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PLASTIC WASTES DISPOSAL IN URBAN AREAS: A REVIEW OF THE IMPLICATIONS ON WATER RESOURCES

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Abstract

The Environmental Protection Agency (EPA) was mandated to monitor the plastic wastes disposal in water bodies and to provide a periodical reassessment of the scientific basis of plastic wastes for public health and environment. Despite that Nigeria has been widely reported as a good destination where hazardous wastes is predominant due to uncontrolled and indiscriminate disposal, the knowledge, attitude and practices of the extent of the hazards are yet to be ascertained to arrive at an effective preventive measures by the government. This study thus aims to investigate the level of knowledge, attitude and practices of plastic wastes disposal in the Federal Capital Territory, Abuja. This involves administration of 100 questionnaires to Physicians, Nurses and Scavengers across the National Hospital, Garki Hospital and Wuse Hospital, respectively. The result shows that 66.67% were knowledgeable of the adverse effects of plastic wastes, 53.67% show a positive attitude to proper disposal, however, 54.33% accept that the existing plastic wastes disposal practices fall short of the best management practices. The study concludes that the existing plastic wastes disposal techniques are inadequate. There is therefore the need to provide a more eco-friendly alternative to plastic use for human health and environment.

Keywords: Knowledge, Attitude, Practices, Plastic Wastes, Environmental Protection Agency

Introduction

The Environmental Protection Agency has declared plastic wastes prohibited because of its potential hazards to or on water bodies (Sheavly, 2007). The monitoring techniques involve the assessment of the trends in amount, distribution

and composition of marine debris and micro plastic, both in the water bodies and in the body protoplasm of wildlife species. Though plastics are useful in industries, homes and agriculture because of its non-biodegradable properties, plastic wastes have altered the urban climate system which includes land surface, hydrosphere, atmosphere, biosphere as well as their interaction with negative implications on water availability and food security (Satish, 2014). When plastics are burned either in the production processes, or primary collection centers, greenhouse gases, notably carbon dioxide, Sulphur dioxide, particulates were produced which have been found to contribute to the increase in global temperature and decrease in rainfall amount, particularly in the tropics (Ezeah, 2014). The production of these greenhouse gases has been pronounced in the marine environment as dead aquatic lives that ingested plastic wastes have contributed more carbon dioxide to the atmosphere and depletion of ozone layers (Sheavly, 2007). Furthermore, additives such as phthalates, bisphenols, brominated flame retardants and perfluorinated chemicals could adversely affect humans while other organisms are also discharged into the marine environment which could affect the quality of water. These have necessitated the need to periodically monitor the plastic wastes disposal methods with a view to reducing the effects of climate variability.

Disposal of plastic wastes has been a major concern across many countries of the world because of its non-biodegradable nature (Satish, 2014). The traditional disposal methods include open burning, landfilling, composting, incineration, and pyrolysis. If incineration of non-recyclable plastics is performed with high-efficiency energy recovery: less CO₂ is released than by disposing plastic waste in landfilling (UNEP, 2017). Open burning, composting and land filling have been attributed to contribute to pollution of land, air and water sources respectively (UNEP, 2017). Moreover, if incineration of non-recyclable plastics is performed with high-efficiency, energy recovery, less CO₂ is released than by disposing plastic waste in landfills; however, it is not cost effective (UNEP, 2017). Pyrolysis on the other hand has been seen to be a more effective method, because of its eco-friendliness and minimal impacts on human health and the environment (UNEP, 2017). Plastic bag ban is a more effective option gaining momentum in the world in which currently about 75 countries in the world have taken actions to reduce the consumption of plastic bags (UNEP, 2017).

