



JOURNAL OF COMMUNITY SERVICE IN SCIENCE AND ENGINEERING

P-ISSN: 2962-1003 E-ISSN: 2962-0767

Homepage jurnal: <http://jurnal.untirta.ac.id/index.php/JoCSE/>



Plastic solid waste management strategies: An overview of implications on environment and health

Sahabi Nasibatu Gada

Department of Geography, Sokoto State University, P.M.B. 2134, Near Airport, Birnin Kebbi Road, Sokoto State, Nigeria.

E-mail: superoxidedismutase594@gmail.com

ARTICLE INFO

Article history:

Submitted 10 March 2024

Reviewed 15 March 2024

Received 20 March 2024

Accepted 25 March 2024

Available online on 1 April 2024

Keywords:

Incineration, plastics, pollution, water environment, land pollution, microplastics, climate.

Kata kunci:

Insinerasi, plastik, polusi, lingkungan air, polusi tanah, mikroplastik, iklim.

ABSTRACT

Plastics are ubiquitous polymers and champions of today's environment because they are numerously useful. This paper's objective is to review different methods of plastic disposal and their impacts on health and the environment using the conceptual review method. Nowadays, anthropogenic developments and growth have increased and are resulting in progress that has led to the application of plastic in almost every aspect of human endeavors. However, today, there is an apparent mismanagement of plastic wastes ubiquitous in our environment (in land, water, and air). The methods used to handle plastic solid waste include landfilling, pulverization, open dumping, and burning or incineration. This paper basically elucidates some of the techniques used for solid waste plastic handling, merits, and demerits. Therein, headings such as plastics, microplastics in the soil, effects of incineration, effects on climate change, plastic in water, policies for correction, types of waste, and relations were elucidated. It is important to stress that plastic waste destroys the routine nature of the environment (beautiful view), alters the physical nature of the environment, causes pollution, and affects macro and microorganisms. Better methods/strategies are needed to address plastic solid waste.

ABSTRAK

Plastik adalah polimer yang ada di mana-mana dan merupakan pelindung lingkungan saat ini karena banyak manfaatnya. Tujuan makalah ini adalah untuk meninjau berbagai metode pembuangan plastik dan dampaknya terhadap kesehatan dan lingkungan menggunakan metode tinjauan konseptual. Saat ini, perkembangan dan pertumbuhan antropogenik telah meningkat dan menghasilkan kemajuan yang mengarah pada penerapan plastik di hampir setiap aspek kehidupan manusia. Namun, saat ini, terdapat kesalahan pengelolaan sampah plastik yang tersebar luas di lingkungan kita (di darat, air, dan udara). Metode yang digunakan untuk menangani sampah plastik antara lain penimbunan, penghancuran, pembuangan terbuka, dan pembakaran atau insinerasi. Makalah ini pada dasarnya menjelaskan beberapa teknik yang digunakan dalam penanganan sampah plastik, kelebihan dan kekurangannya. Selain itu, dijelaskan juga mengenai plastik, mikroplastik dalam tanah, dampak pembakaran, dampak terhadap perubahan iklim, plastik dalam air, kebijakan koreksi, jenis sampah, dan hubungannya. Penting untuk dipahami bahwa sampah plastik merusak sifat rutin lingkungan (pemandangan indah), mengubah sifat fisik lingkungan, menyebabkan polusi, dan mempengaruhi makro dan mikroorganisme. Diperlukan metode/strategi yang lebih baik untuk mengatasi sampah plastik.

Available online at <http://dx.doi.org/10.36055/jocse.v3i1.24700>.

1. Introduction

Plastics are large molecules containing repeating units of monomers and are made into various shapes to benefit human endeavors. Plastics are either macroplastics, the large ones that the eyes can see, or microplastics. Microplastics are plastics of particle size from nanometers to 5 millimeters (the smaller versions of microplastics could be nanoplastics). Some microplastics are made at smaller sizes by the industries, such as fibers, pellets, foams, films, etc; they are termed primary microplastics. Microplastics made through the actions of environmental pressures (such as mechanical force and UV light) from macroplastics are called secondary microplastics [1].



Journal of Community Service in Science and Engineering (JoCSE) is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.

The demand for plastics has been on the rise, and managing plastic waste is daunting and challenging in all facets of the environment and life. For example, in 2014, 311 million metric tons of plastics were made globally, with about 12.7 million ending up in water (ocean environment) due to poor waste management practices [2]. Plastic waste is ubiquitous in land, lakes, seas, oceans, and other water bodies (and affects water organisms and is incorporated into chains or webs) [3]. Consequently, the management or handling of plastic waste is becoming a nightmare; therewith, the mismanagement harms the environment and health. This paper's objective is to review different methods of plastic disposal and their impacts on health and the environment using the conceptual review method.

Table 1. Some types of plastic polymers, source: [4].








