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Review on effect of dumpsite leachate to the environmental and public health implication

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Abstract

Over the years, there has been an increase in the rate of environmental pollution due to improper disposal and management of dumpsite waste. Leachate being generated as a result of the moisture associated within dumpsite, amount to contain various microbial pathogens and hazardous substance like cyanides, heavy metals and other chemicals acquired from the dumpsite. This can serve as a risk factor to the environment and public health when there is leachate migration. The migration of leachate into the environment potentially results in the contamination of soil, food products, animals, ground water, surface water and the air environment' which in turn affect the health of human especially those who consumes from the contaminated products, those who inhabits around the dumpsite and other vulnerable like; young children, waste workers and immunocompromised persons. In Nigeria, though there are municipal waste dumpsites across the nation, these sites are below standard and are not properly managed. Being a great concern to the society, the need for proper design and reconstruction of a well-engineered landfill cannot be over emphasized, among others. This paper will therefore review the environmental and public health implication of dumpsite leachate so as to create more awareness on the need for proper waste management in Nigeria. It concludes by recommending some proper means of waste disposal and management which could be considered for a better health and environment in Nigeria.

Keywords: Environmental and public health; Waste disposal; Leachate; Dumpsite

1. Introduction

The human environment is comprised or surrounded with various wastes generated from daily activities; this includes the combination of residential, industrial and commercial activities of a given area. Waste is any material considered not useful to human. This waste are swept, gathered up and are eventually discarded into a dumpsite. Landfills are the most widely used solid waste disposal method across the world. In Nigeria, landfill disposal method is mostly open dumping. These wastes are dealt with in the simplest and least expensive way, by accumulating them in an uncontrolled dumping site without any consideration to their leaching fate [1].

Leachate is a discharge interface from leaching, it is formed from dissolvable constituent of waste pollute in landfill/dumpsites [2]. When rainwater or any liquid comes into contact or percolates through the concentrated dumpsite wastes, leachate is formed. The dumpsites contain large numbers of pathogenic and opportunistic bacteria, due to the presence of various domestic, industrial and clinic waste found in it [3]. The waste dumpsites are also reliable

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recipient of any electronic waste. Electronic wastes are major source of heavy metals and can be carcinogenic, they are capable of creating irreversible impact to the environment and human health if not properly managed [4].

The dumpsite leachate potentially results in contamination of the soil, groundwater and surface water due to the absence of containment systems at the dumpsites (unregulated). This has led to free leachate migration from the dumpsite into surrounding environment [5, 6].

According to Olalade *et al.,* [7], most dumpsite/landfill are built without engineered liners and leachate collection systems so they function without proper leachate collection and treatment facilities thereby promoting leachate migration with adverse effect on the environment and public health.

In Nigeria, most wastes are released into the surrounding with no considerable treatment. This still remains one of major issues to be dealt with during design, construction, and management of the waste site [8].

As the challenge of poor waste management continues, the production of dumpsite leachate and it migration stands as risk to the environment and public health. Being a challenge needed to be properly managed for the wellbeing of human and it environ, this seminar research will address the environmental and public health implication of dumpsite leachate.

1.1. Dumpsite

A dumpsite is a piece of land where waste materials are disposed off [9]. It accommodates household, industrial and commercial waste. Various harmful substances (organics; alkenes, aromatics, hydrocarbon, acids, esters, alcohols, hydroxyl benzenes, heavy metals and many more) may also be present. Landfill is the simplest, cheapest and most effective method of disposing waste in several part of the world [1, 9].

1.2. Types of landfill

Landfill can be classified into four main types, this includes; the sanitary landfills, municipal solid waste (MSW) landfills, construction/demolition waste landfills, and industrial waste landfills. In most developing countries, including Nigeria, municipal solid waste landfill is most functional. Many cities face serious environmental and health risks due to the weakly developed municipal solid waste management system [10].

1.3. Classification and decomposition phase of dumpsite waste

When refuse is buried in a dumpsite, it goes through a complex series of biological and chemical reactions as it decomposes. It is generally accepted that landfill undergo at least four different phases of decomposition which includes, an initial aerobic phase, an anaerobic acid phase, initial and stable methanogenic phase [11, 12].

The consecutive stages involved in landfill stabilization are as follows;

Phase I: Initial Adjustment - Within a short time after the waste is deposited in the dumpsite, it attracts the presence of microorganisms which builds up to a population sufficient enough to alter the waste.

