



Assessment of the Waste Management System and Its Implication in Benin City Metropolis, Nigeria

Aniekan Essienubong Ikpe^{1,*}, Akanu-Ibiam Effiong Ndon², Promise Joseph Etim³

¹Department of Mechanical Engineering, University of Benin, Benin City, Nigeria.

²Department of Civil Engineering, Akwa Ibom State University, Ikot Akpaden, Mkpata Enin, Nigeria.

³Department of Agricultural Engineering, Akwa Ibom State University, Ikot Akpaden, Mkpata Enin, Akwa Ibom State, Nigeria.

PAPER INFO	ABSTRACT
<p>Chronicle: Received: 08 January 2020 Revised: 17 February 2020 Accepted: 14 March 2020</p> <p>Keywords: Waste Management. Environment. Health Risk. Dumpsites. Environmental Pollution.</p>	<p>The R3 (Reduce, Reuse, Recycle) system of waste management specified by Environmental Protection Agency's (EPA) waste management framework is the pathway to sustainable environment. This system which is practiced in advanced countries is given little or no preference in Nigeria where open waste dumping is mostly practiced. Questionnaire based survey was employed to determine the awareness of the effects of open waste dumping by individuals. A physical survey was carried out to assess the risks posed by open waste dumping on the physical environment and health of individuals. Findings from the questionnaire-based survey indicated that many individuals are aware of the risks posed by open waste dumping system but have little or no knowledge of the R3 waste management standard for proper waste management. The physical survey pointed out that open waste dumping leads to infrastructural dilapidation and environmental degradation from drainage blockage and flooding. The findings also revealed that open waste dumping is responsible for outbreak of diseases such as Cholera, Diarrhoea, Malaria, Tetanus, Lassa fever, Typhoid and Yellow fever, Hookworm, and other parasite infestation as well as the promotion of fecal contamination of the hands, food and water that may result in fecal-oral transmission diseases. Hence, this method of waste management is responsible for water pollution, land pollution and the emission of obnoxious odour and also aid climate change and global warming through the release of Green House Gases (GHGs). From the risk evaluation carried out, simple and effective processes and technologies must be employed to aid the R3 practice for domestic recycling of specific waste.</p>

1. Introduction

Waste is an inevitable by-product of human activities. It takes the form of solid, liquid and gas. Waste, over the past years, has been defined and considered as matter that has no monetary or economic value and discarded or thrown away if it fails to meet its primary function [1]. Recent advances in technology and a better understanding of materials have been applied in the reduce, reuse, and recycling process that adds both monetary and economic value to waste matter while simultaneously mitigating the adverse effects of unchecked waste in the environment [2, 3].

* Corresponding author
E-mail address: aniekan.ikpe@eng.uniben.edu
DOI: 10.22105/jarie.2020.215049.1121

Nigeria, an African country, over the past two decades, has seen a rise in economic and social activities as a result of the continuously increasing population; this has led to the increase in the quantity of waste generated. According to Ikpe et al. [4], the solid waste generation is one of the most significant environmental challenges bedeviling Nigerian cities in recent times. The amount and type of waste generated are directly proportional to the location and season [5]. Nigeria generates all types of waste and a large portion of the waste generated is indiscriminately disposed in the environment, even by waste collectors. Nigeria's poor waste management system has seen it exposes her citizens to public health risks and environmental dilapidation. The health risk posed by the indiscriminate waste disposal is seen by the "black death" epidemic of the 14th century that killed nearly half the population of Europe. Its cause was from the unhygienic environment which aided the spread of the bacteria called "Yersinia pestis" by infected rodents and flea that find refuge in such environments [6]. The implication of improper waste management can result in adverse risk conditions such as ground water contamination, air pollution, increase in insect vectors and diseases transmitted by them, poor environmental aesthetics, attraction of vermin and pests, breeding grounds for disease spreading vectors such as "mastomys natalensis" (responsible for Lassa fever), emission of Green House Gases (GHGs) such as methane (CH₄) and carbon dioxide (CO₂) [7]. For example, decomposition of organic waste matter in open dumpsite releases poisonous gases such as hydrogen sulphide, ammonia, and offensive odour into the atmosphere; toxic leachate is also formed from the decomposition of open dumpsite waste (organic and inorganic) that mixes with water, polluting groundwater and surface water [8]. The exposure of humans to waters contaminated by open waste dumping can lead to diseases like diarrhoea, cholera, skin diseases, malaria, tuberculosis, and cancer from the pathogens in the contaminant [9, 10]. Previous epidemiological studies have found that two main health outcomes -cancer and congenital malformations- are associated with waste exposure to dumpsites [11].

Often man is responsible for the environmental risk-factors in the environment through indiscriminate disposal of waste. In Nigeria, the environmental risk-factor is high as is manifested in the form of piles of indiscriminately disposed waste at uncovered and illegal dumpsites which may contain toxic, infectious and radioactive waste [12]. In Nigeria, open dumpsites are usually sited for convenience, such as the presence of a pre-existing hole (created from sand mining activities) and are located near residential housing and public markets and therefore poses significant threats to human health and the environment [13]. Living with solid waste littered around appears to be an acceptable way of life among the people in the metropolis in recent years as research studies found out that the perception of Nigerians towards sanitation and environmental hygiene contributed to waste management problem [2, 14]. Waste management is commonly seen and practiced as "pick up the waste and go dump it somewhere convenient for you". Unchecked and unmanaged waste that is indiscriminately disposed in the environment finds its way in affecting the surrounding air, surface and ground waters, soil properties, aquatic culture and housing conditions, leading to unsafe, and unsuitable habitat for human life.

