

Quantitative analysis of the impact of using plastic bottle brick for wall construction on solid waste management in Port Harcourt

Abstract

Port Harcourt formerly known as the Garden city of Nigeria was graced with the presence of green vegetations, landscape, and neat culture of the residence, now fondly called Garbage city. As a result of indiscriminate dumping of waste on the streets and other urban infrastructure, leading to environmental issues like flooding, pollution, etc, and climatic issues like global warming. With plastic bottles identified as a major constituent of these wastes with its characteristic of being non biodegradable and durability, resulting to blockage of drains and canals and rapid filling of open waste dumps in the city. This paper tend to ascertain the impact of utilising these plastic bottle wastes as building material and its effect on achieving a sustainable solid waste management in port Harcourt, this was done by estimating the volume of plastic wastes that can be eliminated from waste dumps and used as a sustainable building material. Samples of plastic bottles were collected from waste bins around the city, measurements were taken and calculations done to estimate the quantity of plastic bottles of different sizes that can construct 1 square meter of a wall. Subsequently, a typical 2 bedroom bungalow design was used as a case study to determine an average quantity of plastic bottle to be used to construct the building. At the end, it was concluded that 1sqm of a wall require approximately 245 plastic bottles while the 2 bedroom bungalow with 307.6sqm wall area would require an average of 75,534 plastics bottles (about 3 metric tons) to be constructed. This result indicates that if the plastic bottle house innovation is massively adopted in the housing sector, it's going to lead to a positive impact and a sustainable solid waste management practice in the city. And help contribute to efforts towards returning Port Harcourt to its Garden city status.

Keywords: solid waste, sustainable development, housing, plastic bottle, waste dump, biodegradable

Volume 4 Issue 5 - 2020

Chima Ichendu, Dennis Ejike Amadi

Department of Architectural Technology, Captain Elechi Amadi Polytechnic, Nigeria

Correspondence: Chima Ichendu, Department of Architectural Technology, Captain Elechi Amadi Polytechnic, Rumuola, P.M.B 5936. Port Harcourt Nigeria, Tel +2348032939972, Email Chiabright@yahoo.com

Received: July 10, 2020 | **Published:** November 09, 2020

Introduction

Port Harcourt metropolis that was popularly known as the garden city has been faced with sharp growth in population and economic activities as well as waste management challenge which has affected her garden city status. Researchers have shown that Port Harcourt is identified as one of the cities with highest rate of urbanization, population growth and solid waste generation in Nigeria. The World Health Organization (WHO) defines waste as “something which the owner no longer wants at a given time and space and which has no current or perceived market value”. While the Environment Protection Act of 1990 described waste items as items that are supposed to be remnants of original items after the useful parts must have been used. This could be industrial waste, domestic waste, institutional waste, medical waste and agricultural waste, etc.¹

Solid waste management on the other hand, is defined as the application of techniques to ensure an orderly execution of various functions of collection, transportation, processing, treatment and disposal of solid materials.² It is also described as discipline associated with the control of; the generation, storage, transfer and transport, procession and disposal of solid waste in accordance with the best practice and principles of public health, economic, engineering, conservation, aesthetics, and other environmental considerations, and is also responsive to public attribute.³

Konya⁴ also defined Waste management as the collection, transportation, processing, monitoring and reuse of waste which is

also seen as a way to recover resources from wastes. It can involve managing of solid, liquid, or gases.

However, Waste recycling involves a process of characterization, sorting, grading, reduction and reuse of wastes. The management strategies of Municipal solid wastes vary per country but not limited to; landfill system, incineration and recycling. The underdeveloped nations use landfill system, while developed nations mostly use the recycling method. Although in Nigeria waste recycling has been encouraged by all stakeholders, but unfortunately it is yet to attain full recognition due to slow implementation and insufficient funding. As such, the commonest method of disposal in Nigeria still remains open dump and landfill system and *insitu* incineration which are very prone to environmental pollution.⁵ Effective refuse or solid waste management has been a major problem in the city of Port Harcourt. This is due to several factors, including, poorly managed and uncoordinated approach to waste management practices, unhealthy cultural attitudes and habits, urbanization patterns, rapid population growth, non-mechanized waste disposal methods and poor financing of the sector.⁶

Rapidly increasing urban population, poverty, increasing waste generation trend, uncoordinated industrial activities, changing consumption pattern etc are some of the identified challenges associated with waste disposal and management systems. The municipal city of Port Harcourt generates more waste than can be managed as a result of these problems and this situation tends to be increasing with population, income levels and its economic development.