Plastic can be degraded in the environment through: photo degradation; thermo-oxidative degradation; hydrolytic degradation and; biodegradation by microorganisms (Amin, 2011). The natural degradation of plastic begins with photo-degradation by ultra violet light from the sun which provides the activation energy required to initiate the incorporation of oxygen atoms into the polymer, leading to thermo-oxidative degradation. As a result, the plastic becomes brittle and becomes fractured into smaller pieces until the polymer chains reach sufficiently low molecular weight to be metabolized by microorganisms (Amin, 2011). Over the

years, it has been observed that the recycling process is the best technique to treat waste polymer products, and the old-style methods, such as combustion of waste polymers or burying underground could lead to negative effects such as formation of dust, fumes and toxic gases or the pollution of underground water and other resources (Zare, 2017). However, due to pollution of the environment associated with these conventional methods, waste plastics liquid fuel has succeeded as good alternative method for obtaining new energy resource and eliminate greater problem of plastic waste management (Antony, 2011). The fuel produced in this process satisfies quality of liquid fuel with low sulfur content and low carbon residue.

Regulatory instruments, which are also known as command and control, specify the standards or limits to be followed for each part of solid waste management chain including waste minimization (source reduction), segregation at source, storage and collection, transportation, treatment, disposal, and recycling and recovery (Cascadia Consulting Group, 2004). This includes Environmental Protection Law / Act, Recycling or Resource Recovery Law / Act, Public Services Act – Solid Waste Management, Hazardous Waste Management Law / Act and Clean Air Act - Incineration, Landfill gases respectively. Even though some of the laws might not appear to be related to plastics, depending on the further use of the information, they might become relevant (United Nations Environment Programme, 2009). For example, the Clean Air Act might not seem to be significant for plastic; however, as the case of Philippines, the Clean Air Act bans incineration of municipal, biomedical and hazardous waste (United Nations Environment Programme, 2009). In order to assess the conversion of waste plastics into a resource, the clean water Act becomes relevant which prohibits incineration (Nwufor, 2010). In the same way, the Hazardous Waste Law can specify components used as additives in some plastics which can be considered as hazardous, as it is the case of bromine flame retardants and therefore some countries might call for a separate treatment of such plastics (Nwufor, 2010). Secondly, information on all the relevant regulations need to be collected which could also include various standards covering production and consumption for source reduction, segregation at source, storage and collection of various types of solid wastes, transportation, treatment, final disposal, and recycling and recovery (Nwufor, 2010). The standards may also be available for technology and infrastructure.

In addition, the globally binding agreements directly dealing with plastic wastes on water bodies include: London Convention, Multilateral Convention dealing with trade in hazardous wastes and Persistent Organic Pollutants, such as the Basel Convention and, the Stockhorn Convention. Others include the eighteen (18) regional sea programs, partnerships and the global programs of actions (GPA) (Nwufor, 2010).

In Nigeria, the relevant regulations include Federal Solid and Hazardous Wastes Management Regulation, 1991, Harmful Wastes (Special Criminal Provisions),

Act, 2004, Oil in Navigable Water Act, Cap 6, LFN, 2004, Nuclear Safety and Radiation Protection Act, Cap N142, LFN 2004 and Criminal Code. Sections 245 – 248 deals with offences ranges from water fouling to the use of noxious substances. However, there are no existing municipal laws on plastic wastes.

Plastics could be classified as thermoplastics and thermoset plastics. The thermoplastics make up 80% of the plastics and thermoset plastics make up of remaining 20 % of plastics produced today Zhu, (2011). Thermo plastics can re-melt or remold and therefore could be recycled easily but thermoset plastics cannot re-melt or reshape and therefore it is difficult to recycle it. The use of different types of some thermo plastics is given in table1 below. Plastics are relatively cheap, easily available, easy to manufacture and their versatility to replace conventional materials (Zhu, 2011).

Table 1: Uses of different types of plastics.

Type of Plastics	Uses
Polyester	Textile fiber
PET	Carbonated drink bottles, plastics film
PE	Supermarket bags, plastics bottle
HDPE	Milk jugs, detergent bottles, thicker Plastics film, pipes
LDPE	Floor tiles, shower curtains, cling film
PVC	Agriculture (fountain) pipe, guttering Pipe, window frame, sheets for building material
PS	foam use for insulation of roofs and walls, disposal cups, plates, food Container, CD and cassette box
PP	Bottle caps, drinking straws, Bumper, house ware, fiber carpeting and rope

Source: UNEP, 2009

The durability and chemical structure greatly influences the biodegradability of some organic compounds, therefore an increased number of functional groups (groups of atoms) attached to the benzene ring in an organic molecule usually hinders microbial attack (Tiwari, 2009). Instead of biodegradation, plastics waste goes through photo-degradation and turns into plastic dusts which can enter in the food chain and can cause complex health issues to earth habitants (Tiwari, 2009). Plastics are produced from petroleum derivatives and are composed primarily of hydrocarbons but also contain additives such as antioxidants, colorants, and other stabilizers (Tiwari, 2009).