Polymer types	Examples of applications	Symbols
Polyethylene terephthalate (PET)	Fizzy drink and water bottles, salad trays	 PETE
High Density Polyethylene (HDPE)	Milk bottles, bleach, cleaners, and most shampoo bottles.	 HDPE
Polyvinyl Chloride (PVC)	Pipes, fittings, window, and door frames (rigid PVC). Thermal insulation (PVC foam) and automotive parts	 V
Low Density Polyethylene (LDPE)	Carrier bags, bin liners, and packagings films	 LDPE
Polypropylene (PP)	Margarine tubs, microwaveable meal trays, also produced as fibres, and filaments for carpets, wall coverings, and vehicle upholstery.	 PP
Polystyrene (PS)	Yoghurt pots, foam hamburger boxes, plastic cutlery, protective packaging for electronic goods, and toys. Insulating material in the building, and construction industry.	 PS
Unallocated references	Any other plastics that do not fall into any of the above categories – for example polycarbonate which is often used in glazing for the aircraft industry.	 OTHER



Figure 1. Fates of plastics after uses, source: [4].



Figure 2. Plastics management, source: [4].

2. Methods

Some of the available methods that can be used to dispose of waste are sanitary landfills, incineration, compacting, hog feeding, dumping into the sea, and open dumping [5, 21, 43-44].

2.1. Sanitary Landfill

Sanitary landfills involve disposing of waste on the land by spreading waste materials in layers and compacting them into smaller volumes covered by soil or some inert materials. Their practice can be done daily or frequently to alleviate environmental consequences. Places such as valleys, poor drainages, trenches, quarries, etc., can be filled through landfilling methods of waste disposal [8, 35, 45]. Advantages of landfills include they improve the quality of wastelands such as quarries, are easier to conduct, require little money or cost to be carried out, reduce hazards such as rodents and insects, and are suitable for different waste types [39, 46-47]. Disadvantages of landfills include that they can transform into open dumping sites, sometimes leak and contaminate underground and surface waters, and result in land consumption [19, 48].

2.2. Open Dumping of Waste

Open dumping is an interventional method that involves dumping waste over open land and allowing it to be exposed all along. This type of intervention continuously collects and receives waste over time [9]. The advantages of this method are that it requires minimal planning, maintenance, and skills, is more straightforward, and is not expensive [49-50]. Disadvantages of this method are that it can yield an offensive odor, it can exaggerate or generate air pollution, and it provides room for a chain of disease transmission [51-54].

2.3. Incineration as A Waste Disposal Method

Incineration is the process of disposing of waste materials by burning them. There are some equipment used for incineration purposes either at small scale or large scale, such as bar incinerators, barless incinerators, and behave incinerators [20, 52, 55-56].

2.4. Composting of Method of Waste Disposal

Composting is a method of waste disposal that involves dumping waste materials (excluding the glasses and relations) in a ditch or related gully and allowing for decomposition. It takes about three to four months for the waste to degenerate into manure [15, 47, 57]. The advantages of this method are that many types of waste can be treated in this fashion, that it aids in the disposal of sewage and refuse, and that it provides manure for farms [58]. The disadvantages of this method are that it requires skilled manpower, consumes time during the decomposition process, and involves capital [57].

2.5. Dumping into Sea Method of Waste Disposal

This method is standard in places with waterbodies. It involves dumping waste materials in waters such as rivers, seas, etc. The advantages of this method are that large waste amounts can be disposed of at a time, provide nutrients and food for some aquatic animals, and have less cost intervention [42, 59]. The disadvantages of this method are that it reduces the beauty and lovely nature of waterbodies and is a form of pollution affecting plants, animals, and humans [48, 60].

2.6. Pulverization

This method is done through pulverizing or converting the waste materials into powder applied in depressions or lowland areas [58]. The advantages of this method are that the hugeness of waste is decimated into tiny particles, and the nuisance is reduced due to this treatment. The disadvantages of this method are that it is expensive, done only by skilled labor, and is not a final treatment of waste [11, 61].

2.7. Factors that Should Be Taken into Cognizance while Selecting a Waste Disposal Method

Factors that should be taken into cognizance while selecting a waste disposal method, namely land availability, availability of equipment, availability of funds, availability of trained labor, types of waste to be treated, and the amount of waste to be treated [49, 62].

3. Results and Discussion

3.1. Microplastics Relates in The Soil or Land in The Environment

Plastics, especially the tiny ones (micro and nano forms of plastics), are divulged and dispersed in the environment; in addition to that, the dispersal is aggravated by extreme weather events like flooding, hurricanes, and winds, among others [2]. In farmlands, millions of plastic materials are added deliberately through farming activities such as mulchings, films, manures, fertilizers, packaging, etc. The plastics undergo fragmentation due to actions (such as effects of sunlight photodegradation, manual pressure, etc.) to form harmful tinier forms and accumulate toxic chemicals in the environment [5]. An exploration of the soil environment and plastics interaction revealed that plastics alter the physical parameters of the environment, change plant roots behaviors, alter leaf traits, alter biomass, and alter microbial interactions; for instance, plastic changes soil composition, structure, water holding capacity, permeability, temperature, and increase evaporation rate [6]. Plastic waste in soils is a worldwide concern that has stringent consequences on the environment; about 12,000 million tons of plastic waste are placed in the soil due to improper management. It is a source of contamination to soils and the water environment. Some sources of plastics in the soil/ land are:

- a. Improper disposal of waste.
- b. Landfilling.
- c. Incineration.
- d. Sludge and manure- Waste materials from sludge or accumulated plastics in home-made manure taken to lands for landfilling or fertilizer application is a way that threatens the environment and health because it alters the soil nature and can be absorbed by plants, soil microbes, and feed the water or air with pollutants.
- e. Mulching: This is applying plastic films on plants to act as insulation for better crop yield, erosion control, pest control, etc. However, the mulching is not biodegradable unless made from biodegradable polymers. Innovated polymers contribute to pollution due to the degradation of products [2].



Figure 4. Plastic in the land, source: [7].

3.2. Implications of Plastics Incineration or burning on the Environment and Health

Burning plastics is a common practice at home, in industries, hospitals, etc., because there are no efficient ways to deal with the waste problems affecting many parts of the world. However, the method of getting rid of plastics through burning always involves water, land, and air; on the other hand, it harms humans and other biological systems. Some of the chemicals released during the burning of harmful plastics include the following:

- a. Dioxins. These are emission chemicals that affect biological beings even when the concentration is small because they are linked to cancer, motor disabilities, ischemic heart disease, and cognition problems.
- b. Particulates. Particulates are products emitted during plastic burning and affect humans due to their ability to cause stroke, reduce visibility, and escalate respiratory problems such as asthma.
- c. Toluene. Toluene is a distinctively smelling, clear, and colorless liquid that affects the liver, nervous system, kidney, etc.
- d. Sulfur dioxide. This chemical elicits eye irritation, upper respiratory tract problems, and shortness of breath in humans.
- e. Ethylbenzene. Ethylbenzene is a colorless product utilized as a solvent (e.g., in styrene plastics) and causes dizziness, eye irritation, throat irritation, and damage to the ear.
- f. Carbon monoxide. CO is an odorless, poisonous, colorless, and gaseous chemical that, at low exposure, causes headache, nausea, fatigue, disorientation, and dizziness. However, under high exposure, it quickly kills through its ability to starve hemoglobin from oxygen.
- g. Styrene. A standard monomer of polystyrene and health concerns are prostate cancer, breast cancer, congenital disabilities, premature puberty, aggressiveness, low sperm count, and hyperactivity [8].
- h. Vinyl chloride. A standard part of polyvinyl chloride and its adverse effects are cancer, reproductive defects, development problems, liver problems, and low sperm count [9-10].
- i. Bisphenol A. A common additive in plastics and adverse effects are prostate cancer, miscarriages, aggressiveness, breast cancer, congenital disabilities, hyperactivity, and low sperm count [11].
- j. Dioxins and Furans. Dioxins and Furans cause cancer, growth defects, immune problems, DNA defects, reproductive defects, and hormone disruption [12].
- k. Volatile Organic Compounds. Cancer-causing respiratory illnesses causer, and lung disease [13-14].
- l. Polynuclear Aromatic Hydrocarbons (PAHs). PAHs cause cancer.
- m. Heavy metals. Parable, Pb, Cd, Ar, Hg, etc., cause effects in nearly all body organs. Their effects constitute cancer, reproductive effects, nervous effects, kidney effects, liver effects, and many others [8, 15].
- n. Formaldehyde. Formaldehyde can lead to irritation in the eyes and throat and other effects like nausea and skin rashes.
- o. HCL. HCL causes bronchitis, nausea, edema, visual damage, convulsions, shock, lethargy, dehydration, diarrhea, burns, dermatitis, chills, stupor, etc. [16-17].

3.3. Plastics Affect Climate

Plastic pollution produces enormous harm to climate because greenhouse gases emitted by plastic dealings in its lifecycle is a bump towards achieving a global temperature increase below 1.5 degree Celsius; in addition to that, plastics emit about 56 gigatons (amounting to 10 to 13 % of green global carbon budget). Nevertheless, plastics follow lifecycle trends from the extraction of fuels to shelf life and management. During extraction and transportation of fossil fuels for producing plastics, emissions (such as methane), land disturbance, drilling emissions, etc., are significant concerns. The second step in the plastic lifecycle is the refining and manufacturing, cracking of alkenes to make olefins, polymerization, and plasticization occur; carbon dioxide, methane, hydrogen sulfide, and other detriments are divulged into the environment.

The third step of plastic life is its stay, during management, where it is discarded, recycled, landfilled, and incinerated; in addition, a lot of emissions of poisonous chemicals are made through all the various methods of plastic management. Improperly managed plastics get into the environment, which

causes environmental degradation, interference with climate, and impact on climate change. Parable, the plastic in water affects the ocean's role in carbon sequestration, such as by affecting phytoplankton [18-20].