According to⁷ Port Harcourt generates approximately 2 million kg of solid waste daily and only a fraction of this amount is collected. The rest end up in drain channels, water bodies, canals and illegal dump sites etc.⁸ These Solid Wastes are gathered in bins or collection points and finally conveyed to none environmental friendly open waste dumpsites posing serious environmental hazards causing water, air and soil pollution, flooding, global warming as well as unpleasant sight.

Another study also estimated that 900-1350 metric tons of waste (refuse) is generated daily in Port Harcourt metropolis. And plastics and paper making up 35% of the total solid waste generated which is recyclable, decomposable garbage occupy 41%, scrap metals occupy 15%, construction waste account for 4% sludge 3% while expired chemicals and drugs occupy 2% of the solid waste per mass in port Harcourt.⁹

Among the 35% made up of plastics and paper according to,⁹ are Plastic pet bottles produced from petroleum. These types of petroleum based plastic are non biodegradable. It remains insoluble for as long as 300 years in nature and considered as a sustainable waste and environmental pollutant. Thus reusing or recycling of plastics can be effective in mitigation of its environmental impacts.^{10,11} In the past, the glass was common in packing some foods such as milk and drinks etc. They could be returned to the factory for using again for the same purpose. But now by changing the human's disposal culture, glass bottles have been replaced by plastic bottles, as they have increasingly become one of the substances of destruction of the waste dumpsites because they decompose in a long time. Two alternative solutions against the plastic bottle disposal are recycling and reusing process.¹²

However, Recycling of any waste most times requires additional energy to treat the materials for production of other usable materials. And the process generates waste water and air pollution. Thus, Reusing remains the best solution to waste management because it does not add to air pollution and no additional energy is needed. Reusing of waste non biodegradable plastic bottle waste as innovative sustainable building material not only in the area of reduced financial and energy aspects of managing waste but also minimal environmental impacts.

The first bottles house was built using 10,000 glass Beer bottles by Wiliam F. peck in 1902 in Tonopah, Nevada, USA.¹¹ Twumasi¹³ After that the newer innovative concept has been using plastic bottle instead of glass bottles in constructing the houses. This innovative idea took to account for some reasons such as providing a cost-efficient construction method for pauperized third-world countries, reusing the plastic bottles due to their not indecomposable characteristic. ECO TEC Environmental Solutions realizing that about 80% of plastic produced every year in Honduras could not be recycled, and was able to achieve this through clean-up exercises. Andreas Froese, the founder of Eco-Tec Environmental Solution, in searching for an inventive solution to junk, established the innovation of building plastic bottle houses, they constructed over 50 buildings including residential houses, schools, churches and parks in Bolivia, Columbia, Honduras, Mexico, India, Nigeria and Uganda¹³ They also established the innovation of the first plastic bottles house in Africa constructed in the village of Yelwa in Kaduna state of Nigeria .he used the plastic bottles instead of bricks, bound the bottles together with string and at the end applied the plaster.^{12,14} Researches have shown that the concept of plastic bottle bricks is cost effective, energy efficient and commercially feasible. Using PET bottles is also Bio-climatic and thus described it as Green construction.¹⁵ Several buildings have been built from plastic bottles such as: ecological house constructed using

8,000 bottles in Honduras; an Eco-Tec home in Bolivia constructed using the PET and wine bottle; a house of waste plastic bottles built in Serbia by Tomislav Radovanic; Taiwan's plastic bottle building; ecological bottle house built using 1200 PET plastic bottles for the walls near the Iquazu Falls, Misiones, Argentina; etc.

The Development Association for Renewable Energies, an NGO based in Nigeria also built an incredible two-bedroom bungalow entirely out of plastic bottles which is bullet and fireproof, earthquake resistant, and maintains a comfortable interior temperature of 64 degrees Fahrenheit year round. Using the same method, an NGO; "My environment my wealth" a subsidiary of "Bliss Octanoprise International", in a bid to contribute to waste management in Nigeria, in 2019, designed and commenced the construction of the maiden plastic bottle shelter in the Niger Delta located at the model primary school, okoro nodo Rumuokoro, Obio Akpor local Government area of Rivers state, Nigeria. (Figure 1)



Figure 1 Plastic bottles filled with sand and in stretcher form ready to be used for construction.