Table 2: Type of Plastics as raw materials and its contents

Type of plastics	Contents
PE (HDPE, LDPE), PP, PS	hydro carbons
PET, PVA, PF	hydro carbons with oxygen
PVC, PVCD	hydrocarbons with chlorine
Nylon (polyamide), PU	hydrocarbons with nitrogen
Polyphenylene sulfide	hydrocarbons with sulfur

Source: UNEP, 2009

Effect of Raw Materials in Plastic Production

The types of plastics and their products are presented in table 3

Table 3: Product of Plastics in Production

Type of plastics	Product
PET	terephthalic acid and benzoic acid
PVA	water and alcohol
PVC, PVDC	HCL gas and carbonous compound
PU, PE, NYLON	carbonous product
PE, PS, PP	liquid fuels

The WRATE model assumes that polyethylene (PE) and polyethylene terephthalate (PET) are recycled into clean pellets or flakes that can be substituted for virgin materials on a one-to-one basis in closed loop manufacturing. In reality, however, they could be recycled into lower grade products such as wood substitute, traffic cones or used as a partial aggregate substitute in concretes, as suggested by Siddique et al. (2008). The burning of plastic wastes releases dioxin and furans into the atmosphere which could consequently affect the breast feeding mother due its carcinogenic and toxic nature (Chaturved, 2000). Toxic dyes and chemicals could also be used as additives during the recycling, which may be dangerous to workers in the recycling processes (Chaturved, 2000). Plastic bags are among the major toxic pollutants of our times which is composed of toxic chemicals such as lead and cadmium pigments, commonly used in light-density polyethylene (LDPE), high-density polyethylene (HDPE) and polypropylene (PP) and also pollutes the air, water and soil (Satish, 2014). There are three possible environmental problems caused by plastic bags. First, plastic bags are mostly made from oil, natural gas or coal, and these are all limited natural resources that must be conserved. Second, the manufacture of plastic produces large quantities of harmful pollutants, which manufacturing companies need to deal with properly. The major chemicals that go

into the making of plastic bags are highly toxic and some of the constituents of plastic such as benzene and vinyl chloride, have been proven to cause cancer, while others like gases and liquid hydrocarbons spoil the earth and air (Satish, 2014). The noxious substances emitted during the production of plastic are synthetic chemicals like ethylene oxide, benzene and xylenes. Besides seriously impairing an already fragile ecosystem, these chemicals can cause an array of maladies ranging from birth defects, cancer, and nerve and immune disorders, to blood and kidney ailments. Third, old and unwanted plastic bags are not always easy to dispose of. Plastic bags defy any kind of attempt at disposal, be it through recycling, burning or land filling (Satish, 2014). When plastic bags are burned, they release a host of poisonous chemicals including dioxin into the air. Moreover, recycling of plastic is uneconomical, polluting and labor intensive (Satish, 2014). It is associated with skin and respiratory problems resulting from exposure to and inhalation of toxic fumes, especially hydrocarbons and residues released during the process. Also, recycling plastic bags merely puts them back into circulation in the market place and eventually the environment, thereby increasing the environmental risks (Satish, 2014). Garbage mixed with plastic bags interferes in waste processing facilities and causes problems in landfilling operations. Since plastic bags do not undergo bacterial decomposition, hence landfilling using plastic bags would mean preserving the poison forever which could negatively affect water quality (Satish, 2014).