The earth is primarily a life support system. It consists essentially of biochemical processes that imbue it with the capacity to sustain life. As an ecosystem, the earth however, has a threshold [15]. Waste generated must be managed to ensure the environmental conditions suitable for human life. Unchecked and unmanaged waste poses great threats to environment, health and economy. Aside the public health risk posed by the indiscriminate dumping of solid waste, also there is the economic risk of lost employment opportunities: Optimized labour and equipment to enhance productivity, improved standard of living, threats to structural integrity as a result of drainage blockage causing flooding from rain water and also loss of arable land for agricultural productivity. The recent view of waste as a resource implies monetary and economic value that can be added to waste matter when it is processed.

Waste could be an unofficial measure of prosperity; it can also be a major problem on man especially where it is not well managed.

With the continuous increase in the population of people, Nigeria is likely one of the most populous country on earth with a population of over 190 million people. This invariably implies that Nigeria is one of the largest producer of methane (CH_4) from the decomposition of organic wastes at open dumpsites. Food waste (garbage) by characterization is generated from commercial solid waste in Benin Metropolis [2]. Organic matter decomposes producing methane (CH_4) gas as one of the gaseous products as well as biofertilizer. Methane is a greenhouse gas that is 25 times more potent than Carbon Dioxide (CO_2) in causing global warming over time horizon of 100 years [16]. According to Ngumah et al. [17], Nigeria has the potential of yielding about 25.53 billion cubic meter of biogas (about 169, 541.66 MWh) and 88.19 million tons of biofertilizer per annum. Both have a combined estimated value of about \$ 29.29 billion.

This potential biogas yield will be able to completely replace the use of kerosene and coal for domestic cooking, and reduce the consumption of wood fuel by 66%. An effective organic waste program in Nigeria will also remarkably reduce the environmental and public health concerns, deforestation, and Greenhouse Gas (GHG) emissions. Methane finds application domestically for cooking of food and heating of homes. Industrially, methane (CH_4) is a common fabric, plastic, anti-freeze and fertilizer agent; the combustion help businesses dry, dehumidify, melt and sanitize products. Methane (CH_4) gas is a natural resource with tremendous economic benefits when is harnessed from the decomposition of organic matter. Organic fertilizer is also obtained from the decomposition of organic waste and impacts positively on economic growth by reducing the cost of purchasing fertilizer by farmers for better crop yield, thereby increasing agricultural produce as well as ensuring food security.

Several environmental problems arising from man's activity have to be solved in a cost-effective and an environmentally friendly approach [9]. Apart from the various diseases and toxic conditions inhere in and derivable from wastes products, the presence of waste degenerates the aesthetic value of the environment [15]. Although waste can be recycled or processed into viable products for economic use, it also has a negative effect and implication which is assessed in this paper using Benin City Metropolis as a case study.

2. Research Methodology

A step-by-step process was employed in knowing the nature of waste management carried out by individuals, industries and waste managers in selected communities where open dumpsites are located.

Firstly, a physical survey was carried out to check the waste disposal method on the immediate and surrounding environment. As shown in *Fig. 1*, open dumpsites and open waste dumping in unauthorized area were the primary methods of waste disposal.



Fig. 1. Waste disposal methods at different locations in Benin City, Nigeria.

The notations in *Fig. 1* indicates the following: (a) Waste disposed along Uselu Market (b) Waste disposed along Benin Lagos High Way (c) Waste disposed at University of Benin Campus (d) Waste disposed at a commercial area in Ugbowo, Benin City (e) Waste disposed at open dumpsite in Oluku, Benin City.

Secondly, a questionnaire (see *Table 1*) was designed and distributed to individuals, residents', businesses and road users to gather information of waste management practices carried out and their effect in and around the immediate environment of open dumpsite locations. Interviews with some of the persons living around and close to open dumpsites were carried out to understand their perception of personal hygiene and individual waste management practice. Open waste dumpsite scavengers were also interviewed to ascertain the awareness and safety requirements of open waste scavenging.

Thirdly, interviews with some of the staffs of waste management companies and the Edo state waste management board was carried out to obtain the views and actions taken towards waste management as an economic resource in Benin City. Statistical Package for the Social Science (SPSS) was employed in analyzing the data extracted from the retrieved questionnaires.

Table 1. Questionnaire based survey on waste management practices in Benin City.