Phase II: Transition – in this stage, there is transformation from the initial aerobic state to an anaerobic environment occurs. A trend toward reducing conditions, in which elements or molecules gain electrons, is established as electron acceptors shift from oxygen to nitrates and sulfates. By the end of this phase, measurable concentrations of chemical oxygen demand (COD) and volatile acids (VOAs) appear in the leachate.

Phase III: Acid Formation – In this phase, some wastes are hydrolyzed, they reacts with water to produce soluble products. Here, anaerobic, acid-forming bacteria metabolize biodegradable organic matter in the waste producing volatile acids. The resulting level of VOAs increases the load of dissolved metals and lowering of pH in the leachate. During this stage, there is fermentation of Organic matter.

Phase IV: Methane Production – this phase is characterized by rise to dominance of another group of microorganisms, methane producing bacteria. These convert the organic acids produced in Phase III to methane and carbon dioxide. A highly reducing chemical environment develops and results in the reduction of sulfates (SO_4^{-2}) to sulfide (S^{-2}). The pH is maintained in the neutral range by bicarbonates (HCO_3^-) and this supports the continued flourishing of the methanogenic bacteria. The presence of sulfides and hydroxides (OH^-) favors the precipitation of metals. This phase is also referred to as the methanogenic phase.

Phase V: Maturation – In this phase, biological activity declines due to the depletion of readily-degradable organic matter and other nutrients. Gas production also declines and concentrations of pollutants in leachate are lower than in previous phases.

1.4. Dumpsite leachate

Leachate is a wastewater formed due to precipitation, deposited waste moisture, and water formed within the body of the dumpsite [12]. Leachate is generated as a result of combined biological and chemical reaction of solid waste deposited in the landfill [5]. The process of leachate production depends on the amount of liquid which passes through the dumpsite. Leachate volume is produced during decomposition of carbonaceous material producing a wide range of other materials including methane, carbon dioxide and a complex mixture of organic acids, aldehydes, alcohols and simple sugars. Rainfall is a major contributor to generation of leachate [13].

1.4.1. Composition of dumpsite leachate

The composition of dumpsite leachate varies greatly from site to site depending on the characteristics of the dumpsite. Some factors which may include; the age of the dumpsite, the type of waste, degree of decomposition and physical modification of waste [13].

In a landfill that receives a mixture of municipal, commercial, and mixed industrial wastes, the landfill leachate may be characterized as a water-based solution of four groups of contaminants: dissolved organic matter (alcohols, acids, aldehydes, short chain sugars etc.), inorganic macro components (common cations and anions including sulfate, chloride, iron, aluminum, zinc and ammonia), heavy metals (Pb, Ni, Cu, Hg) and xenobiotic organic compounds such as halogenated organics, [14]. Among the organic compounds detected in the landfill leachate, the main compounds are different hydrocarbons, esters, alcohols, and ketones, as well as aromatic and heterocyclic compounds. Dumpsite leachate may also comprise of mineral pollutants, chemicals, microbial pathogens and other dangerous substances [15].

1.4.2. Microorganisms in dumpsite leachate

The dumpsite provides a suitable environment for the growth and development of diverse microbial populations because of the various substrates available to support their physiological requirements. Leachate being generated from the moisture associated with wastes within landfill/dumpsite amounts to contain diverse microbial pathogens. The complexity and composition of microbial communities present in any dump leachate depends on several characteristics such as the waste dump origin, moisture available, dumpsites age and toxicity of waste components present. The leachates can be contaminated with bacteria, including aerobic, psychrophilic and mesophilic bacteria, coliform and fecal coliforms, spore-forming-bacteria, and with numerous fungi [16, 17].

Bacteria from waste/leachate dumpsite may include; *Arthorobacter, Bacillus, E. coli, Klebsiella, Micrococus, Proteus, Serratia marcescene, Klebsiella aerogenes, Staphylococcus aureus, Alcaligens sp.* and *Proteus mirabilis and Salmonella*. Obire et al., [18], reported the isolation of fungi from waste dumpsite including; Aspergillus, Fusarium, Mucor, Penicillum, Rhizopus and Saccharomyces while the isolation of Aspergillus niger, Aspergillus flavus, Rhizopus and yeast species from dumpsite leachates were also reported by Michaela et al., [5].