3.4. Unique Harmful Nature of Plastic Waste

Plastic waste is widespread in our environment due to poor management, and some plastic features are dangerous. Some of the features of plastics are as follows;

- a. Persistence: Plastic waste is generally persistent and non-biodegradable; therefore, it stays in the environment for years while causing harm. A plastic beverage container stays for 400 years, and a bag stays for about 1000 years, the plastic bottle stays for 100 to 1000 years, synthetic fabric dwells for 500 years, foam cup lives for 50 years, fishing line lives for 600 years, plastic case dwells for about 100- 1000 years [21-22].
- b. Accumulation and Leaching of Chemicals: Plastic waste is a polymer containing diverse chemicals that can migrate easily into the environment; additionally, many chemicals adhere to plastic to be detached at some other points. Microbes also comply with the plasticsphere [22-24].

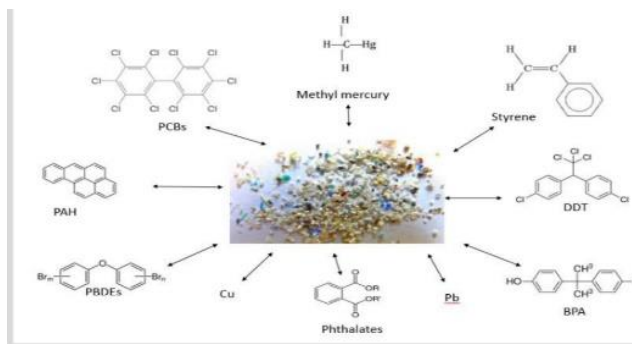


Figure 5. Some harmful chemicals of plastics, source: [25].

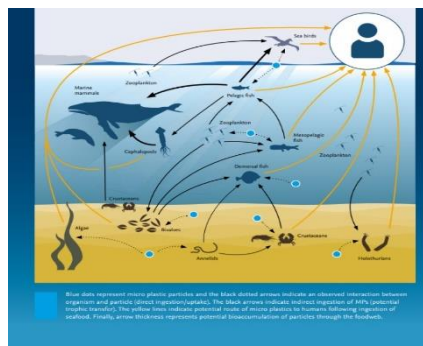


Figure 6. Plastics affecting water organisms, source: [22].

3.5. Plastic Waste in the Water Environment

Plastics in the water are stored by mismanaged wastes from the land; however, there are fewer ways of plastic waste in the water environment [26]. Plastic waste in the waterbodies travels far and near across various regions and continents. However, along the course of plastic water in water conveyance of toxic chemicals, detachment of harmful compounds that affect the diversity of biologicals occurs. Ultimately, the food chain and aquatic organisms are affected due to the presence of plastic waste in the water [22].

3.6. Policies for Regulation of Plastics

- a. Innovated designs. This involved making plastics that are environment-friendly, are able to exert less harm to the environment. It implies changing the trend of the way conventional plastics are manufactured. For example, bioplastics are new trends proposed to be biodegradable and biobased. Oxoplastics contain a component that aid in triggering degradation by sunlight or heat or relations [27].
- b. Individualized approaches. At individual level every person should rationally do some tips as follows: Avoiding plastics as ably as possible, separate waste for easy recycling, avoiding single-use plastics, use other alternative containers to substitute plastics, educate other on harms of plastic waste, etc.
- c. Banning. It is better to ban some plastics that are more harmful to save the environment and health, for example banning of bags, and other single-use plastics aid in reducing plastic pollution and it's consequences as well [28].
- d. Taxation. Increasing taxes or other charges is a method that was believed to reduce demands of certain plastics according to the demands and supply laws that show the higher the price, the lower the demand.
- e. Water regulations. Some of the waste management policies in place contain loopholes, there should be effective laws that are properly applied to boost waste management efficiently to avoid reckless handling of water by public, government, and business moguls or industries.
- f. Recycling. Recycling involves using old plastics to make new plastic materials by the manufacturers. This process requires careful handling of waste by the public or managers, and requires energy, as well as cost [21].
- g. Upcycling. This is an approach that constitutes the utilization of plastic water for other uses after lifecycle exhaustion, for example use of plastic waste in building, teaching aids, furniture making, shoe making etc.



Figure 7. Use of plastics in building, source: [29].

3.7. *Biotechnological Approaches Needed*

Indeed, every environmental effort or activity has consequences in bulk or minute quantities; therefore, it is impressive to use less disadvantageous methods and activities to reduce impacts on the environment and, ultimately, the biological systems living on earth, of which humans are most precious. Biotechnological approaches use bioresources to convert toxic substances into less-toxic or non-toxic forms [4].