S/N	Questions	Options				
1	How often does waste management team visit your locality for waste collection and disposal?	Once a week	Once a month	Once in 6 months	Never	
2	How do you dispose your household waste?	Bury it in the ground	Burn it	In the bush	At open dumpsite	
3	What (category) of waste is dominant in your daily household waste?	Food waste	Plastic waste	Paper waste	Textile	
4	What effort has been made by the waste management to control the offensive odour from dumpsites in your locality?	Recycling	Provide waste disposal plastic bags.	None	Biological Treatment	
5	Is there any specific use of the waste generated individually or collectively in your locality?	Revenue generation	Composting	Biogas	None	
6	Do you have any knowledge on the effects of Municipal Solid Waste (MSW) on public health and environment?	Yes		No		
7	What significant effect has the presence of Municipal Solid Waste (MSW) caused in your locality?	Flood	Air pollution	Disease	None	
8	How can you rate the waste management situation in your locality?	Good	Better	Bad	Worst	
9	How many waste collection points do you have in your locality?	1 to 2	3 to 4	5 to 6	None	
10	How often does environmental sanitation take place in your locality?	Never	Once per weeks	Once in 2 weeks	Once in 3 weeks	

3. Results and Analysis

Table 2. Results obtained from questionnaire on waste management practices in Benin City.

Question	Variable	Percentage
Question 1	Once a week (%)	10%
	Once a month (%)	17%
	Once in 6 months (%)	16%
	Never (%)	57%
Question 2	Buried in the ground (%)	14%
	Burn it (%)	20%
	In the bush (%)	37%
	At open dumpsite (%)	29%
Question 3	Food waste (%)	51%
	Plastic waste (%)	42%
	Paper waste (%)	7%
	Textile (%)	0%
Question 4	Recycling (%)	0%
	Provide liners underneath waste dumpsites (%)	0%
	None (%)	100%
	Biological treatment (%)	0%
Question 5	(Revenue generation) (%)	0%
	(Composting) (%)	0%
	(Biogas) (%)	0%
	None (%)	100%
Question 6	Yes (%)	34%
	No (%)	66%
	Flood (%)	50%
Question 7	Air pollution (%)	25%
	Disease (%)	25%
	None	0%
Question 8	Good (%)	0%
	Better (%)	0%
	Bad (%)	45%
	Worst (%)	55%
Question 9	1 to 2 (%)	41%
	3 to 4 (%)	0%
	5 to 6 (%)	0%
	None (%)	59%
Question 10	None (%)	53%
	Once per weeks (%)	12%
	Once in 2 weeks (%)	16%
	Once in 3 weeks (%)	19%

Questionnaire based survey was employed to determine the awareness of the effects of open waste dumping by individuals. The questions asked are shown in *Table 1* and the results from the respondents

are shown in *Table 2*. The questionnaires were distributed to residents and business owners at a radius distance of 1km from open dumpsites.

The first question was aimed at determining the effectiveness of waste collectors from residents' point of view. Statistical survey reveals that 57% of respondents indicated that their locality has never been visited by waste collectors, 17% agreed that their locality is visited once a month, 16% of the people accepted that waste collectors visits their locality once in 6 months, and 10% of the people indicated that waste collection occurs once a week in their respective locality. As shown in *Fig. 2*, the reactions and response form the respondents' reveals dissatisfaction from the services provided by waste collectors.

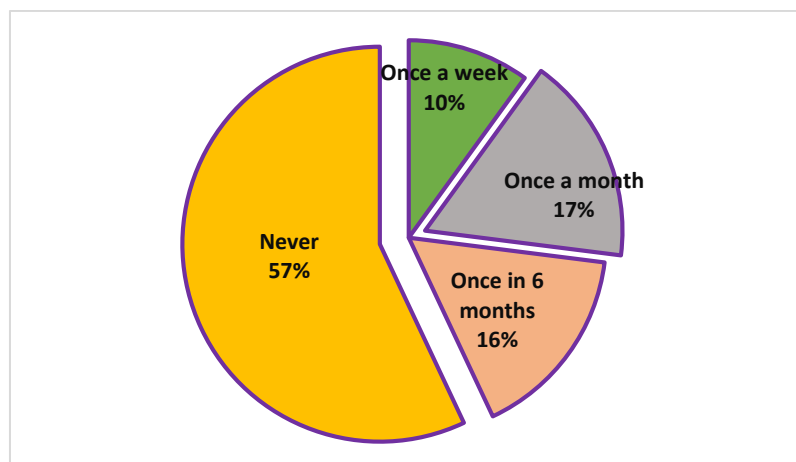


Fig. 2. Results of question 1 obtained from the questionnaire.

The second question was to determine the method by which people in Benin City dispose their household waste. Statistical survey reports that 37% of the people throw their household waste into the bush, 29% of the people prefer disposal at open dumpsite, 20% prefer burning their household waste while 14% of the people bury their waste in the ground. Considering the responses and interview of the respondents, none of these waste disposal methods is in accordance with the R3 system of waste management implying that the respondents don't practice waste management. The percentile is presented in *Fig. 3*.

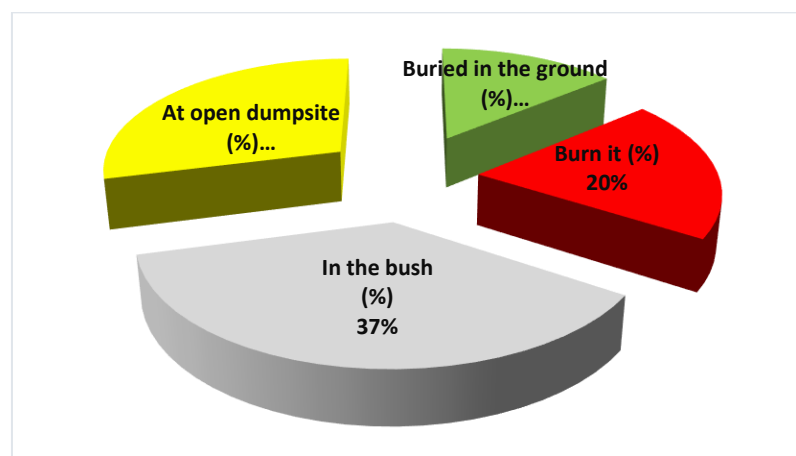


Fig. 3. Results of question 2 obtained from the questionnaire.