With a serious housing shortage but no shortage of plastic bottles littering the streets of Port Harcourt metropolis, adopting the green technology of plastic bottle house in the housing sector of the city can guarantee a sustainable solution to the two major problems of housing deficit and solid waste management in Port Harcourt. The purpose of this research is to study the impact of reusing plastic bottle waste in building wall construction on the volume of non biodegradable solid waste content in waste management in Port Harcourt metropolis. The study is limited to non-biodegradable plastic wastes that are abandoned at public bins, dump sites, residential areas, public places, some floating in drains and river banks and others. The study tends to ascertain the quantity of plastic bottles needed to construct a square meter of a wall and the quantity needed to construct a simple housing unit, which will give an idea of the volume of plastic waste a single residential building can put out of the solid waste dump sites in Port Harcourt.

The study area

Port Harcourt metropolis is the present capital of Rivers state in the Niger Delta region of Nigeria and the largest city in Rivers state, located at the extreme southern part of Nigeria between longitude 7000" and 7015" East of the Greenwich meridian and Latitude 40

30°N and 4047" North of the equator. On the eastern and western parts of Port Harcourt are the meandering creeks of the Delta and on the southern part is the first dockyard creek of bonny river and mangrove swamps. It is bounded on the north by the upland ikwerri local government area. The city was established in 1912 and in 1920, in accordance with the provision of Nigeria Township ordinance cap 126. It became the capital city of River State in 1976. The town was named Port Harcourt after the founder of its Port, the then British Secretary of State of the colonial Masters, Lewis Harcourt. The present Port Harcourt has grown in size, status, population and importance economically and politically. With booming oil and gas industrial activities which have lead to population growth as a result of migrants from wide and near. The population of Port Harcourt has been estimated to have increased from 1,382,592 inhabitants as at 2006 to 1,865,000 in habitants in 2016, which accounts for about 900-1350 metric tons of solid waste generated daily in Port Harcourt metropolis. The city has two seasons; the rainy season characterised with large rainfall between April and November and the dry seasons, between December and March. The temperature level of Port Harcourt varies within 24°C and 30°C throughout the year.

Sustainable development

Plastic bottle house and sustainable development. Sustainable development is a concept viewed differently by environmentalists, social reformers and the big business in the form that suits their ideology.^{16,17} However, the concept has created intense argument amongst parties, creating room for people to have different notions, especially relating to the Brundtland definition, which seems to be the traditional definition of Sustainable development 'meeting the present needs without infringing on the need of the future generation'. Sustainable development is the intersection between the economy, environment and the society. Where the economy is often times given more priority in the policies,¹⁸ the interconnectedness of these three entities is vital as the economy depends on the environment and the society while the society and human existence depend on the environment.

The purpose of Sustainable development entails: To ensure a healthy environment by supporting and inculcate the reusing and recycling culture and reducing the waste management culture of waste dumpsites which leads to environmental degradation. Conservation of non-renewable resources like minerals, fuels etc to ensure adequate supply of such resources for the present and future generations. To promote developments that tends to reduce the gap between the rich and the poor and ensure social equality.

To ensure the natural environment is protected and respected by integrating environmental considerations into developmental planning. The use of plastic bottles in construction considered as sustainable material suites sustainable development objectives and it adopts the reusing option of solid waste management principle which as against recycling, does not require waste of energy (energy saving), does not generate more waste in cause of reusing waste, and does not generate waste water pollutants (healthy environment), and produces minimal construction waste unlike bricks and concrete blocks. It also create job opportunities thus contributes to poverty reduction in the society which in turn will reduce the gap between the rich and the poor the society. Thus adopting the plastic bottle brick technology in housing development as a strategy to fight against the poor state of waste management practices in Port Harcourt can best be described as sustainable development.

Plastic bottle brick: (eco brick)

According to the US green building design, a Green building is defined as an environmentally sustainable building constructed and operated with the aim of mitigation of environmental impacts such as natural resource depletion as well as CO₂ emission. It addresses sustainable site planning, energy efficiency, conservation of material and resources by using renewable resources as well as recycling and reusing and indoor air quality. A sustainable principle is an ideal standard that deals primarily with the basic aspects of life, such as social, economic and environment. It involves the community in all aspects and stages of its dealing and noteworthy to establish these principles.¹⁹ The use of some renewable resources and unusable things like plastic bottle waste in construction of buildings can be helpful in conserving the renewable resources, the environment and the society to achieve a green building development by using the non biodegradable plastic bottles usually considered as junk as building materials in constructing some building components like wall, roof, landscaping etc; By so doing, Energy consumed in the factories for production of cement, blocks, brick etc will be saved.^{20,21}

CO₂ emission as a result of the use of cement in construction will be reduced. Reusing plastic bottles as wall materials also helps to save the energy used for recycling plastic waste either by heating or shredding to produce new products, Also the CO₂ emission in course burning fossil fuel for the recycling process is also reduced. Waste dumpsites will be saved and have increased lifespan by reducing the volume of indecomposable waste dumped in them and thus saving the environment.