3.8. *Biomass*

Because many plant materials are able to make hydrocarbons or related organic compounds, they can be used to make ideally safer plastic materials. Biomass is a result of plants' photosynthesis. Therefore, plastics made from biomass materials could be used to produce fuel in the environment so that the non-degradable nature of conventional plastic solid waste can be ideally diminished [5]. However, the disadvantages of this idea are as follows:

- a. Biomass utilized usually possesses lower thermal energy than fuels.
- b. It sometimes contains significant moisture that prevents proper combustion, consequently causing energy wastage.
- c. The technique could be costly, requiring many laboratory facilities and management [4].

3.9. *Bioremediation*

Bioremediation involves organisms (such as microorganisms) to degrade or transform harmful chemicals into less toxic or completely safe forms [4].

3.10. *Types of Plastic Waste*

- a. Industrial solid waste. This type of waste emanates from industries through production processes or relations, including rubbish, packaging materials, etc.
- b. Agricultural waste. This waste is generated through farming activities from planting, harvesting, and animals.
- c. Medical waste. This type of waste comes from hospitals and related health posts, including syringes, placenta, used gloves, laboratory specimens, etc.
- d. Commercial waste. This waste is from commercial areas like markets, hotels, parks, shops, and relations.
- e. Municipal waste. This type of waste is produced from the towns and related areas due to home activities and relations [30-32].

3.10.1. *Solid Waste Management and Goals*

Solid Waste Management is the "systematic administration of human and material resources in the course of generation, collection, storage, transfer and transportation, treatment, and final disposal of waste to render it less harmful to humans, animals, and the entire environment" [17].

3.10.2. *Goals of Solid Waste Management*

The main goal is to ensure the effective elimination of hazards that may harm the community

- a. It also aimed to preserve and protect the environment against pollution and degradation.
- b. Facilitates the continuous supply of materials needed by the industries for recycling and related processes.
- c. To help provide employment opportunities to society members [33].

3.11. *Processes of Solid Waste Management*

The processes of Solid Waste Management are run basically through the following activities:

- a. Waste generation. Involves the amount of waste made by a given source that is channeled to the management stream [19].
- b. Storage of waste. During waste storage, types of containers, locations, and methods for collection are essential and should be selected appropriately. Containers should be significant depending on the nature of the waste. For example, drums, bins, bags, and buckets store waste in homes, offices, and public places [7, 34-35].
- c. Collection of waste. Collection involves the removal of waste from the stored container and alighting it on the disposal site. It also includes transporting the waste from storage to the disposal site [36]. Collection can be done in the following formats:
 - 1) Collection from one-unit household and taking it to where it will be gathered.
 - 2) Collection can be done from high-density living areas or community waste areas.
 - 3) Collection from the upstairs building to the downstairs.
 - 4) Collection can be done from medical posts such as hospitals, and this needs adequate care to avoid public health catastrophes.
 - 5) Collection from schools, markets, and other related public gatherings [37-38].
- d. Transportation of Solid Waste. This waste involves the collection and transport of waste materials from smaller collection sites to huge collection sites. It usually/mainly occurs by ferrying the waste over a longer distance to the extensive disposal sites [39]. Some vehicles used to collect the waste could include tippers, compactors, bulldozers, etc. Things such as cost, the layout of the community, distance, climate, equipment, vehicle availability, and population of the areas generating the waste are supposed to be considered during the transition of waste [40-42].

4. *Conclusion*

Plastics are very useful in numerous aspects of human life. However, plastics are very damaging to our environment, aggravated by poor management. This paper has explored the consequences of plastic solid waste on the environment and health and stressed the types of strategies for handling plastic solid waste materials in terms of merits and demerits. It also suggested strategies to help prevent pollution and its effects at minimal cost.

