INDUSTRIAL SOLID WASTE GENERATION IN ENUGU METROPOLIS: AN INVESTIGATION OF CONTRIBUTORY FACTORS

AGU JOACHIM AMAZILO
Department of Urban and Regional Planning
Imo State University Owerri
Imo State, Nigeria

&

OSUJI SABINA CHIAKA
Department of Urban and Regional Planning
Imo State University Owerri
Imo State, Nigeria

Abstract

The aim of the study is to investigate the factors of industrial solid waste generation in Enugu metropolis of Nigeria. The study used the survey design type of research using questionnaire to solicit information from members of staff of five categories of industrial establishments in Enugu Metropolis. A total of 300 copies of questionnaire were used as the sample size for the study. The multiple linear regression statistic was used to the hypothesis. The result of the computation gave a regression equation of $Y = 0.888 + 0.082_{x1} - 0.575_{x2} - 0.0798_{x3} + 1.001_{x4}$, with a table value of 0.784. While the calculated values are 0.082, - 0.515 and + 1.001. The result of the hypothesis shows positive relationship between y (Average volumes of solid waste) and x1 (Average volume of product and x4) Average volume of raw materials input, but a negative relationship between y and x2 (Average number of employees) and x3 (Average price per product). In otherwords average volume of waste generated in Enugu Metropolis is caused mainly by average volume of product produced daily, average raw materials input used while average number of employees and average price per product play little role to determine the quantities of industrial solid waste generated. The study recommended measures to arrest the situation include among others waste recovery and recycling to minimize the quantities of solid wastes disposed to the environment and waste dumps.

Key words: Industrial Solid Wastes, Industrial Solid West Generation, Contributory Factors, Enugu Metropolis.

Introduction

Industrial waste is generated by industrial activity which include any material that is rendered useless during a manufacturing process such as that of factories mills and mining operations. It has existed since the start of the industrial revolution (Maczulak and Elizabeth 2010) General Environmental Conservation Public Company, argue that rapid industrialization has resulted in the generation of large quantities of waste (solid liquid and gas) in industrial sectors of many countries of which Nigeria is among (Genco, 2014).

Industrial waste could be reactive or radioactive even in its solid form, and could pollute the air, soil or nearby water sources which may eventually end up in the sea (Alcott, 2015).

Industrial solid waste generation could easily covey two different meanings. One is connected with such wastes generated and mixed into municipal wastes, thereby making accurate assessments difficult, (Foster and Clark, 2011). The second was by Morris (2015) who defined industrial solid waste generation as wastes that is generated by businesses from an industrial or manufacturing process and remain as useless which can be recycled. As such the aim of this study is to investigate the contributory factors responsible for the quantities of solid waste produced/generated by individual production of products by each industrial type.

Literature Review and Theoretical Framework

Haga and Yano (1992) have since noted that the main reason industries generate much waste is for profit propelling them to produce more products and increasing solid waste outputs. According to them the priority of most industrial policies is geared towards development particularly the strengthening of competitiveness of enterprises and neither for the protection of human health nor for the preservation of the environment. They lamented that “it is a very selfish approach typical of most developing economies”. It is of recent that the environmental impact assessment (EIA) policy was incorporated into the guidelines for establishment of industries.

Industrial waste defined by Maczulak and Anne (2010), is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, industries, mills, and mining operations. Types of industrial waste include dirt and gravel, masonry and concrete, scrap metal, oil, solvents, chemicals, scrap lumber, even vegetable matter from restaurants. Industrial waste may be solid, liquid or gaseous. It may be hazardous or non-hazardous waste. Hazardous waste may be toxic, ignitable, and corrosive. As explained by Alcott (2015), industrial waste could be reactive, or radioactive. Industrial waste may pollute the air, the soil, or nearby water sources, eventually ending up in the sea. Industrial waste is often mixed into municipal waste, making accurate assessments difficult. Foster and Clark (2011), argue that an estimate for the United States goes as high as 7.6 billion tons of industrial waste produced every year. Most countries have enacted legislation to deal with the problem of industrial waste, but strictness and compliance regimes vary. Enforcement is always an issue.

Classification and Treatment

Toxic waste, chemical waste, industrial solid waste and municipal solid waste are designations of industrial wastes. Sewage treatment plants can treat some industrial wastes, that is, those consisting of conventional pollutants such as biochemical oxygen demand (BOD). Industrial wastes containing toxic pollutants or high concentrations of other pollutants (such as ammonia) as narrated by Clark and Foster (2019), require specialized treatment systems. Industrial wastes can be classified on the basis of their characteristics: waste in solid form, but some pollutants within warehouses and plants. This waste may include harmful or dangerous chemicals and chemical residue, and waste disposal must adhere to careful guidelines. These guidelines are instituted and regulated by various government and environmental agencies, such as the Environmental Protection Agency, and the Occupational Safety and Health Administration. There are generally fines associated with non-compliance. Chemical waste according to Kahie; Eda Gurel-Atay (2014), must be segregated on-site, and waste disposal may need to be handled by a specialist to ensure compliance with health, safety, and legal requirements.