The third question is aimed at knowing the dominant waste generated in residential homes. Statistical survey revealed that food waste accounts for 51% of the total waste generated in residential homes. Other wastes generated include plastics and paper waste which account for 42% and 7% of the total waste generated, respectively. The responses and interview revealed that all waste generated were mostly domestic with no indication of any industrial waste being part of the waste generated. The percentile is presented in *Fig. 4*. The problem associated with food waste is becoming a major societal concern. This is because food consumption and generation of food waste occurs on daily basis, which contributes to environmental pollution [18] and means of sustenance for rodents, flies and animals that can transmit diseases to humans.

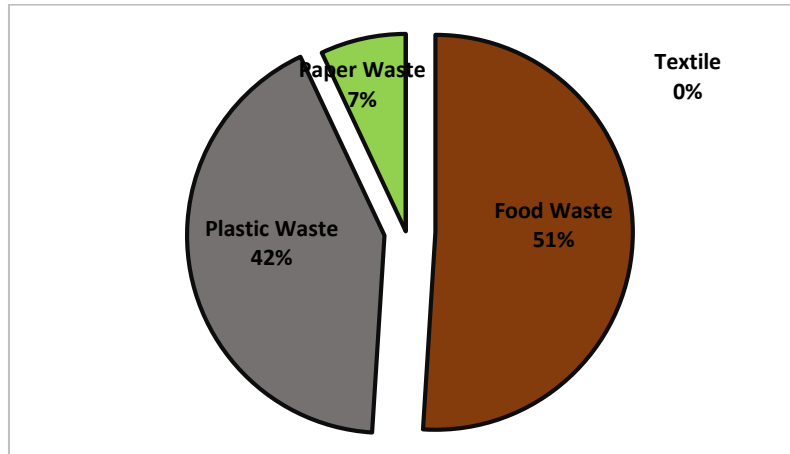


Fig. 4. Results of question 3 obtained from the questionnaire.

The fourth question was to identify any knowledge form the respondents' point of view of the efforts made by the waste management board in Benin City towards controlling the offensive from dumpsites in different localities in Benin City. Survey carried out revealed that no effort is made (in terms of treating or recycling the waste disposed at dumpsite) to control the stench generated from waste dumpsites. This may not be true, as majority of the respondents provided their feedback based on the present situation of waste management in their locality and may not really have an insight on what is currently being done to control this problem. The percentile is presented in *Fig. 5*.

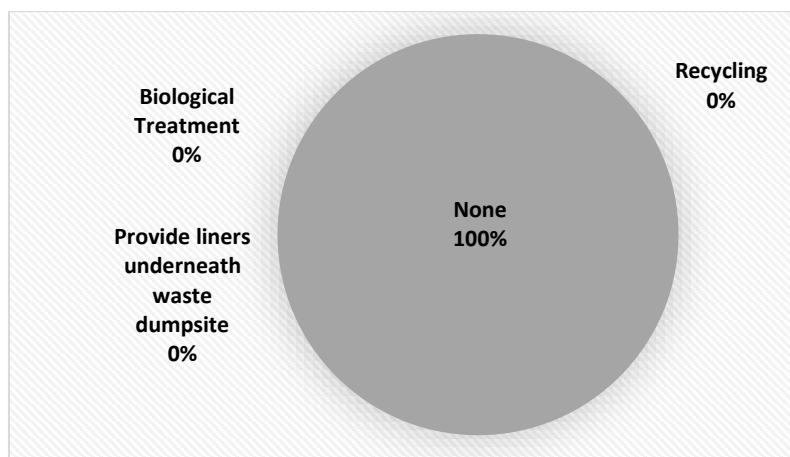


Fig. 5. Results of question 4 obtained from the questionnaire.

The fifth question is aimed at knowing the waste treatment method employed individually or collectively by residential homes. Reports from questionnaire-based survey revealed that little or no knowledge of the monetary value of the waste generated is known to the respondents as all the options in this category recorded a 0% implementation individually and/or collectively. The treatment options provided under this category included revenue generation, composting and biogas generation which is practiced in countries where waste is seen as a resource rather than just unusable material. The percentile for each of the options is presented in *Fig. 6*.