Benefits of reusing plastic bottle as a building material

Plastic bottle has been identified as one of the regular everyday waste that can be used in construction of building walls, landscaping etc. The use of the plastic bottle waste as a building material in Port Harcourt metropolis will attract the following benefits:

- Reduction in the volume of non biodegradable waste that ends up and remains in waste dumpsites without decomposing for years.
- Flood control; by using up the plastics bottles that blocks the drain channels in Port Harcourt and other cities as shown in Figures 2&3.
- Reduce the amount of CO₂ emission by reducing the amount of cement used in building construction.
- Energy saving; the use of plastic bottle in construction can help in saving the energy consumed in the factory for baking the bricks, recycling plastics and cement production.
- Solid waste reduction: minimize the volume of municipal non biodegradable solid waste in the environment since the plastics bottle will then be collected from consumption points to construction sites.
- Availability: plastics have become an unavoidable packaging material globally. Many people use at least 1 plastic bottle package product daily. Thus as long as beverage companies continue using plastic bottles and humans continue to consume it, Plastic bottle will remain readily available for construction.
- Resistance to water, chemical and impact.

- Low production cost: plastic bottle waste is far less expensive than conventional bricks and concrete blocks.
- Durability and longevity: plastic have been known to remain under composed as long as 300years thus, buildings constructed with plastic bottle bricks tends to have improved durability and lifespan.



Figure 2 Plastic bottle wastes floating on a canal at Rukpokwu, Port Harcourt.



Figure 3 Plastic bottle wastes blocking a drain in Port Harcourt.

Materials and methods

The materials used in this study comprise; Samples of plastic pet bottles, (Figures 5&6), a 150mm Whitworth digital stainless Vernier Caliper (Figure 4), a simple 2 bedroom bungalow design covering a total floor area of 116.74 square meter. (Figures 7&8) And a Microsoft excel software for analysis of data and results. The Plastic bottles were collected from waste bins around the shopping areas in three different locations within three higher institutions in Port Harcourt metropolis. Namely; Rivers state university, university of Port Harcourt and Port Harcourt polytechnic. The bottles collected were analysed and 12 different types were identified as mostly used plastic bottles in Port Harcourt metropolis, which includes; beta malt (33cl), coke (35cl), sprite (35cl), smooov chapman (35cl), fanta (35cl), arctic blue table water (50cl), enna table water(50cl), lasien table water(50cl), mirinda (50cl), pepsi (50cl), coke (60cl), and eva table water(75cl). (Figure 5) The scope for the choice of bottles to be used for the study was limited to only the most commonly consumed soft drinks and table water plastic bottles. And the 12 types selected for this study were chosen by physical observation the types and number of each of the plastic bottles types found in the waste bins and these 12 were in abundance in all the three higher institutions visited. The choice was also affirmed by interviewing some shop owners in the shopping centres to determine the products with highest demand rate.



Figure 4 A 150mm whit worth digital stainless Vernier calliper.



Figure 5 12 selected waste plastic bottles and the digital vernier calliper.



Figure 6 Measurements being done using the digital vernier calliper.



Figure 8 A 3D view of the typical 2 bedroom bungalow designed with plastic bottle wall.

The typical 2 bedroom bungalow design (Figures 7&8) is to be used to estimate the total square area of wall needed to construct it by measuring the total perimeter and height of the solid walls, multiply them to get the square area. Then the area of the openings (doors, windows, beams etc) was deducted to arrive at the estimated square area of the building wall. And 307.60 Sqm, Was gotten as the area of the solid wall in the building. Thereafter, the digital vernier calliper was used to measure the diameter and height of all the collected plastic bottles. The diameter is used to calculate the unit surface area to be covered by each plastic bottle (Table 1) when used to construct the walls using a stretcher bonding system. While the height of the plastic bottles shows the expected thickness of the wall. Further calculations were done using the relevant statistical tools in Microsoft excel software to determine other required data as shown in (Figure 9) and (Tables 1&2).