In industrial services, solid waste as notified by Bonnie (2016), includes a variety of different materials, including paper, cardboard, plastics, packaging materials, wood, and scrap metal. Some of these materials can be reused and recycled by a recycling centre. If you don't have a comprehensive waste management plan that includes recycling, your waste disposal is not going to be as cost-effective or environmentally friendly as it could be. A recycling centre can process the majority of industrial solid waste, effectively reducing your waste disposal costs.

Toxic and hazardous waste by RecyclingToday (2015), is comprised of materials that can cause serious health and safety problems if waste disposal is not handled correctly. This type of waste typically includes dangerous by products materials generated by factories, farms, construction sites, laboratories, garages, hospitals, and certain production and manufacturing plants. The Environmental Protection Agency (EPA) and state departments regulate toxic and hazardous waste disposal. This waste disposal is only legal at special designated facilities around the country. While disposal into exhausted open pits is generally a straightforward operation, disposal into underground voids is more complex. A common modern approach stated by Zeng, Ning, Yoon and Jinho (2019), is to mix a certain quantity of tailings with waste aggregate and cement, creating a product that can be used to backfill underground voids and stopes.

Theoretical Framework

Constructing the Waste Management Theory (WMT) by Love (2002), Waste Management Theory (WMT) as developed by Love was introduced to channel environmental sciences into engineering design. WMT is a unified body of knowledge about waste and waste management. It is an effort to organize the diverse variables of the waste management system as it stands today in the industrial. WMT is considered within the paradigm of Industrial Ecology, and built side-by-side with other relevant theories, most notably Design Theory. Design Theory is a relatively new discipline, still under development. Following its development, offers valuable insights about evolving technical theories. According to Love (2002), it is crucial to theory development to integrate theories from other bodies of knowledge, as well as the clarification of the definitions of core concepts, and mapping out key issues, such as domains, epistemologies and ontologies.

The theory explains the present stage of Waste Management Theory (WMT) development which has offered scientific definitions of key concepts, and evolving of WMT under the paradigm of Industrial Ecology.

The purpose of this theory is to explain systems of regularities that cannot be explained with scientific laws in handling industrial wastes. The basic proposal of WMT as developed by Love is that it is able to define waste in straight forward term. The theory recommended that industries should choose abundant, non-toxic materials when designing products, re-use of products or parts of products as well as when disassembling complex products and reuse of components. It states that every process and product should be designed to preserve the embedded utility of the materials used. An efficient way to accomplish this goal is by designing modular equipment and by remanufacturing. The theory also recommended that internal recycling of production waste industries should get most of the needed materials through recycling streams (theirs or those of others) rather than through raw materials extraction, even in the case of common materials. It also advised that every product should be designed so that it can be used to create other useful products at the end of its life. It added that every industrial landholding or facility should be developed, constructed or modified with attention to maintaining or improving local habitats and species diversity, and minimising impacts on local and regional resources.

Empirical Studies

Ezezika, Singer and Peter (2010), conducted an empirical research on the effect of Genetically engineered oil-eating microbes for bioremediation on the production of industrial wastes in Lagos between 1975-2009 using SPSS software. They discovered that much industrial waste were generated and means of disposal was very slow which affected environmental health. They recommended that both government and the companies should be involved in solid waste disposal.

Clark, Weaver, Brook and Cook (2018), conducted a regression research on the place of technology on industrial waste generation in Heksinki between 1970-2015 , by using e-View software. They discovered that technology was the engine drive of industrial revolution which again affected the rate of industrial waste generation and advised that if any company was not prepared to obey environment al laws in handling industrial wastes, it should be closed down due to hazards to life wastes posit.