Effects of Plastic Wastes on Water Resources

The marine pollution is increasing at a faster rate due to indiscriminate disposal by the consumers on soil rivers and coastal areas. The plastic wastes have virtually choked the drainage system in the urban centers of many African countries to such an extent that it takes only the slightest of rainfall to precipitate floods (Accra Sanitation Workshop, 1998). Burning of plastics give Nitrogen oxides, Carbon oxides, Sulphur oxides, particulate, dioxins, furans and fumes to increase air pollution which results in acid rain and increase global warming. Plastics in land fill area could also leach toxins into ground water (Tiwari, 2009). Plastic bags when dumped into rivers, streams and sea, contaminate the water, soil, marine life as well as the air we breathe (Satish, 2014). Plastic bags are known to clog drains and thus hit urban sewage systems. Plastic wastes could choke drains and provide excellent breeding grounds for mosquitoes. They could also release toxic metals such as lead and cadmium pigments leach into underground water (Satish, 2014). Approximately, 80% of plastic waste in the ocean comes from land-based sources, the items most commonly found on beaches are single-use plastics such as grocery bags, food packaging, bottles and utensils and 40% of plastic produced each year becomes single-use packaging (UNEP, 2017). Again, about 8 million metric tons of plastic waste enter the ocean every year, fishes off the west coast ingest over 12, 000 tons of plastic every year. It has been predicted that, by 2050, there will be more plastic than fish in the world's oceans (UNEP, 2017).

Control of Plastic Wastes

Primary recycling is a simplified and low-cost process of reuse of products in their original structure (Kolek, 2001). The secondary or mechanical recycling involves only the thermoplastic polymers because they can be re-melted and reprocessed into end products, though the mechanical recycling does not involve the alteration of the polymer during the process (Kolek, 2001). The disadvantages of this method refer to the heterogeneity of the solid waste and the deterioration of product's properties in each cycle which occurs due to the low molecular weight of the recycled resin. Chemical recycling is defined as the process in which polymers are chemically converted to monomers or partially depolymerized to oligomers through a chemical reaction (a change occurs to the chemical structure of the polymer). The resulted monomers can be used for new polymerizations to reproduce the original or a related polymeric product.

This method is able to transform the plastic material into smaller molecules, suitable for use as feedstock material starting with monomers, oligomers, or mixtures of other hydrocarbon compounds (Francis, 2016). The chemical reactions used for decomposition of polymers into monomers include hydrogenation, glycolysis, gasification, hydrolysis, Pyrolysis, methanolysis, Chemical depolymerization, thermal cracking, catalytic cracking and reforming, photodegradation, ultrasound degradation and degradation in microwave reactor. Hydrolysis is a recycling method that involves a reaction of PET with water in an acid, alkaline or neutral environment, leading to total depolymerization into its monomers. The disadvantages of the hydrolysis method are represented by the high temperatures (between 200 and 250°C), pressures (between 1.4 and 2 MPa) and by the long time needed to complete depolymerization respectively however, it is a costly method.

Neutral hydrolysis, using hot water or steam, high-pressure autoclaves at temperatures between 200 and 300 °C and pressures of 1–4 MPa can also be used, which is even more effective at temperatures higher than 245°C for a complete depolymerization at 275°C (Karayannidis, 2002). The neutral hydrolysis is a more common method because it is environment friendly, though all mechanical impurities present in PET are left in the TPA, thus the product can be considered of lower purity than the product of acid or alkaline hydrolysis (Yoshioka, 2001). In a study, it was observed that the basic ionic liquid, 1-butyl-3-methylimidazolium hydroxyl exhibits higher catalytic activity for PET glycolysis, compared with 1-butyl-3-methylimidazolium bicarbonate 1-butyl-3-methylimidazolium chloride and 1-butyl-3-methylimidazolium bromide (Yoshioka, 2001). In another study, it was found that the purification process of the products in the glycolysis catalyzed by ionic liquids was simpler than that catalyzed by traditional compounds (metal acetate) (Karayannidis, 2002). Also, the reactivity order of different glycols varies according to the conditions of temperature and catalysis. The global reactivity depends on the chemical reactivity of the glycol and on its physicochemical

properties such as the polarity of the reaction mixture and ability to solvate the solid polyesters (Karayannidis, 2002).