REFERENCE

- [1] Gazal, A. A., & Gheewala, S. H. (2020). Plastics, microplastics and other polymer materials—a threat to the environment. *J. Sustain. Energy Environ*, vol. 11, pp. 113-122.
- [2] Liboiron, M. (2016). Redefining pollution and action: The matter of plastics. *Journal of material culture*, vol. 21, no. 1, pp. 87-110.
- [3] Food and Agriculture Organization (FAO). (2021). *Assessment of Agricultural Plastics and Their Sustainability: A Call for Action*. Rome: FAO UN.
- [4] UN Environment Programme (UNEP). (2018). *Single-Use Plastics: A Roadmap for Sustainability*. Nairobi: UNEP.
- [5] Hayes, D. (2019). *Micro and Nanoplastics in Soil: Should We Be Concerned. Report No.PA-20k-01*. Washington: United States Department of Agriculture.
- [6] de Souza Bido, D., & Da Silva, D. (2019). SmartPLS 3: especificação, estimação, avaliação e relato. *Administração: Ensino e Pesquisa*, vol. 20, no. 2, pp. 488-536.
- [7] Ibrahim, M. F., Hod, R., Toha, H. R., Nawi, M. A., Idris, I. B., Yusoff, M., & Sahani, M. (2021). The impacts of illegal toxic waste dumping on childrens health: A review and case study from Pasir Gudang, Malaysia. *International Journal of Environmental Research in Public Health*, vol. 18, no. 221, pp. 1-18.
- [8] Sidi, A. S., & Yahaya, U. F. (2022). Chemical additives of concern in electronic plastics: Theoretical view. *ISSRA Journal of Applied Medical Sciences*, vol. 1, no. 3, pp. 12-19.
- [9] Magami, I. M., Maishanu, H. M., & Danbare, B. M. (2017). Survey of waste disposal and its perception among residents of Sokoto Metropolis, north-Western Nigeria. *International Journal of Pure and Applied Biosciences*, vol. 5, no. 2, pp. 9-13.
- [10] Manisalidis, I., Stavropoulou, E., Stavropoulos, A., & Bezirtzoglou, E. (2020). E-waste: A review. *Frontiers of Public Health*, vol. 8, no. 14, pp. 1-13.
- [11] Verma, R., Vinoda, K.S., Papireddy, M., & Gowda, A. N. S. (2016). Toxic pollutants from solid waste- A review. *International Conference on Solid Waste (IconSWM)*, vol. 35, pp. 701-708.
- [12] National Institute of Environmental Health Sciences. (2019). *Children's Health: Why the Environment Matters*. Accessed at 1 January 2024. Accessed at www.niehs.nih.gov.
- [13] Nasir, Z. M., & Ibrahim, A. G., (2022). Appraisal of people perception on waste disposal and management in Sokoto metropolis. *International Journal of Innovative Environmental Studies Research*, vol. 10, no. 4, pp. 1-8.
- [14] Salau, I. A., Ibrahim, N. M., Aliyu, M., & Jaafar, K. S. (2022). Assessment of Azadirachta Indica (L.) in the removal of heavy metal from soil contaminated with lead poisoning in Anka, Zamfara state. *FUDMA Journal of Sciences*, vol. 6, no. 6, pp. 138-145.
- [15] Sarkar, M. S. I., & Bhuyan, S. (2018). Analysis of physical and chemical composition of the solid waste in Chittagong City. *Journal of Industrial Pollution Control*, vol. 34, no. 1, pp. 1984-1990.
- [16] Park, Y. K., Kim, W., Jo, Y. M. (2013). Release of harmful air pollutants from open burning of domestic municipal solid wastes in a metropolitan area of Korea. *Aerosol and Air Quality Research*, vol. 13, pp. 1365-1372.
- [17] Alabi, O. A., Ologbunjaye, K. I., Awosolu, O., & Alalade, O. E. (2019). Public and Environmental health effects of plastic wastes disposal: A review. *Journal of Toxicology and Risk Assessment*, vol. 5, no. 2, pp. 1-13.
- [18] Center for International Environmental Law. (2019). *Plastic & Health: The Hidden Costs of Plastic Planet*. Washington: CIEL.
- [19] Obebe, S. B. & Adamu, A. A. (2020). Plastic pollution: Causes, effects and preventions. *International Journal of Engineering, Applied Science and Technology*, vol. 4, no. 12, pp. 85-95.
- [20] Sarkingobir, Y., Bello, A M. Yabo, H. M. (2021). Harmful effects of plastics on air quality. *Academia Letters*, vol. 2967, pp. 1-6.
- [21] Koushal, V., Sharma, M., Sharma, R., & Sharma, V. (2014). Plastics: issues challenges and remediation. *International Journal of Waste Resources*, vol. 4, no. 1, pp. 1-6.
- [22] Kershaw, P. J. (2015). *Sources, Fate and Effects of Microplastics in the Marine Environment: A Global Assessment*. London: GESAMP.
- [23] Ryan, P. G. (2015). A brief history of marine litter research. *Marine Anthropogenic Litter*, pp. 1-25.
- [24] Avio, C. G., Gorbi, S., & Regoli, F. (2017). Plastics and microplastics in the oceans: from emerging pollutants to emerged threat. *Marine Environmental Research*, vol. 128, pp. 2-11.
- [25] Bas, O. N. & Nzewi, N. U. (2018). Plastic water bottles, sand and hydroform blocks, building materials for the urban poor housing: A new phenomenon. *Journal of Environmental Management and Safety*, vol. 9, no. 1, pp. 1-35.
- [26] Valentine, K., Cross, R., Cox, R., Woodmancy, G., & Boxall, A. B. (2022). Caddisfly larvae are a driver of plastic litter breakdown and microplastic formation in freshwater environments. *Environmental Toxicology and Chemistry*, vol. 41, no. 12, pp. 3058-3069.
- [27] Washam, C. (2010). *Plastic Go Green: ChemMatters*. Accessed at 1 January 2024. Accessed at www.acs.org/ChemMatters.
- [28] Jambeck, J. R., Geyer, R., Wilcox, C., Sisegler, T. R., Perryman, M., Andrady, A., Narayan, R., & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Marine Pollution*, vol. 347, no. 6223, pp. 768-771.
- [29] Patel, P. A., Shah, A., & Patel, H.(2016). Waste plastic bottle materials with sustainable application. *International Journal of Innovative and Emerging Research in Engineering*, vol. 3, no. 3, pp. 38-45.
- [30] Alam, P. & Ahmade, K. (2013). Impact of solid waste on health and the environment. *International Journal of Sustainable Development and Green Economics*, vol. 2, no. 1, pp. 165-168.
- [31] Olugbemiga, O. S., Adeola, A. C., Oluwasola, A. S. (2017). Constituents of municipal solid waste generated in Ado-Ekiti, Nigeria. *American Journal of Environmental Policy and Management*, vol. 3, no. 2, pp. 12-18.
- [32] Rasul, T., Islam, M., Sajjad, S.I., Islam, Z. (2021). Impact of wastewater discharge to the River Turag: A case study adjacent to the IUBAT. *IUBAT Review*, vol. 4, no. 1, pp. 48-54.
- [33] Fikri, E., Purwanto, P. & Abdurachimi, H. R. (2017). Characteristics and household toxic hazardous waste generation based on economic status and