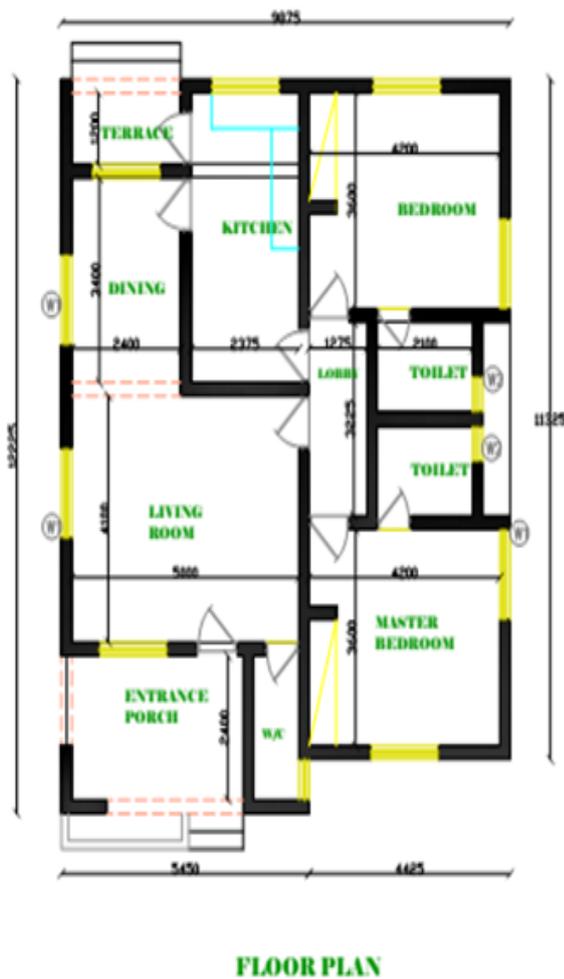


Figure 7 A typical 2 bedroom bungalow covering 116.74 square meter floor area.

Tables and bar charts were adopted for the data analysis and presentation.

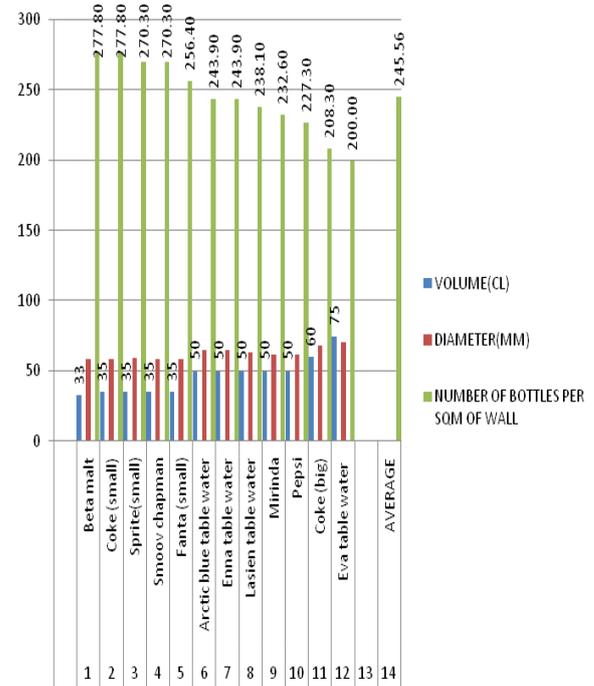


Figure 9 Pictorial representation of the findings illustrating the relationship between the various plastic bottle types and the number required to construct 1 square meter of a wall.

Table 1 Types of sample bottles collected and statistical data

S/no	A Type of bottle	B Volume of bottle (cl)	C Height of bottle (mm)	D Diameter of bottle (mm)	E Diameter of bottle when laid (mm)	F Radius of bottle when laid (mm)	G Area of bottle when laid (sqm)
1	Beta malt	33	195	58.2	68.2	0.034	0.0036
2	Coke (small)	35	195	58.4	68.4	0.034	0.0034
3	Sprite(small)	35	195	58.4	68.4	0.0342	0.0037
4	Smooov chapman	35	200	58.4	68.4	0.0342	0.0037
5	Fanta (small)	35	195	59.5	69.5	0.035	0.0039
6	Arctic blue table water	50	205	61.8	71.8	0.036	0.0041
7	Enna table water	50	235	61.5	71.5	0.036	0.0041
8	Lasien table water	50	205	63.2	73.2	0.0366	0.0042
9	Mirinda	50	220	64.75	74.75	0.037	0.0043
10	Pepsi	50	220	65	75	0.0375	0.0044
11	Coke (big)	60	235	68.23	78.23	0.0391	0.0048
12	Eva table water	75	250	70.8	80.8	0.04	0.005