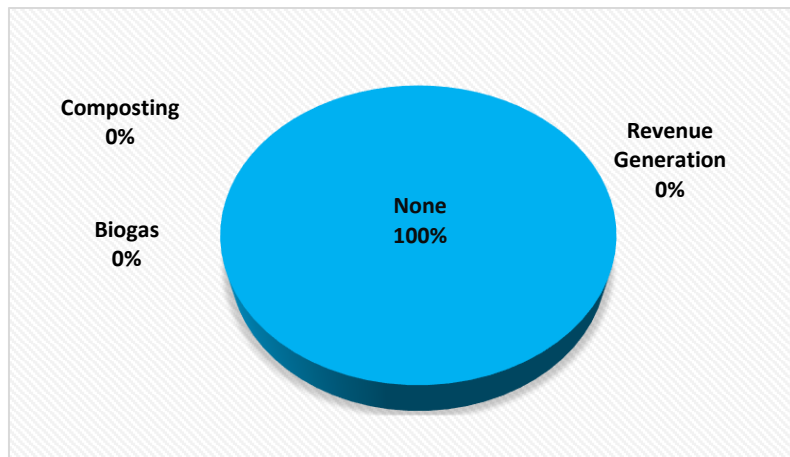


Fig. 6. Results of question 5 obtained from the questionnaire.

The sixth question was aimed at finding the respondents level of knowledge of waste management and the health benefits from proper waste management. Survey carried out revealed that 34% of the people are aware of the effects of Municipal Solid Waste (MSW) on public health and environment while 66% of the people are not aware of the health and environmental effects of waste. This implies that unawareness of the problems posed by the mismanagement of MSW is one of the factors affecting people’s perspective on solid waste management.

However, those who know the impact on public health by the indiscriminate waste disposal have also resulted in participating in open dumping as waste collectors are seldom available to collect the waste generated. Percentile from the respondents is presented in *Fig. 7*.

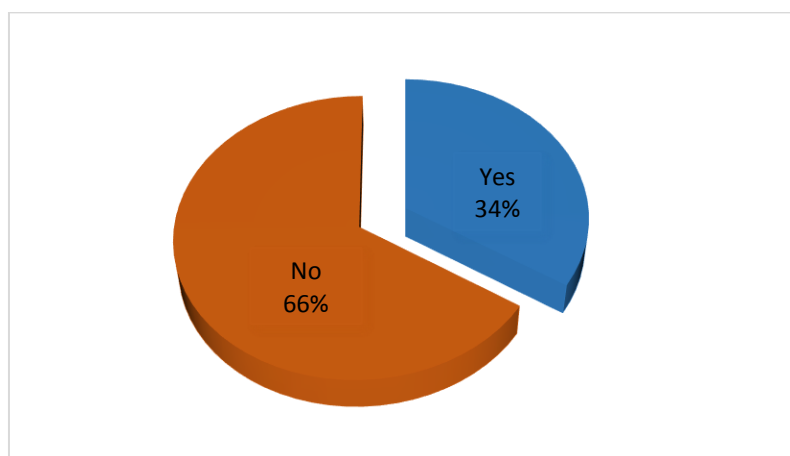


Fig. 7. Results of question 6 obtained from the questionnaire.

The seventh question was to determine the impact on the residents' economic and social activities by the presence of unchecked and unmanaged open dumpsite. Statistical survey reveals that about 50% of the respondents indicated that flood is the major effect of improper management of MSW. This is due to the blockage of drainage systems and water channels by waste materials during the rainy season which results in flooding. The remaining 50% from the respondents indicated that the offensive odour as well possible infectious diseases that may be contracted also impact negatively on economic and social activities. These are possible effects of MSW, as microorganisms, flies, insects and animals that are attracted to waste dumpsites which can cause environmental pollution in the process of organic waste decomposition in such dumpsites. Percentile from the respondents is presented in *Fig. 8*.

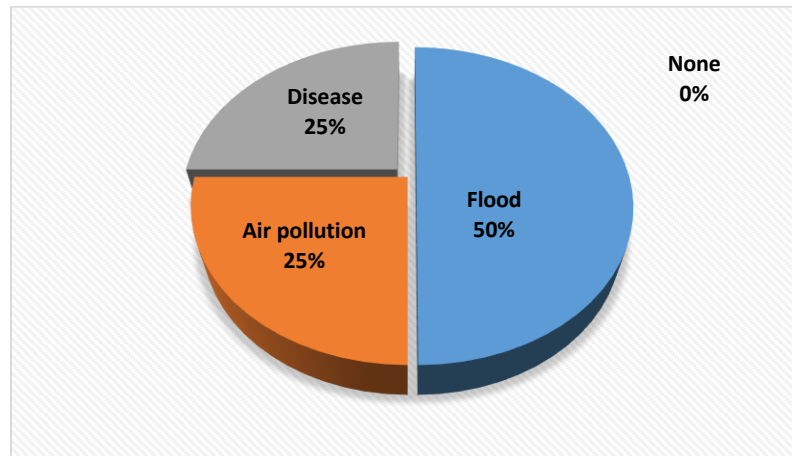


Fig. 8. Results of question 7 obtained from the questionnaire.

The eighth question was aimed at determining the efficiency of waste managers from the perspective of domestic residents. Statistical survey indicates that 45% of the respondents rated the waste management situation in their locality as bad while 55% of the respondents rated the waste management situation in their locality as worst. Other options provided in this category were “Good” and “Better” but no rating was given to any of the two options by the respondents. Considering that “Bad” and “Worst” were rated highly by respondents, it therefore implies that occupants in most localities in Benin City are not satisfied with the situation of waste management in their locality. Percentile from the respondents is presented in *Fig. 9*.