Zeng et al, (2019), conducted a regression research on the effect of biochemical oxidation on industrial waste management between 1980-2018 using SPSS software. It was discovered that oxidation in the industry though improved productivity, it also contributed to the generation of industrial wastes. Kaplan, (2018), conducted a regression research on the effect of industrial waste on environmental degradation at Aba, Abia State, Nigeria between 1980- 2017 using SPSS software. It was discovered that productivity defines the city of Aba, but that generation of industrial wastes are not properly handled. Morris (2015), conducted a regression research on the effect of landfilling or incineration with energy recovery on industrial waste generation at Kano, Nigeria between 1980- 2014, using SPSS software. It was discovered that landfill was very efficient in handling industrial waste

Area of Study

Enugu Metropolis lies within 221m and 317m above sea level. It is located on latitude $70^0 29^1$E and longitude 60^0 25^1N. It is located within the guinea savanna region. Enugu lies on the upper stretches of the Cross River plain. Enugu Metropolis is bounded in the North by Enugu East LGA; South by Nkanu LGA; East by Udi LGA and West by Emene. The Metropolis is generally surrounded by a rolling escarpment in the nature of eastern scarpland. The temperature and rainfall patterns follow the average pattern: high and equable temperature with corresponding high rainfall (75^0F and> 2000mm) respectively.

Enugu Metropolis has a population of about 722 664 (NPC 2006). It also has a total land area of 556km^2 leaving a population density of about 1,300 persons km^2.

The gradual growth of industrial processes and production over the last few decades meant that industrial and domestic wastes now contribute to the overall waste regime in the Metropolis contributing to environmental degradation in the area.

Presently in Enugu Metropolis many landuses exist but largely unplanned. It is even worsened by poor environmental quality caused by industrial establishment, and poor refuse disposal among others (Agu 1999).

Methods and Materials

The study covers Enugu Metropolis. The data for the study were sourced both from primary and secondary sources. Data were collected with the use of questionnaire copies. 300 copies of questionnaire were administered using the combination of stratified random sampling technique.

Data Analysis

Table 1: Estimated Volume of Solid Waste Generated Daily (in kg) yield the table below:

Serial No.	Item	Response	% Response
1	1kg	10	3.33
2	1-5kg	20	6.67
3	6-10kg	70	23.33
4	4kg	50	16.67
5	11-15kg	10	3.33
6	16-20kg	40	13.33
7	21-25kg	70	23.33
8	More than 25kg	30	10
9	Total	300	100

Source Field work (2019)

300(100%) responded 10(3.33%) said that the volume of wastes generated daily in kg is both 1kg and between 11-15 kg; 20 (6.67%) said 1-5 kg; 70(23.33%) said 6-10 kg and 21-25 kg respectively; 50(16.67%)said 4kg;10(3.33%) said 11-15kg 40 (13.33%)said 16-20 kg while 30(1O%)said more than 25kg. So, we conclude that 6-10 and 21-25 kg J wastes are being generated daily.

Table 2: The Estimated Number of Products Produced Daily

Serial No.	Item	Response	% Response
1	100	20	6.67
2	500	30	10
3	1,000	50	16.67
4	1,500	150	50
5	2,000	10	3.33
6	More than 2,500	40	13.33
7	others specify	-	-
8	Total	300	100

Source: Field work (2019).

300(100%) responded 20(6.67%) said that the estimated number of products produced daily is 100;30(10%) said 500; 50 (16.67%) said 1,000; 150(50%) said 1,500; 10(3.33%) said 2,000 while 40 (13.33%)said more than 2,500. So, we conclude that 1,500 are produced daily.

Table 3: The Correct Price Per Product Price Industry.

Serial No.	Item in Naira	Response	% Response
1	100	20	6,67
2	200	30	10
3	300	20	6.67
4		10	3.33
5	500	60	20
6	1,000	140	46.67
7	2,000	10	3.33
8	2,500	-	-
9	Others specify	300	100

Source: Field work (2019).

300(100%) 100(6.67%) both said that the price per product is 100 and 300 naira respectively; 30(3%) said 20 naira; 10(3.33%) said 500 and 2,500 naira respectively, while 140(46.67%) said 2,000 naira. So, we conclude that greater percentage agree that the price per product is 2,000 naira.

Table 4: The Number of People the Company Employed

Serial No.	Item	Response	% Response
1	2	30	10
2	5	30	10
3	10	30	10
4	15	10	3.33
5	20	50	16.67
6	25	150	50
7	Total	300	100

Source Field work (2019)

300(100%) responded 30(10%) said that their company employs 2,5 and 10 respectively; 10(3.33%)said 15; 50(16.67%) said 20, while 150(50%) said 25. So, we conclude that the number majorly employed is 25.