- topographic regions in Semarang City, Indonesia. *Journal of Ecological Engineering*, vol. 18, no. 5, pp. 8-16.
- [34] Mbue, I. N., Bitondo, D., & Azibo, B. R. (2015). Municipal solid waste generation, composition, and management in the Douala municipality, Cameroon. *Journal of Environment and Waste Management*, vol. 2, no. 4, pp. 91-101.
- [35] Prakash, S. (2017). Impact of plastic pollution on environment and human health: An overview. *Iconic Research and Engineering Journals*, vol. 1, no. 5, pp. 53-59.
- [36] Ibrahim, M., Barau, L., Alhassan, M., Gidadawa, Z. S., & Dan Galadima, H. (2019). Assessment of environmental impact of solid waste generation and disposal in Sokoto metropolis. *International Journal of Scientific and Research Publications*, vol. 9, no. 5, pp. 377-383.
- [37] Iwuoha, G. N., Osuji, I. C., & Onwuachu, U. I., (2013). Impact of waste dump on the sediment and surface water quality of Otamiri River, Nigeria. *Journal of Applied Science and Environmental Management*, vol. 17, no. 4, pp. 573-575.
- [38] Irianti, S. & Prasetyoputra, P. (2019). Open burning of household solid waste and child respiratory health: Evidence from Indonesia. *Jurnal Teknologi Kesehatan*, vol. 17, no. 3, pp. 123-134.
- [39] Kaoje, U. Garba, J., Christiana, O. N., Olayinka, R. M., Mohammed, Y., Mohammed, A. U. (2018). Biomedical waste handling and knowledge of its health hazards among waste handlers in a tertiary hospital in Sokoto, Nigeria. *Public Health Review International Journal of Public Health Review*, vol. 5, no. 1, pp. 26-32.
- [40] Pavani, P. & Rajeswari, I. R. (2014). Impact of plastics on environmental pollution. *Journal of Chemical and Pharmaceutical Sciences*, vol. 3, pp. 87-93.
- [41] Karhsima, S. N. (2016). Public health implications of poor municipal waste management in Nigeria. *Vom Journal of Veterinary Science*, vol. 11, pp. 142-148.
- [42] Sabo, G., Zayyanu, A., Abdullahi, K. M., Malami, Z., Aliyu, A., Muhammad, S., Bello, A. (2022). Assessment of biomedical waste management among primary healthcare workers in Gwadabawa local government of Sokoto state, Nigeria. *Transaction on Biomedical Engineering Applications and Healthcare*, vol. 2, no. 1, pp. 1-9.
- [43] Wagner, M., Scherer, C., Alvarez-Munoz, D., Brennholt, N., Bourrain, X., Buchinger, S., Fries, E., Grosbois, C., Klasmeyer, J., Marti, T., Rodriguez-Mozaz, S., Urbatzka, R., Vethaak, A. D., Winther-Nielsen, M., & Reifferscheid, G. (2014). Microplastics in freshwater ecosystems: what we know and what we need to know. *Environmental Sciences Europe*, vol. 26, no. 12, pp. 1-9.
- [44] Reza, A., & Yousuf, T. B. (2016). Impacts of waste dumping on water quality in the Burigangan River, Bangladesh and possible mitigation measures. *Journal of the Environment*, vol. 11, no. 1, pp. 35-40.
- [45] Lovo, S., Rawlings, S. (2021). Garbage in, garbage out: the impact of e-waste dumping sites on early child health. Department of Economics, Discussion paper No.2021-07. Accessed on 1 January 2024. Accessed at www.readings.ac.uk.
- [46] Kingsley, E. N., Paschal, I. O., & Jude, E. O. (2016). Assessment of landfill sites for solid waste management in Delta State, Nigeria. *Journal of Environment and Waste Management*, vol. 3, no. 1, pp. 116-122.
- [47] Kaoje, U. Garba, J., Christiana, O. N., Olayinka, R. M., Mohammed, Y., Mohammed, A. U. (2018). Biomedical waste handling and knowledge of its health hazards among waste handlers in a tertiary hospital in Sokoto, Nigeria. *Public Health Review International Journal of Public Health Review*, vol. 5, no. 1, pp. 26-32.
- [48] Singh, A., & Raj, P. (2018). Segregation of waste at source reduces environmental hazards of municipal solid waste in Patna, India. *Archives of Environmental Protection*, vol. 44, no. 4, pp. 96-110.