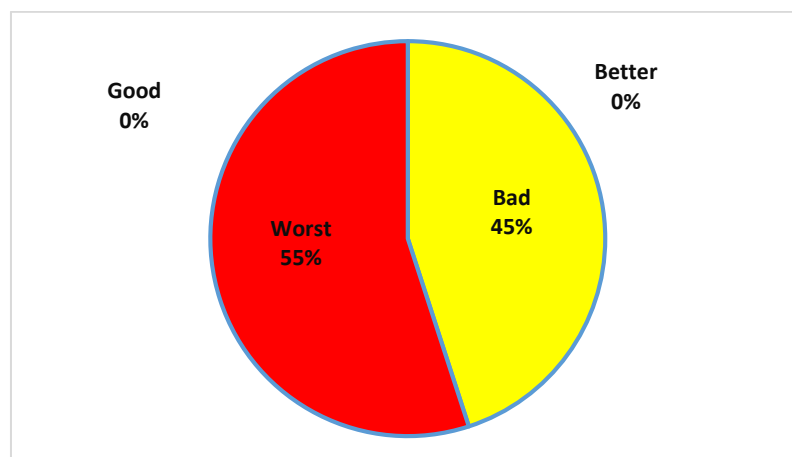


Fig. 9. Results of question 8 obtained from the questionnaire.

The ninth question was to determine whether or not there is any waste collection point in different localities in Benin City. Survey conducted revealed that 59% of the respondents do not have any waste collection point in their locality and therefore use any alternative waste disposal method while 41% agreed to have 1 to 2 waste collection points in their locality. Random survey on available waste collection points also revealed that some of these points designated for waste collection eventually turn dumping grounds due to the lack of availability of waste collectors to receive the waste items from people. As a result of that people see it as a norm to drop whatever waste items they have at the collection points and this eventually accumulates due to inconsistency on the part of waste collectors. Percentile from the 100 respondents is presented in *Fig. 10*.

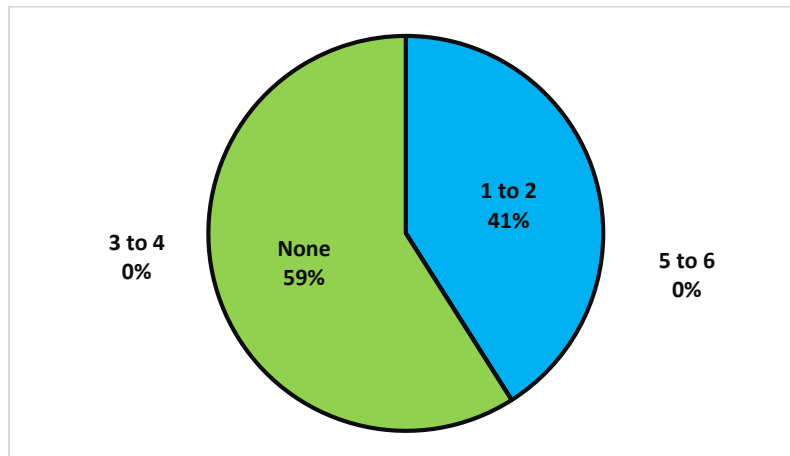


Fig. 10. Results of question 9 obtained from the questionnaire.

The tenth question was to determine the frequency at which environmental sanitation takes place in different localities in Benin City. Survey from respondents reveals 53% indicated that the environmental sanitation does not take place in their locality, 19% indicated that the environmental sanitation in their locality takes place once in 3 weeks, 16% of the respondents agreed to once in two weeks, and 12% agreed to once per week. With the aforementioned statistics from respondents from different localities on the frequency of environmental sanitation in Benin City, the environmental sanitation is not given a high preference and this can result in environmental pollution, degradation as potential risk to public health and environment. The percentile in this category is presented in *Fig. 11*.

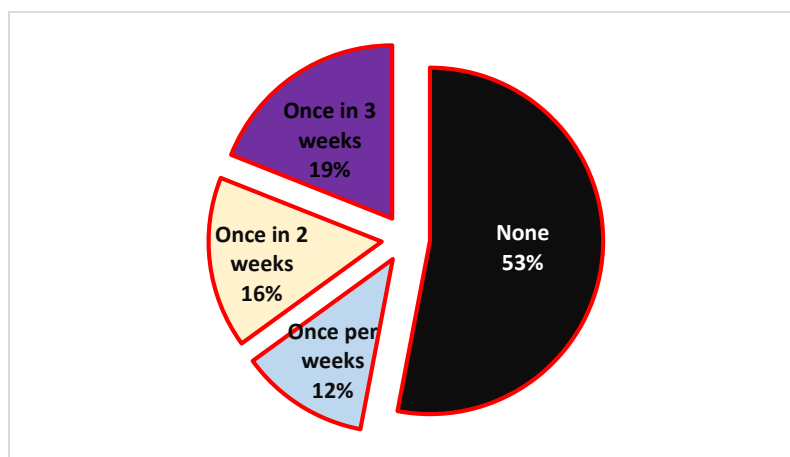


Fig. 11. Results of question 10 obtained from the questionnaire.