Table 5: The Volume of Raw Material Input Yielded

Serial No.	Item	Response	% Response
1	10kg	10	3.33
2	20kg	30	10
3	30kg	60	20
4	More than 40kg	200	66.67
5	Total	300	100

Source Field work (2019)

Table 6: **The responses were summarized in the table below which was statistically analyzed using the Multiple Linear Regression (MLR) model**

Type of industrial	**Average vol. y industrial vlilustic**	**Average vol. of product x1**	**Average No y Employees**	**Av. Price / product x3**	**Av. Vol. flaw materials input x 4**
Manufacturing	51.9kg	114.3kg	22	248	157.7kg
Service	15.5kg	22.0kg	5	150	11.7kg
Food processing	25.2kg	80.4kg	18	75	54.4kg
Agr alied	44.21kg	102.6kg	12	127	67.9kg
Chemical adied	23.4kg	85.6kg	13	88	44.6kg

Source: Field work (2019).

Data computation and result

y = Average Volume of solid waste.
X_1 = Average Volume of products.
X_2 = Average Number of Employees
X_3 = Average Price per product.
X_4 = Average Volume of Raw Material Input.

year	Y	X_1	X_2	X_3	X_4
Manufacturing	51.9	114.3	22	248	157.7
Services	15.3	22.0	5	150	11.7
Food Processing	25.2	80.4	18	25	54.4
Agro Allied	44.2	102.6	12	127	67.9
Chemical Allied	23.4	85.6	13	88	44.6

In this regression, duration is taken as five (years): manufacturing = 1^{St} year, Services 2^{nd} year, Food Processing= 3^{rd} year, Agro Allied = 4^{th} year and Chemical Allied= 5^{th} year.

Interpretation of Results

Regression Equation:

$y = 0.888 + 0.082x_1 — 0.575\ x_2 — 0.798\ x_3 + 1.001\ x_4$

Table Value = 0.784

Calculated Values are 0.082, —0.575, —0.798 and + 1.001

So, there is a positive relation between y and x_1 and x_4 but a negative relation between y and x_2 and x_3

The descriptive statistics result above shows that Average Volume of Solid Waste has an average value of 22.5780 with a corresponding standard deviation of 13.62218. Average Volume of Products has an average value of 65.9610 with a corresponding standard deviation of 32.54028. Average Number of Employees have an average value of 100.1720 with a corresponding standard deviation of 47.34830. Average Price per Product have an average value of 279.1000 with a corresponding standard deviation of 204.91254, while Average Volume of Raw Material Input have an average value of 35.1860 with a corresponding standard deviation of 27.15672.

The diagnostic test shows that there is multicollinearity problem in the series. The ordinary least squares (OLS) results above indicates that Average Volume of Products with a coefficient value of 0.018, t-statistic value of 0.082 and corresponding probability value of 0.93 8> 0.05, has a positive and insignificant impact on the Average Volume of Solid Waste. The result also shows that Average Number of Employees with a coefficient value of -0.107, t-statistic value of -0.575 and corresponding probability value of 0.590> 0.05 has a non-significant negative impact on Average Volume of Solid Waste; Average Price per Product with a coefficient value of -0.058, t-statistic value of -0.798 and corresponding probability value of 0.461 has a negative and insignificant effect on Average Volume of Solid Waste, while the Average Volume of Raw Material Input with a coefficient value of 0.442, t-statistic value of 1.00 land corresponding probability value of 0.363> 0.05 has a no significant positive influence on the Average Volume of Solid Waste.

The F-statistic value of 0.429 and corresponding probability value of 0.784>0.05 indicates that Average Volume of Products, Average Number of Employees, Average Price per Product and Average Volume of Raw Material Input have joint insignificant effect on Average Volume of Solid Waste.

The adjusted R^2 value of -0.340(0%) indicates that Average Volume of Products, Average Number of Employees, Average Price per Product and Average Volume of Raw Material Input could not account for at least 1% of the proportion of total variations on the Average Volume of Solid Waste. The Durbin-Watson statistic value of 2.072 from the rule of thumb indicates that there is no autocorrelation problem in the model.

Summary of Findings

1. There is positive correlation between Average Volume of Products and Average Volume of Solid Waste.
2. Average Number of Employees does not positively relate with Average Volume of Solid Waste.
3. There is no significant relationship between Average Price per Product and Average Volume of Solid Waste.
4. Average Volume of Raw Material Input strongly significantly relates with Average Volume of Solid Waste.

Discussion of Results

From the result quantities of industrial solid waste generated in Enugu Metropolis are not only by the deposits at the municipal dumps, but by the ones generated by the industries in their production processes. Industries lend to maximize profits by producing more of products to maximize sates thereby profits (Haga and Yano 1992). Thus as more raw materials are imputed, and more products are produced more industrial solid wastes are generated at this stage. On the other hand number of employees and price per product do not affect the significant quantities of solid wastes generated by these industries. In as much as households introduce some industries wastes in various municipal dumps in the Metropolis, these are combined with the ones generated by the industries in their production especially since most of these industries had no internal deposit arrangements.