1.4.3. Dumpsite leachate toxicity

The disposal of various waste items in dumpsite as led to the presence of different hazardous substance and facilitates the growth of pathogenic microorganism in the dump ground. The internal biochemical decomposition processes taking place in waste dumpsite have a great impact on dumpsite leachate. Due to precipitation or rainfall, waste may dissolve and washed out product of biochemical processes which may produce toxic leachate. Landfill leachates are characterized by high concentrations of numerous toxic and carcinogenic chemicals, heavy metals, and organic as well as inorganic matter. Various groups of pollutant such as organics; alkenes, aromatics, hydrocarbon, acids, esters, alcohols, hydroxyl benzenes, heavy metals and many more are capable of leachate toxicity. Clément et al., [19] found that the most toxic leachates were those originating from landfills with co-disposed hazardous industrial waste. Based on toxicity testing of 27 landfill leachates, Clément et al., [19] concluded that ammonia and alkalinity were the most probable factors contributing to the observed toxicity. The tendency of leachate toxicity depends on the composition of the waste it percolates from, depending on the level of leachate toxicity, the leachate is capable of exhibiting adverse effects on ecosystem and human health.

2. Environmental and Public health impact of dumpsite leachate

The environment is comprised of various factors in which one is surrounded. It may consist of the air, water and soil environment. The effect of dumpsite leachate on the environment majorly results from running a landfill below ideal standard. The lack of proper engineered landfill for waste disposal and treatment in Nigeria has led to the cause of dumpsite leachate effect on the environment and public health because the dumpsite leachate are contained with various element capable of causing adverse effect on the environment and public health [20,21].

Dumpsite leachate has been recorded to contaminate soil, ground and surface water. It can also be said to contaminant the air environment as it may pollute the air with unpleasant odor. Dumpsite leachate pollution may lead to the contamination of plants, animals or food products which in turn affects the health of human who consumes from them [22].

2.1. Leachate as a potential source of pathogen and health implication

Studies has shown that leachate from dumpsite contains large number of pathogenic and opportunistic microorganisms [1, 5, 18, 20]. It pathogenicity can be linked to the disposal of raw human faeces and other human waste on the dumpsite which is suitable for the growth of diverse microbial pathogens like *Arthorobacter, Bacillus, E. coli, Klebsiella, Micrococus, Proteus, Serratia, Aspergillus, Fusarium, Mucor, Penicillum, Rhizopus* and *Saccharomyces* (Obire *et al.,* 2002). Direct handling of the waste can result in various types of infectious and chronic diseases with the waste workers and community at large [10]. Scavengers both young and old are open to various infections from the dumpsites as they move from one dumpsite to the other. Some live very close to the dumpsite.

A review carried out by Njoku *et* al.*,* [23] shows that people living closer to landfill sites suffer from several illnesses such as diarrhea, abdominal pain, cough, asthma, skin irritation, malaria, respiratory diseases, recurring flu, eye irritation, body weakness, cholera, tuberculosis etc. more than the people living far away from landfill sites. The location of dumpsite closer to residential buildings and other sensitive areas like market place, river and stream should be considered not safe and a public health threat that needs to be properly addressed. Consumables such as fruits, vegetables, condiments and other food items being sold close by are opened to various pathogens from the dumpsite, will pose serious health risk to human within the dumpsite vicinity due to possible cross contamination of food and fruit items [9]. Sellers, buyers and any individuals who consumes from such items without washing or cooking well are at high risk of contamination, especially the aged, young children and immune compromised persons are more vulnerable.

Some of the pathogens associated with dumpsite leachate include; *E.coli, Enterobacter*, Bacillus, Salmonella, *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus*, yeast species, *Serratia marcescene*, *Klebsiella aerogenes*, Staphylococcus *aureus, Alcaligens* species and Proteus species. Many outbreaks of disease such as typhoid, cholera, diarrhea, skin rash *etc.*, may result from these pathogens through contamination in water, plant or food sources.

2.2. Incidence of heavy metal in dumpsite leachate and exposure to human health

The indiscriminate disposal of some hazardous waste such as electronic waste, batteries, construction and demolition wastes as led to the increased heavy metal being present in waste dumpsite because many of this wastes are disposed off in the dump site without adequate or no treatment or management. When leachate is produced from such dumpsite, it eventually contains traces of heavy metals present from the dumpsite. Leachate may contain different metals depending on the types of wastes it generates from and the age of dumpsite. Out of ninety-two naturally occurring elements, approximately 30 metals and metalloids are potentially toxic to humans, Be, B, Li, Al, Ti, V, Cr, Mn, Co, Ni, Cu, As, Se, Sr, Mo, Pd, Ag, Cd, Sn, Sb, Te, Cs, Ba, W, Pt, Au, Hg, Pb, and Bi [24].

Lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are known to have no beneficial effect on human and even at low concentration of ingestion, they are harmful to human health [25]. Heavy metals may get into human through the consumption of heavy metal contaminated plant or water. For example, Cadmium spread in the environment may remain in the soils and sediments for decades, plants gradually take up accumulated metals along the food chain and ultimately reach into human who feeds from such plants. Bernard *et al.,* [26] recorded cadmium to be predominantly found in the fruits and vegetables due to its high rate of soil to plant transfer as cited by Showkat *et al.,* [27]. Planting vegetables and legumes around dumpsite should be discouraged to prevent transportation of toxic metals into human system [28]. The uptake of metal by plant from soil at high concentration has great health risk for mankind if consumed [29]. Other effects from leachates may also occur through the ingestion of other organisms such as fish and aquatic plants that habitat an environment contaminated by leachates. The presence of toxic heavy metal in leachate contaminated soil indicates that there is appreciable contamination of the soil and if actions are not taken, pollutants

will eventually migrate through soil strata and may contaminate ground water after a certain period of time which can create serious problem because these metals cannot be degraded [30].

Heavy metals being proven as toxic to human health have been regarded as a major threat, associated with several health risks and illness such as reduced growth and development, nervous system damage, organ damage, and increase cancer rates when it is being consumed [31].

3. Leachate soil contamination

The soil is an important component of dumpsite where various polluted materials are deposited. Biological, chemical and physical processes within the landfill promote the degradation of wastes and result in the production of leachate. The movement of water first through the waste dumps and then through soil results in soil pollution. Leachates are known to cause pollution within and around landfill soil [32]. Leachate may contain various hazardous substances like chemicals, heavy metals, batteries, pharmaceuticals etc. The migration or flow of leachate into the soil has contributed to the soil being a sink of contamination. Contamination with heavy metals such as lead, copper, zinc, iron, manganese, chromium, and cadmium may lead to serious problems because these heavy metals cannot be biodegraded [30]. Heavy metals indirectly affect soil enzymatic activities by shifting the microbial community which synthesizes enzymes. The heavy metals affect soil microorganism by changing their microbial diversity, population size and overall activity of the soil microbial communities [33].

Lin *et al.,* [34] revealed that leachate from landfill is capable of degrading the quality and safety of soil, contaminating the food system and posing long-term health risks. The migrations of heavy metal contaminated leachate to agricultural farm land may affect the quality and productivity of crops as they are capable of deteriorating the soil, making it no longer suitable for agricultural purposes [35]. High concentration of Pb in soils may decrease the soil productivity and even at a very low concentration it may inhibit some vital plant processes like; photosynthesis, mitosis and water absorption with toxic symptoms of dark green leaves [33].

Other effect of leachate soil contamination may include;

- Modification of soil composition
- Landscape change and visual discomfort
- Plant /crop effect; Abnormal growth and development due to toxic compounds
- Affects the local economy; usually unattractive for tourists or investors

3.1. Ground and surface water contamination

The major potential environmental impacts related to landfill leachate are pollution of groundwater and surface water. The dumpsite is composed of various kinds of waste which are being degraded by microbial activities together with various chemicals, metals and other constituents of the dump. The waste becomes a source of water contamination when it found its way to water body through leachate migration, leachate may also mix with surrounding environment and water bodies by rainfall flow. The production of leachate is associated with precipitation that infiltrates through the refuse dump which normally results in the migration of leachate into the groundwater zone and pollutes it [36]. Several report as recorded the contamination of ground water by leachate from solid waste dumps [9, 37, and 38]. Ground water pollution from dumpsite leachate may be produced from different kinds of pollutants including heavy metals, nitrogen species, chlorinated hydrocarbons phenols, cyanides, and bacteria among others [21]. Electronic waste thrown in dumpsite contributes to groundwater pollution; it releases toxins, which seep into ground water. Electronic wastes are sources of heavy metals, their presence in water bodies may affects both land and sea animals. This in turn affects the health of human especially those drinking from the source. A report from the agricultural district of Chachoengsao, in the east of Bangkok, stated that the local villagers had lost their main water source as a result of e-waste dumping. A nearby Chinese-run factory started bringing in foreign e-waste items such as crushed computers, circuit boards and cables for recycling to mine the electronics for valuable metal components like copper, silver and gold. These items contains lead, cadmium and mercury, which are highly toxic, during rainfall, the water went through the pile of the waste, passed through their homes and went into the water system. Water tests were conducted in the province by both environmental group Earth and the local government and it was confirmed that toxic levels of iron, manganese, lead, nickel and in some cases arsenic and cadmium were found. Furthermore, the communities observed that the shallow well had unpleasant odor", there was also some development of skin disease when they use water from the well [39].