3.1. Discussion of Results

Open waste dumping has left a devastating effect on the aesthetic outlooks of the immediate and surrounding environment of open dumpsite locations. The offensive odour emanating from the waste has exposed residents' close by to health risks such as shortness of breath, headaches, eye irritation, and possibly death when large amount of such offensive odour is inhaled as indicated by McKendry et al. [19]. Also the dilapidated road networks is observed as a result of flooding caused by eroded waste from the dumpsites which end up obstructing the free flow of flooded waters in the drainage system. This has the effect of holding waste water on road surface which reduces the strength and consequently the design life of the road. Another effect caused by the eroded waste is the spread of water-borne diseases from contaminated waste water flowing through the dumpsite to residential and commercial areas. One common illness from the areas open dumpsite is located is Malaria which is a major cause of infant mortality in Nigeria [20]. The interviews and discussions with residents revealed that the open waste dumping is the available means of disposing waste generated which agrees with the response from the retrieved questionnaires. However, most of the respondents revealed that they had no knowledge of Malaria as one of the effects of open waste dumping. Leachate generated from some dumpsites was seen flowing to an unknown destination, indicating that industrial waste is also being indiscriminately disposed in the dumpsites without proper treatment.

The questionnaire revealed that waste is generally referred to and seen as the definition implies, as a material that has no economic value after it has been used for its primary purpose. No single waste generated is used for economic purposes, such as is indicated in the questionnaire as the waste generated is improperly disposed in unauthorized environment. Also, the fact revealed from the questionnaire was that the waste managers and those who generate most of the waste do not interact to exchange ideas about improving the waste management situation as most residents revealed a poor quality of service from the waste managers. The results indicated that the waste collectors are not effective with more than 50% of residents having limited options in disposing the waste generated. This gives room for open dumping of waste at unlawful and undesignated areas.

Interview and discussions with residents living close to open dumpsites revealed that personal hygiene is difficult as a result of the interaction of a waste filled environment which have the conditions that encourages and fosters the growth and spread of disease, contaminated rodents, flies and insects, etc. Also, the lack of any planned and routine general environmental sanitation practices makes it difficult to lead a personal hygiene. From the response, there is little of no practice of the R3 (Reduce, Reuse, and Recycle) waste management system in both residential and commercial areas. Scavenging was however seen at the heart of the open dumpsite. It was observed in all open dumpsites visited that there is no safety measure such as protective wears or practice is taken by these scavengers as most of them were seen to be fully exposed to bacteria contamination. This also revealed that the open dumpsites are "uncontrolled". Such uncontrolled open dumpsites also create room for human aside rodents and insects to be a vector for spreading disease. Discussion with some of the scavengers revealed that most of them had no knowledge of contaminating any disease or getting sick from scavenging at open dumpsites.

Interviews and discussions with some of the staffs of some waste management companies revealed that the primary aim of these companies was to collect and transport waste from the point of collection to the point of disposal i.e. authorized dumpsite. When asked what type of waste recycling or treatment is carried out before disposal, the staffs of some of the companies also revealed that the companies are not making any immediate plans to recycle, treat or add value to the waste collected, stating finance and bureaucracy as a hindering factors. Some were not aware of technologies used for recycling or treating

waste. From the discussion with some staff of Edo state waste management board, no concrete plans or policies have been made to convert waste to an economic resource.

The economic risk of waste mismanagement is enormous, and this has led leading to loss of revenue from tourism and dilapidated road networks as well as public health risks. It was gathered that the residents have experienced loss of economic activities as well as the depreciation of residential property due to the presence of open waste dumpsite. The risk involved in a particular practice takes into consideration several indicators such as judgement from experts in that field, the number of complains on the risk associated with such practice, and the number of people affected by the practice etc. Salimi et al. [21] suggested that the judgement from experts can be used as a tool to quantify the risk level, but the risk level in this study was determined using judgment from the masses in Benin City metropolis who are victims of the waste management practices in this region.

4. Conclusion

The R3 system of waste management is one of the most effective waste management system in the world but little or no preference is given to this approach in most developing countries such as Nigeria. In this study, respondents in Benin City metropolis revealed that the waste management characterized by open dumping, open dumpsites, indiscriminate disposal of waste at road sides, bush and any available spaces are the commonest method of waste disposal in Benin City, Nigeria, where this investigation was carried out. Response from the survey revealed that the R3 system of waste management is not practiced at domestic level, giving room for the negative impacts of waste mismanagement to take effect. The negative effect of open dumping, open dumpsites and the indiscriminate waste disposal as a waste management method cannot be over emphasized. Flooding, health risks, environmental dilapidation, and ground and surface water contamination are some of the few negative impacts aside the loss of revenue of such waste management practice. The perception of individuals and waste managers to proper and adequate waste management stems from the fact that the knowledge and technologies as well as the finance for proper and adequate waste management are unavailable, hence the pilot scale recycling plants for specific waste should be encouraged by policy makers. Bureaucracy is also a major factor to proper waste management, as policies meant for converting waste to wealth have not been encouraged. Waste management education such as the “R3 waste management” method should also be practiced to enable individuals and companies manage waste at the source. Proper and adequate waste management is necessary for public health safety and for maintaining the environmental conditions necessary for the sustenance of human life. Based on response from the survey carried out in this study, the following recommendations are suggested as follows:

- An engineered landfill system should be adopted for channeling of organic waste (such as food waste) therein to minimize the odour emitted during decomposition to minimum level.
- Organic waste should be processed into biogas for energy purpose and organic manure for improvement of soil supplement for plant growth.
- Mandatory segregation/sorting approach should be adopted to enable waste managers determine appropriate methods of waste treatment.
- Recycling centers should be established for proper handling and processing of other forms of waste separated from organic waste.
- Environmental sanitation should be enforced as weekly or monthly routine in order to keep Nigerian environment clean and safe from airborne diseases.

