents the volume of solid waste generated in the institution by each of the locations considered. It reveals that the highest amount of waste is generated in Lagos hostel while the least amount is generated in Olusegun Obasanjo Centre of Engineering Innovations.

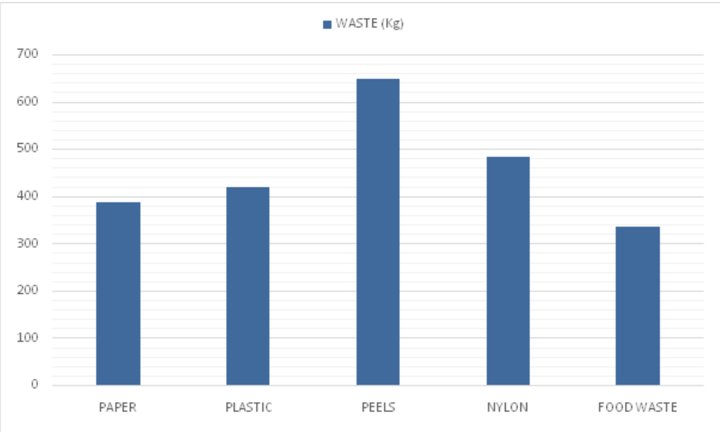

Figure4.1. *Classification of Waste Generated In the Federal Polytechnic, Ado-Ekiti by Type*

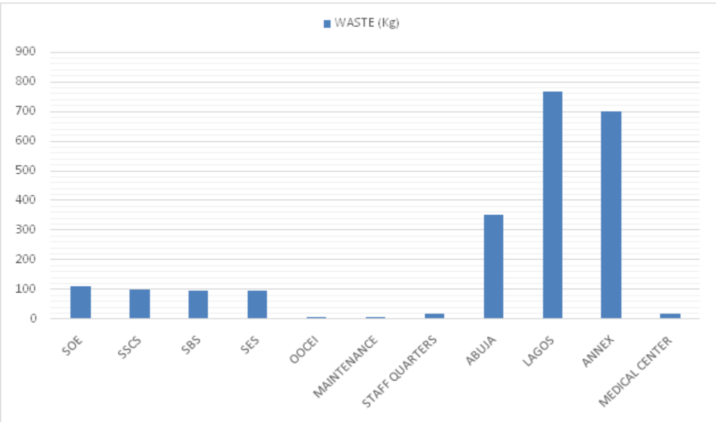

Figure4.2. *Volume of Waste Generated in the Federal Polytechnic, Ado Ekiti in Studied Locations*

4.4. Recyclable Potential of the Solid Waste Generated in the Federal Polytechnic, Ado-Ekiti.

A reasonable proportion of the MSW generated in FPA campus is recyclable or is potentially recyclable. The FPA campus has a lower non-recyclable potential when matched with some reported university studies by Chee and Sumiani (2014). At present, FPA is not able to recycle, reuse or recover energy from any of its waste categories.

Wastes Composition obtained From Various Units in the Federal Polytechnic, Ado Ekiti.

4.5. Derivation of Regression Equations

To achieve the set goal of developing an integrated model, there is need for equation which would guide the operation of the model. It was decided to use Regression equation, hence the need for determinant variables. The population of staff and students in the institution from 2016 till date was sourced from the ICT Department of the Institution. The population of the various years was plotted against individual estimated waste type generated for each year respectively. This was used to generate regression equation to formulate our proposed Java program to facilitate waste management in the institution. The results are as presented in Table 4.4 to Table 4.8. Hence, the independent variables would be the result that is generated by the regression equation.

Table4.4. *Population of the Institution since 2016 till Date (Source: FPA ICT Department)*

Year	Population
2016	9384
2017	10454
2018	14835
2019	14835
2020	15689

Regression Statistics for Paper Waste

Table4.5. *Paper Waste of the various years plotted against the population*

Year	Paper	Population
2016	341.22	9384
2017	380.13	10454
2018	366.19	14835
2019	366.19	14835
2020	387.27	15689

Regression Statistics for Plastic Waste

Table4.6. *Plastic Waste of the various years plotted against the population*

Year	Plastic	Population
2016	262.61	9384
2017	292.55	10454
2018	396.92	14835
2019	396.92	14835
2020	419.77	15689

Regression Statistics for Nylon Waste

Table4.7. *Nylon Waste of the various years plotted against the population*

Year	Nylon	Population
2016	405.23	9384
2017	451.44	10454
2018	456.95	14835
2019	456.95	14835
2020	483.26	15689

Regression Statistics for Food Waste

Table4.8. *Food Waste of the various years plotted against the population*

Year	Food	Population
2016	200.31	9384
2017	223.15	10454
2018	316.67	14835
2019	316.67	14835
2020	334.9	15689

4.6. Derived Regression Equation

For plastic waste,

$$y = 34.2026 + 0.024507(x) \quad (4.1)$$

For paper waste,

$$y = 324.9797 + 0.003315(x) \quad (4.2)$$

For nylon waste,

$$y = 344.5467 + 0.008146(x) \quad (4.3)$$

For food waste,

$$y = -0.00696 + 0.021347(x) \quad (4.4)$$

Where,

y = is the dependent Variable. It is the probable waste quantity that could be generated.

x = is the independent variable. It is the population which determines y.