Surface or ground water contaminated with heavy metals may cause devastating effects on the ecological balance of the aquatic environment, and the diversity of aquatic organisms becomes limited with the extent of contamination.

Accumulation of heavy metals by an aquatic organism can be transferred through the upper classes of the food chain. Carnivores being the top of food Chain including humans, obtain most of their heavy metal burden from the aquatic ecosystem by way of their food.

The factors influencing the pollution potential from leachate are: the concentration and flux of the leachate, the basic quality, volume and sensitivity of the receiving water bodies. Assessing groundwater quality and developing strategies to protect aquifers from contamination are necessary for proper planning and designing water resources [38].

3.2. Formation of leachate plume

The movement of leachate from dumpsite/landfill to ground water zone is made possible by gravity. It causes the leachates to move through to the bottom and side of the landfill, going through the underlying soil until it reaches the groundwater zone or aquifer.

The movement of leachate to the subsurface of landfill causes it to mix with the groundwater held in soil space, this moves along the groundwater flow path as a plume of contaminated groundwater. As leachates move down the subsurface, they mix with groundwater held in the soil spaces and this mixture moves along the groundwater's flow path as a plume of contaminated groundwater.

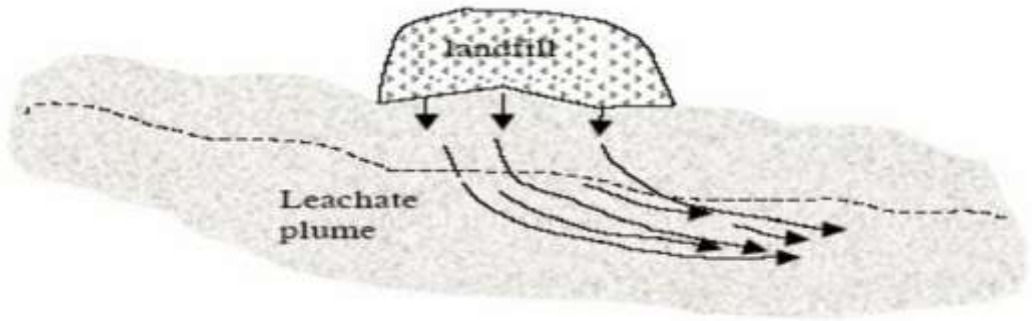

Figure 1 Formation of leachate plume [39]

The leachates contaminants first enter the unsaturated zone and eventually are transported to the groundwater table in the saturated zone.

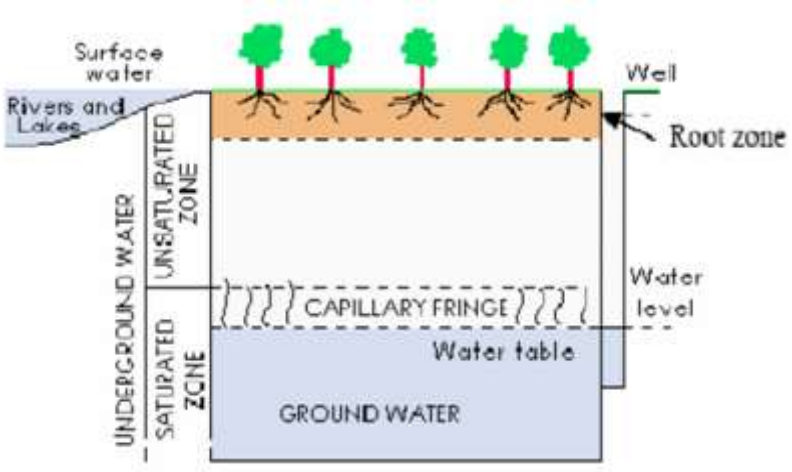

Figure 2 Subsurface [39]