References

- [1] Aniekan, I., & Ikechukwu, O. (2016). Review of municipal solid waste management technologies and its practices in China and Germany. *International journal of technology enhancements and emerging engineering research*, 4(5), 1-7.
- [2] Igbinomwanhia, D. I. (2012). Characterization of commercial solid waste in Benin metropolis, Nigeria. *Journal of emerging trends in engineering and applied sciences*, 3(5), 834-838.
- [3] Ikpe, A. E., Owunna, I. B., & Agho, N. (2019). Physiochemical analysis of municipal solid waste leachate from open dumpsites in Benin City metropolis. *Journal of applied sciences & environmental management*, 23(1).
- [4] Ikpe, A., Imonitie, D. I., & Ndon, A. I. E. (2019). Investigation of the energy (biogas) derivation from anaerobic digestion of food waste products. *Akademik platform mühendislik ve Fen bilimleri dergisi*, 7(2), 332-340.
- [5] Nwaokobia, K., Ogboru, R. O., & Okolie, P. L. (2013). Solid waste management: efficient approach towards sustainable development in Nigeria. *Greener journal of environmental management and public safety*, 7(2), 035-042.
- [6] Gani, O. I., & Okojie, O. H. (2013). Environmental audit of a refuse dump site in the Niger Delta region of Nigeria. *Journal of public health and epidemiology*, 5(2), 59-65.
- [7] Ikpe, A. E., Ebunilo, P. O., & Okovido, J. (2018). Geotechnical evaluation of bentonite clay for municipal solid waste landfill lining membrane. *Applied journal of environmental engineering science*, 4(3), 337-351.
- [8] Ikpe, A. E., Ndon, A. E., & Adoh, A. U. (2019). Modelling and simulation of high density polyethylene liner installation in engineered landfill for optimum performance. *Journal of applied sciences and environmental management*, 23(3), 449-456.
- [9] Onwurah, I. N. E., Ogugua, V. N., & Otitoju, O. F. (2006). Integrated environmental biotechnology-oriented framework for solid waste management and control in Nigeria. *International journal of environment and waste management*, 1(1), 94-104.
- [10] Samuel M. M., Davou D. D., Juliet D. D. and Ruth A. N. (2016). Environmental hazards of continued solid waste generation and poor disposal in municipal areas of Nigeria. *Journal of geography, environment and earth science international*, 6(3), 1-10.
- [11] Mavropoulos, A., & Newman, D. (2015). Wasted Health—The Tragic Case of Dumpsites. *International Solid Waste Association, Vienna*.
- [12] Essienubong, I. A., Okechukwu, E. P., Ejuvwedia, S. G., Essienubong, I. A., Okechukwu, E. P., & Ejuvwedia, S. G. (2018). Effects of waste dumpsites on geotechnical properties of the underlying soils in wet season. *Environmental engineering research*, 24(2), 289-297.
- [13] Aderemi, A. O., & Falade, T. C. (2012). Environmental and health concerns associated with the open dumping of municipal solid waste: A Lagos, Nigeria experience. *American journal of environmental engineering*, 2(6), 160-165.
- [14] Banjo, A. D., Adebambo, A. A. R., & Dairo, O. S. (2009). Inhabitants' perception on domestic waste disposal in Ijebu Ode, Southwest Nigeria. *African journal of basic and applied sciences*, 1(3-4), 62-66.
- [15] Abdullahi, M. S., & Ugbede, A. R. (2013). Environmental safety and sustainability: A panacea for healthy national development in Nigeria. *Academic journal of interdisciplinary studies*, 2(13), 77-77.
- [16] Mohan, S., & Jagadeesa, K. (2013). Production of biogas by using food waste. *International journal of engineering research and application*, 3(4), 390-394.
- [17] Ngumah, C., Ogbulie, J., Orji, J., & Amadi, E. (2013). Potential of organic waste for biogas and biofertilizer production in Nigeria. *Environmental research, engineering and management*, 63(1), 60-66.
- [18] Ali, A. Y., & Ayele, A. (2019). Contribution of quality tools for reducing food waste in university canteen. *Journal of applied research on industrial engineering*, 6(2), 125-130.
- [19] McKendry, P., Looney, J. H., & McKenzie, A. (2002). *Managing odour risk at landfill sites: main report*. MSE Ltd & Viridis.
- [20] Maigemu, A. Y., & Hassan, K. R. H. (2015). Malaria as a cause of morbidity and mortality: A socio-economic overview. *Research on humanities and social sciences*, 5(8). <https://www.iiste.org/>
- [21] Salimi, A., Tavakoli Moghadam, R., & Bashiri, M. (2015). Designing reverse logistics network with a social approach to recycle great household waste under uncertainty conditions. *Journal of applied research on industrial engineering*, 2(3), 168-179.