Chemical recycling of PET by methanolysis involves PET degradation by methanol at temperatures between 180 and 280°C and pressures from 2 to 4 MPa to produce dimethyl terephthalate (DMT) and ethylene glycol (EG) under the optimal depolymerization conditions refers to the temperature between 260 and 270°C, the pressure of 9.0–11.0 MPa and the weight ratio (methanol to PET) ranges from 6 to 8 (Karayannidis, 2002). Studies have also shown that the rate of methanolysis strongly depends on the solubility of PET (Karayannidis, 2002). Polyolefins cannot be degraded with simple chemicals to their monomers due to the random scission of the C-C bonds. Polyolefins are a major group of thermoplastics used throughout the world in applications such as toys, containers, bags, film, battery cases, and electrical components (Yoshioka, 2001). Chemical recycling involving the degradation of the polymeric materials by heating in the absence of oxygen could be used to produce oil and gaseous fractions with a great potential to be recycled back into the petrochemical industry as a feedstock for the production of new plastics (Yoshioka, 2001). The recycling of LDPE, HDPE and PP by both a dissolution/precipitation technique (mechanical recycling) and pyrolysis (chemical/feedstock recycling) could lead to high recovery of pure polymer. In the case of pyrolysis, a higher decomposition in PP, followed by LDPE and finally HDPE was observed as less crystalline or more branched polymers are less stable in thermal degradation (Yoshioka, 2001). The degradation of PS in various supercritical solvents (benzene, toluene, ethylbenzene) at 310–370 °C and 6.0 MPa, a pressure was studied to produce the highest yield of styrene from PS in toluene at 360°C for 20 min (Yoshioka, 2001).

Energy Recovery of Plastic Wastes

This method refers to the recovery of the plastic's energy content by incineration. The method is a good solution because it generates considerable energy from polymers, however, it is not ecologically acceptable because of the health risk from airborne toxic substances, for example, dioxins (in the case of heavy metals, chlorine-containing polymers, toxic carbon, and oxygen-based free radicals). Among the above recycling techniques, the only acceptable one, according to the principles of sustainable development, is chemical recycling, because this method leads to the formation of the monomers from which the polymer is made (Yoshioka, 2001).

Alternative Plastic Wastes Disposal

- I. **Reusable Bags:** This is an alternative to single-use paper or plastic bags, which can be reused many times for shopping. These come in canvas, woven plastic fiber, hemp, cotton and even leather.

- ii. **Biodegradable Plastics:** Bio-plastics or organic plastics are a form of plastic derived from renewable organic sources, such as vegetable oil, corn starch and pea starch. The basic characteristic of these plastics is that they are capable of being decomposed by bacteria or other living organisms (Satish, 2014).

Best Management Practices for Plastic Wastes Disposal

Education of the public about the dangers of plastic wastes can be effective. Trash receptacles can also be useful for proper disposal of cigarette butts and to prevent litter from spilling into waterways (Yoshioka, 2001). Programs and ordinances to promote recycling can also reduce the stem of plastic into the ocean. Another best management practices could be a law requiring a larger percentage of goods to be recycled. Efforts to provide incentives for recycling can increase the fraction recycled. Structural controls (e.g. physical filtering devices such as mesh screens, centrifugal separation, and trash racks) are an effective, but more expensive, way to control plastic debris. Municipal storm drain systems can be modified and systems that capture all trash less than 5 mm in size can be installed to lower the cost of monitoring water bodies (Yoshioka, 2001).

These structural devices usually cannot prevent plastic wastes from entering the environment. Also, regular street sweeping can prevent litter from accumulating before it is washed into nearby water ways. Another affordable mandate could be covering landfills when not in use and building sufficiently high landfill walls to avoid dispersal of pollutants from regular winds. Other possible state regulations include requiring more sustainable packaging, reforming loading requirements for nurdles that diminish the risks of incidental spills or mandate cleanup of spills, putting in more garbage bins, and instituting cleanups or educational campaigns.

The best management practices to control plastic wastes from entering water bodies necessarily put the onus on plastic manufacturers. There are, however, relatively cheap and easy solutions to curb the release of these dangerous pollutants. EPA has already endorsed several best management practices for plastic pellets and must provide this information to state water quality managers. These practices include education of manufacturers, containment systems, recycling, spill clean-up procedures, puncture-resistant packaging, and periodic inspections of pellet containers. These kinds of procedural protections against plastic pollution reduce the amount of plastic that is ever added to waters and may be the most efficient way of reducing our nation's plastic pollution problems. The EPA should highlight and recommend such preventative measures against plastic pollution wherever possible.