3.3. Leachate air contamination

Air serves as a mode of transmission for the dispersal of bacteria, fungi, viruses and can cause a variety of diseases in humans and animals. Due to the concentration of microorganisms and different kinds of toxic elements generated on landfill, the leachate promotes foul odor on the site and around neighborhood thereby polluting the air. Airborne

releases from the sites can have significant adverse effect on human health. Obiekezie *et al.,* [9] isolated 15 organisms from the air environment of waste dumpsite which indicates a potential health risk to people living or selling around the site. People living close to dumpsite, waste worker and scavengers' are prone to constants exposure to various contaminants present on the dumpsite. Long time inhalation of the contaminant can cause Anosmia. Anosomia is the human health condition where people loss their sense of smell due to constant exposure to offensive odor produced by different compounds like sulphuric and hydrogen sulphide compound being diffused into the atmosphere from the dumpsite [22]. Foul odor from such dumpsite is usually unpleasant and unhygienic to breathe in. It can trigger other health challenges like asthma, abdominal pain, sneeze, skin irritation etc.

3.4. Problems confronting proper waste/leachate management

Waste management is serious problem across developing countries including Nigeria. Though there are municipal solid waste disposal site across the states, these sites are not properly managed. The inability for the nation to properly manage it waste has led to the increased leachate effect and pollution which is a great concern to the environment and human health. In Nigeria, the problem of Solid waste management is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste [40]. Most states/cities lack proper placement for waste management, there is no standard engineered landfill; most landfills are designed without an engineered liner and leachate collection/treatment system; so there is free flow and migration of leachate waste from the dumpsite which leads to environmental hazards [7, 41]. It is also interesting to state that some problems faced with improper waste management can be linked to irregular discharge of duties by the environmental waste workers/agency; no regular cleanup, there seem to be no routine check on how waste is properly managed in the community/ dumpsite, there is improper or no allocation of waste dumpsite, this contributes to the proliferation of open dumpsites thereby increasing the chances of health and environmental hazards through leachate migration. Other problems contributing to environmental and public health effect of dumpsite leachate may include;

- Lack of financial constraint for proper waste management.
- Lack of political will to protect and improve the public.
- Poor publicity/sensitization of community members on proper health hygiene.
- Unselective disposals of dangerous industrial/clinical wastes on dumpsite.
- No speculated area for waste disposals/dumpsite.
- Location of dumpsite close to residential/river/market area.
- No proper regulation/control of waste dumpsite.
- Inadequate or no treatment of waste/leachate dumpsite.

In Nigeria, though not many cases have been recorded from leachate migration, existing problems of waste management could extensively worsen if not genuinely looked into/tackled.

4. Conclusion

The lack of proper placement of dumpsite has led to the proliferation of open dumpsites (unregulated landfills) in Nigeria. This has enhanced poor waste management and brought about several environmental and public health hazards through leachate migration. There is need for the adoption of a good design plan for proper construction and allocation of waste sites across the nation, this landfill should be far from residential and other sensitive areas like market, farmland, rivers etc. where waste can be properly managed and regulated to minimize or end the negative impact of leachate on the environment and public health. As the saying goes 'health is wealth' the health of human is so vital and must be properly managed.

Recommendation

Proper means of waste disposal and management should be considered for a better health and environment. I therefore recommend that;

- The state and federal authorities should see to the construction of modern landfills (with liner and leachate collection system/treatment) across the states. Waste shouldn't be left in open dumpsites without adequate treatment. Leachate waste treatment should be taken serious. It is interesting to state that some researchers like Oyebode [42] and Ojuri *et al* [43] has worked on a good design plan for an engineered landfill in Ado Ekiti and Akure Ondo state respectively. Ojuri *et al.,* [43] designed the landfill with the view to encourage a shift

from the use of open dumpsite. The design is composed of specification for a liner, a lapping system, leachate collection system, polyethylene pipe system, gas capture and monitoring system against leachate and landfill gas migration from the landfill. This wouldn't be an error if such approach is adopted by the state and federal government for proper waste management.

- More funds should be allocated to the environmental agencies for proper management of waste. This should be done with proper monitoring to ensure a successful execution.
- The public especially the rural communities should be properly sensitized on the need to avoid creation of dumps around homes and the need for personal hygiene.
- Waste baskets/collector should be provided and available in all streets to ensure proper home waste disposal.
- Government should ensure that environmental workers effectively carry out their duties timely and always.
- Home/huts of scavengers cited/living close to the dumpsites should be discouraged.
- In addition, the government should encourage recycling and reuse system as this will help reduce the amount of waste and hazardous leachate effect, that is; waste degeneration and also regenerate wealth for the country.

Compliance with Ethical Standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

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