A study by Agu, (1999) had shown that about 33%of the respondents in the various industries deposit in municipal open dumps and 27% in industrial waste tank. Another task for the industries would be to maintain an internal waste tank to minimize the qualities of waste generated to the environment as industrial solid waste are generally more toxic than the ones generated from the households.

Recommendations

Undoubtedly, industrial production deposit its contributions to general economic development and growth of nations, is beset with the problem of industrial waste (solid, liquid, gaseous) in those countries especially the developing ones.

To address this, the Environmental Impact Assessment (EIA) was introduced to mitigate and minimize the environmental and human impacts.

In addition to other recommendations by well meaning researchers, we recommend that Enugu Metropolis should consider seriously resource recovery and waste recycling efforts to re-use those wastes and produce other goods as well as preserving health and the environment.

Again, we encourage the use of new plant designs to reduce wastes while increasing profits and finally, there should be standard that applies to aspects of industrial waste management, in terms of collection, storage, transfer, recovery and disposal (UMP 1993), importantly also fund should be adequately provided to fund all aspects of industrial wastes management to engender sustainability.

Conclusion

This study has attempted to examine the industrial solid waste generation in Enugu Metropolis and its applying diverse methods. Despite the efforts made in this research, if proper implementation and monitoring of the recommendation are not fully followed everything might come to naught in terms of effective industrial solid waste management in the study area.

References

Agu J.A (1999). *Industrial Solid Waste Generation in Enugu Metropolis*: An Investigation of Contributing Factors A Masters Dissertation in the Dept of URP in Enugu Campus (Unpublished).

Alcott, B. (2015). *Jevons Paradox*" (PDF). *Ecological Economics.* 54: 9—21. Bibcode:2005ecec.book….C. doi:10.1016/j.ecolecon. 2005.03.020.hdl:1942/2257.

Bonnie, DeSimone. (2016). *Rewarding Recyclers, and Finding Gold in the Garbage*. The New York Times, February 21.

Clark, B. & Foster, J.B. (2019). *Ecological imperialism and the Global Metabolic Rift: Unequal Exchange and the Guano/Nitrates Trade* (PDF). *International Journal of Comparative Sociology.* 50(3—4): 311—334.

Clark, P.U., Weaver, A.J., Brook, E. & Cook, E.R. (2018). *Executive Summary*. In: Abrupt Climate Change. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Reston, VA: U.S. Geological Survey.

Ezezika, C, Singer, B.M. & Peter A. (2010). *Genetically Engineered Oil-Eating Microbes for Bioremediation: Prospects and Regulatory Challenges* Technology in Society. 32 (4).

Foster, J.B. & Clark, B. (2011). *The Ecological Rift*: Capitalisms War on the Earth. Monthly Review Press. p. 544.

General Environmental Conservation Public Company Limited GENCO Retrieved Nov. 22 2014.

Haga K. & Yano Y. (1992) *Environmental Management in Japan Challenges and Responses* Prepared by OECD Dept Paris.

Kahie, L.R. & Eda Gurel-Atay, eds. (2014). Waste Disposal in the Congested Cities of W. Germany. Journal of Environmental Studies. Vol. 201 No 1295

Kaplan, S. (2018). *Climate Change could render many of Earth's Ecosystems Unrecognizable.* The Washington Post. Archived from the Original on 30 August 2018. Retrieved 30 August 2018. Kinver, Mark (3 July 2017). *Mechanics of E-waste Recycling*". BBC.

Love, U. (2002). Waste Handling and Recycling in the Carribean. International Journal of Social Science Vol. 113 no 825.

Maczulak, B.M &Elizabeth, K.M. (2010). *Pollution: Treating Environmental Toxins* New York InfoBase Publishing Co p. 120.

Morris, J. (2015). *Comparative LCAs for Curbside Recycling Versus Either Landfilling or Incineration with Energy Recovery*. *The International Journal of Life Cycle Assessment,* 10(4), 273—284.

National Population Commission (2006). National Population Census Figures of Federal Republic of Nigeria, Abuja.

RecyclingToday (2015). *Recycling and Waste have $6.7 Billion Economic Impact in Ohio* Archived from the original on 18 May 2015.

UMP (1993) *Environmental Innovation and Management* Curitaba Brazil. The world Bank Publication, Washington ix

Zeng, L.F., Ning, N.J., Yoon, K.E. & Jinho, E. (2019). *Expansion of the World's Deserts Due to Vegetation-Albedo Feedback under Global Warming*. Geophysical Research Letters. 36(17).