Case Study

The Study Area

The study was carried out in the Federal Capital Territory between latitude 8 degrees .25 minutes and longitude 6 degrees 45 minutes. The city has a current population estimate of 3,028,807 (UNFPA Report, 2010). Abuja is characterized by two main seasons, namely rainy and dry seasons. The rainy season lasts between April and October with mean annual rainfall of 162.75 mm while the dry season starts from November and ends in March (Balogun, 2001). The temperature ranges between 20.4°C – 34°C. The city produces 0.66 kg per capital per day of solid wastes. Although government has banned the use of plastic in the country, the existing regulations on its uses are still fragmented.

Method of Study

A set of 100 structured questionnaires were used to elicit information about the extent of knowledge, attitude and practices of plastic wastes disposal, particularly as related to the trends in amount, distribution and composition of plastic wastes in water bodies in the National Hospital, Garki Hospital as well as Wuse Hospital respectively. The questions were arranged in three sets: 40 questions were randomly administered in the National Hospital among the Physicians, Nurses and the Scavengers; 30 questions in each of Garki Hospital and Wuse Hospital respectively. Data was analyzed using simple descriptive statistics.

Result

The result shows that the average of 66.67% were knowledgeable of the adverse effects of plastic wastes, an average of 53.67% show a positive attitude to proper disposal, and an average of 54.33% accept that the existing plastic wastes disposal practices fall short of the best management practices. However, 73.33% were knowledgeable of the adverse effects of plastic wastes in the National Hospital, 66.33% was obtained in Garki Hospital while 70% was obtained in Wuse Hospital. Further, The National Hospital respondents show an average of 70%, that is, a positive attitude to proper disposal. The figure is the same in Garki Hospital, however, the result is 73.5% in Wuse Hospital. Moreover, regarding the best management practices, basically, 53% in the National Hospital graded it poor while 55% graded it poor in both the Garki and Wuse Hospitals respectively. However, 2% graded the practices excellent in the National Hospital and Wuse Hospital. No respondent graded the practices excellent.

Discussion

The high knowledge of the adverse effects of plastic wastes in the three Hospitals shows that the respondents are educated about plastic wastes. This also has a positive influence on the attitude to the plastic wastes disposal. The result is in line with Nwafor (2010), who attributed knowledge of the adverse effects of plastic wastes to education by people across socioeconomic classes, who are majorly

administrative staff of government. However, the poor result obtained for compliance with best management practices shows that the respondents are not satisfied with the present situation and will be eager to embrace adequate compliance with the best management practices, if the government could provide adequate resources for implementation. The reason for the 2% obtained for excellence is not clear, although many could argue that it is because some people are afraid to say the truth for fear of job losses. This is similar to the result by Balogun (2001), who attributed poverty to hazards due to plastic wastes.

Conclusion and Recommendations

The physical, chemical and biological composition of plastic wastes is complex and can vary greatly, depending on the nature of the plastic and treatment processes it undergoes. Although there is no scientific certainty about the hazards of all wastes, studies have confirmed fears about the dangers of plastic wastes by revealing their toxicity, carcinogenicity, mutagenicity, corrosivity and other characteristics harmful to human health and environment. It is therefore incumbent upon regulatory bodies to ensure that all the rules and standards are based on the best available science and recommendations are assiduously applied. This include: strict adoption of precautionary and pollution pays principles such that adequate knowledge of hazard is a precondition for plastics use and that the burden of proof is moved to the proposer/manufacturer and finding solutions to land based sources of marine pollution; phasing-out of hazardous additives and monomers used in the production of plastic in favor of more ecofriendly alternatives.

Abbreviations

PET- polyethylene terephthalate
 HDPE- high density polyethylene
 LDPE- low density polyethylene
 PS- polystyrene
 PVC- polyvinyl chloride
 PP- polypropylene
 PF- phenol formaldehyde
 PU- poly urethane
 PVA- poly vinyl alcohol
 PVDC- polyvinylidene chloride

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