- [49] Shamaki, S. B. & Shehu, A. A. (2017). Assessment of solid waste management in Sokoto metropolis. *Journal of Agriculture and Environment*, vol. 13, no. 2, pp. 159-167.
- [50] Sripada, K., Wierzbicka, A., Abass, K., Grimalt, J. O., Erbe, A., Rollin, H. B., Weihe, P., Diaz, G. J., Singh, R. R., Visnes, T., Rautio, A., Odland, J. O., & Wagner, M. (2022). A children's health perspective on nano-and microplastics. *Environmental Health Perspectives*, vol. 130, no. 1, pp. 1-15.
- [51] Soumiya, M., Balakrishnan, & Shanthi, K. (2018). Composition of municipal solid waste accumulated in Vellalore dump yard from Coimbatore City. *Research Journal of life Sciences, Bioinformatics, Pharmaceutical and Chemical sciences*, vol. 4, no. 40, pp. 156-164.
- [52] Sarkingobir, Y., Umar, A. I., Miya, Y. Y., Hamza, A., Tambari, U., Sule, I. F., & Magori, D. Z. (2022). Determination of selected essential (copper, zinc) and non-essential (lead, chromium, cadmium) heavy metals in some single-use plastics from Sokoto Metropolis, Nigeria. *Journal of Materials and Metallurgical Engineering*, vol. 12, no. 3, pp. 29-37.
- [53] Sarkingobir, Y., Umar, A. I., & Shagari, K. A. (2020). Nanoplastics: Small science with bigger consequence. *Proceedings of Virtual International Conference on Advancements in Nanotechnology (VICAN) & association of Indian Biologists (AIB)*, pp. 82-90.
- [54] Shehu, A. A., Maiyaki, F. U., Yahaya, M. H., & Aliyu, S. (2020). Stakeholders views on ways to reduce the use of plastic bags and its environmental and public health impacts in Sokoto metropolis, Sokoto state, Nigeria. *International Journal of Research and Scientific Innovation*, vol. 7, no. 4, pp. 196-200.
- [55] Malami, Z., Adamu, K., Sahabi, M., & Bodinga, M. (2022). Compliance to infection control practice among blood transfusion laboratory staff of healthcare facilities in Gwadabawa local government, Sokoto state, Nigeria. *Research Journal of Trauma and Disability Studies*, vol. 1, no. 4, pp. 30-45.
- [56] Bergmann, M., Gutow, L., & Klages, M. (2015). *Marine Anthropogenic Litter*. New York: Springer Nature.
- [57] Singh, J., Saxena, R., Bharti, V., & Singh, A. (2018). The importance of waste management to environmental sanitation: A review. *Advances in Bioresearch*, vol. 9, no. 2, pp. 202-207.
- [58] Tait, P. W., Brew, J., Che, A., Costanzo, A., Danyluk, A., Davis, M., Khalaf, A., McMahon, K., Watson, A., Rowcliff, K., & Bowles, D. (2020). The health impacts of waste incineration: A systematic review. *Australian and New Zealand Journal of Public Health*, vol. 44, no. 1, pp. 40-48.
- [59] Ngeno, E. C., Mbuci, K. E., Necibi, M. C., Shikuku, V. O., Olisah, C., Ongulu, R., Matovu, H., Ssebugere, P., Abushaban, A., & Sillanpaa, M. (2022). Sustainable re-utilization of waste materials as adsorbents for water and wastewater treatment in Africa: Recent studies, research gaps, and way forward for emerging economies. *Environmental Advances*, vol. 9, no. 100282, pp. 1-14.
- [60] Sarkingobir, Y., Waheed, S.A., Abubakar, M., & Gilani, N. (2023). Plastic waste materials in a classroom environment: An assessment of nursery

classes in Sokoto state, Nigeria. *Pakistan Journal of Social Science*, vol. 43, no. 2, pp. 217-226.

- [61] Umar, A. I., Sarkingobir, Y., and Dikko, M., (2022). Spectro-analytical research of selected heavy metals (Cu, Cd, Cr, and Pb) in four different single-use plastics commonly in contact with food from Sokoto, Nigeria. *Jurnal Teknokes*, vol. 15, no. 1, pp. 76-80.
- [62] Abubakar, A., Barnabas, M. H., & Tanko, B. M. (2018). The physico-chemical composition and energy recovery potentials of municipal solid waste generated in Numan Town, North-Eastern Nigeria. *Energy and Power Engineering*, vol. 10, pp. 475-485.