R as shown in the Summary output for each waste type represents how linear the results are i.e. the dependability of the output. Most of the wastes have high linearity while some are perfectly linear.

4.7. Profitability of the Model

The model was developed to help determine the Total Revenue which can be generated from the wastes and hence – the Profitability of the model. In the course of the research, as the option of "Buy-back-system" was considered for recycling of the inorganic wastes, two waste recycling companies situated in different locations were contacted to inquire the price they purchase waste materials (Plastic, Paper, and Nylon). The response of the respondents is as presented in Table 4.9. In the development of the model, it was determined that if salary is to be paid to the workers at the rate of ₦25,000 per month, payable to two workers – 48.64% of the Total Revenue generated will be expended on payment of salary. Also, 0.973% was budgeted for transportation and 0.0584% for Miscellaneous.

Table4.9. *Price of waste Buy-back at some Recycling Companies*

Name of Correspondent	Company Name	Location of Company	Purchase Price/kg (₦)		
			Plastic	Paper	Nylon
Mr. Adebayo Babatunde	Westman Recycle LTD	Lagos State	30	45	40
Mr. Sunny Umoh	Kaduna Recyles	Kaduna State	20	30	30
Price used to calculation in the developed Model			25	35	30

4.8. Validation of the Model

The model developed was validated by calculating the percentage difference between the results obtained from the developed model and the manual calculation carried out. This is to verify the reliability of the estimated result generated by the model against the actual result.

Actual Result = Result derived manually using calculator

Estimated Result = Result derived using the developed Java program`

Following the steps sated in the Process of Operation of the designed Model as shown in Table 3.2, and considering the population of 2020 Academic Session (15689) as example, the result will be as follow:

The Actual result for Total Revenue generated = ₦1,233,488

Estimated result for Total Revenue generated = ₦1,210,637.04

Difference = 22850.96

$$\% \, Error = \frac{22850.96}{1233488} \times 100\% = 1.8525 \,\%$$

5. Conclusion and Recommendation

5.1. Conclusion

The Actual result for Total Revenue generated is ₦1,233,488 while estimated result for Total Revenue generated is ₦1,210,637.04. The Confidence level of the developed model is 98%.

Conclusively at the end of the Project, the main and specific objectives of the project were achieved. The solid wastes were characterized and the quantities of waste products per period (daily, weekly and monthly) were determined. Buy-back method was employed for combustible wastes for energy generation and biodegradable waste for biogas production. Thereafter, the developed model was validated. This brought us to another conclusion that if the model is utilized, there will be creation of employment for two manual labour, who would be paid #25,000 each, also the institution would be able to generate substantial profit.

5.2. Recommendation

There has not been any Waste Management Plan in many Nigerian institutions and if available in any of the institutions it is likely it is not substantial. This unfortunately is one major challenge in Nigerian institutions. Therefore, in order to achieve a waste free environment in our institutions, while fostering a healthier learning environment, particularly The Federal Polytechnic, Ado-Ekiti it is recommended that:

- There should be investment in infrastructure for waste management.
- Provision of human capacity for administrative and technical issues on waste management
- Students are sensitized on posing Right attitude towards solid waste disposal. Educational campaigns should be undertaken on the dangers of mismanaging wastes. Environmental awareness should be introduced to stress on the implications of poor solid waste storage, collection and disposal on the health of the institution populace.
- Financing – The proposed model should be funded while anticipating its return on investment
- There should be proper planning for waste collection within the campus. E.g the use of colour coded bins for waste collection at offices, workshops, lecture rooms, and institutional yards. This will facilitate easy sorting.
- Waste collectors should be urged not to rapidly rush through the institutions during collection as much waste is strewn all over the roads.

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Citation: *Ejiko S. O, et.al.(2023)" Development of an Integrated Model for Effective Waste Management (A Case Study of the Federal Polytechnic, Ado-Ekiti)", International Journal of Modern Studies in Mechanical Engineering (IJMSME), 9(1), pp.11-24, DOI: http://dx.doi.org/10.20431/2454-9711.0901002*