Table 2 Data showing the average number of plastic bottles to construct 1 square meter of wall and the 307.65 square meter wall of a bungalow

S/no	A Types of plastic bottles	B Volume of bottle (cl)	G Area of bottle when laid (sqm)	H Number of bottles per sqm of wall	I Number of bottles to construc the 307.6sqm wall.
1	Beta malt	33	0.0036	277.8	85,451
2	Coke (small)	35	0.0034	277.8	85,451
3	Sprite(small)	35	0.0037	270.3	83,144
4	Smooov chapman	35	0.0037	270.3	83,144
5	Fanta (small)	35	0.0039	256.4	78,869
6	Arctic blue table water	50	0.0041	243.9	75,024
7	Enna table water	50	0.0041	243.9	75,024
8	Lasien table water	50	0.0042	238.1	73,240
9	Mirinda	50	0.0043	232.6	71,548
10	Pepsi	50	0.0044	227.3	69,918
11	Coke (big)	60	0.0048	208.3	64,073
12	Eva table water	75	0.005	200	61,520
Average			0.0041	245.6	75,534

Results and discussion

After the necessary measurements and calculations for concluding a result was done, the data obtained is tabulated in (Tables 1&2) and a bar chart (Figure 9).

Figure 9 shows a pictorial representation of the findings illustrating the relationship between the various plastic bottle types and the number required to construct 1 square meter wall. It was deduced that an average of 245 plastic bottles is required to construct 1 sqm of wall the result also indicates the number of plastic needed for 1sqm wall for each of the sample bottles as also shown in (Table 2). as follows;

33cl beta malt=277, 35cl coke =277, 35cl sprite=270, 35cl smooov chapman=270, 35cl fanta=256, 50cl arctic blue table water=243, 50cl enna table water=243, 50cl lasien table water=238, 50cl mirinda=232, 50clpepsi=227, 60cl coke=208 and 75cl eva table water=200 plastic bottles. The chart also shows that the higher the volume and diameter of the plastic bottles, the lower the number of bottles needed for a square meter wall.

Table 1 shows the statistical data illustrating the breakdown of the calculations and assumptions to determine the actual square area to be covered by each plastic bottle when used to lay the wall.

While Table 2 is a statistical data showing the result of the expected findings. It shows the estimated number of the sample plastic bottles needed to construct 1 square meter of a wall for each plastic bottle size (Table 2, column H). The table also shows the number of bottles needed to construct the wall for the typical 2 bedroom bungalow design with 307.6SQM and covering 116.74 SQM floor areas. For each bottle size (Table 2, column I) The results shows that an average of 245 plastic bottles will be needed to construct 1 square meter wall while 75,534 plastic bottles will be needed to construct the 2 bedroom bungalow. Which suggests that each unit of the 2 bedroom bungalow design is capable of removing as much as 75,534 plastic bottles (equivalent of 3 metric tons of plastic) from the waste management system in Port Harcourt if this construction method is adopted?

Conclusion

From the findings, experiments and observations, we can infer that there would be a considerable positive impact on the waste management problems in port Harcourt metropolis should the sustainable green plastic bottle house technology be adopted for building construction. Only 1 square meter of a wall will engulf an average of 245 plastic bottles and a typical 2 bedroom bungalow design with 307.6 sqm wall coverage used as a case study will use up an average of 75,534 plastic bottles that would have been littering over the streets, water drains and canals causing flooding and others that manage to get to the waste dumps remain under composed for hundreds of years occupying useful spaces and causing the waste dump to full frequently. We therefore, recommend that the eco-brick construction idea be adopted by the Government and real estate developers for housing projects in Port Harcourt, as a strategy to solve the problems of both sustainable waste management and housing deficit in Port Harcourt metropolis. The problems associated with poor handling of plastic waste will be drastically reduced.

Because the technology involves reusing of plastic bottles, the city stands to gain from minimal or no energy wastage in managing plastic waste as against recycling. Reduced emission of CO₂ from recycling plants and production of cement and low soil, water and air pollution will also be reduced. Thus we can conclude that using plastic bottle bricks as a building material for wall construction can positively improve the waste management challenges of Port Harcourt metropolis and ensure a more environmentally friendly, cost effective, energy efficient and sustainable waste management system.

Acknowledgments

None.

Conflicts of interest

There is no conflict of interest exists.

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