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Review Article

The harmful nature of plastic waste mismanagement in the medical laboratory: A review

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ABSTRACT

This papers objective is reviewing the harmful nature of plastics mismanagement in the medical laboratory. Plastics are polymers of great uses. Definitely, they are utilized in the medical laboratory for many purposes, such as wares, safety equipments, etc. However, waste management arround the world, especially in poor settings is difficult as well leading to health and environmental effects. Plastics such as PET, PVC, HDPE, PP, PS, LDPE are useful, buy mismanagement plasticized foods, pollute water, pollute soils; by persistent, emitting hazardous chemicals such as Bisphenols, heavy metals, pthalates, etc. Awareness, education, behavior change, innovation, laws, are key principles in reducing plastic mismanagement effects nowadays.

Introduction

Nowadays, advancements have made healthcare to be delivered by different contributions such as from the laboratory department. A laboratory consists of diagnostic item, tools, and workers professionals that help in diagnosis of problems (Bucci et al., 2020; Velis & Cook, 2024). Laboratory is a place that have different set of instruments, chemicals, and equipments to conduct experiments, researches, investigations. In the laboratory there are several chemicals, instruments, and equipments, that help in curative, preventive, and promotes healthcare delivery (Hamid & Asghar, 2017; Nnebue & Abubakar, 2023). In the laboratory a lot of plastic wares and equipments are utilized. Plastic materials will be more important because they are generally resistant to a lot of chemical attack, withstand mechanical pressure, cheap, and adapt to temperature changes (USEPA, 2023). Plastic laboratory materials are made usually from polymers. However, biomedical waste generally becomes a threatening problem arround the world. Mismanagement of biomedical wastes spur issues such as infection, escalation of chronic diseases, and environmental pollution as well (Kaoje et al., 2017; Kaoje et al., 2018; Ibrahim et al., 2019; Ibrahim et al., 2019).

The Nature of Plastics

Some plastics are of the size > 2-5cm and are called as macro plastics; plastics of the size 1 micrometers-5 millimeters are known as mesoplastics; and the nanoplastics are 1-100nm in size (Bucci et al., 2020; Horton & Blissett, 2021). Generally, plastics are defined as groups of synthetic materials manufactured from polymers composing large molecules. They are integral parts of many useful products in the human societies nowadays because plastics are moldable, durable, flexible, and resistant to certain adversities (Irianti & Prasetyoputra, 2019; Ngeno, et al., 2022; Akanmbi et al., 2024; Deji-Oloruntoba et al., 2024).

Polymer plastics are bioinorganic molecules composing repeating units of monomers that are naturally or synthetically made through a process known as polymerization. Fossil fuel- based made plastics are synthetic and may be thermoplastics (such as polyethylene, polypropylene, polyetheneterepthalate, polyvinyl chloride), and thermoset (such as epoxy, polyurethane)(Pavani & Rajeswari, 2014; Sarkar & Bhuyan, 2018). Some plastics termed as biobased could be biopolymers, biodegradable (assumed to be degradable by microbes and related biological agents of decomposition like fungi and bacteria) (Gazal & Ghewala, 2020). Thermoplastics ideally do not alter their chemical nature upon heating, are therefore molded severally; while thermoset plastics stay adamantly solid, cannot be melted and molded further (Gazal & Ghewala, 2020).

Mostly, plastics can be categorized based on certain polymer resins as enumerated below:

Polyetheneterepthalate (PET)- This category of polymer is found in bottles, clothing, mouthwash bottles, carpet, medicine jars, and ropes.

High density polyethylene (HDPE)- This type of polymer is used to make items such as milk containers, soap bottles, food drinks containers, detergents bottles, etc

Polyvinyl chloride (PVC)- This category is utilized in times such as pipes, tiles.

Low density polyethylene (LDPE)- This category is used to make sandwich bags, grocery bags, squeezable bottles, cling-films.

Polypropylene (PP)- PP resins are categorized in lunch boxes, prescription bottles, yoghurt bottles, syrup bottle, margarine pot.

Polystyrene (PS)- PS plastic is utilized in coffee cups, food boxes, fast food containers, cutlery, as well as packing foam.

Other- This category mostly consists of kinds of plastics other than the aforementioned, such as polycarbonate (PC), as well as polylactide found in medical discharge containers, baby bottles, as well as compact discs(Alam & Ahmade, 2013; Bas & Nzewi, 2018; Ademakoya, 2020).

Nevertheless, the items containing plastic polymers enumerated here are morethan what were identified here, there are other several examples to contend with (Alabi et al., 2019).

Plastics Significance in the Laboratory

Medical Laboratory is handled by scientists and relations in hospitals, research facilities, public health laboratory, schools, universities, etc. The medical laboratory and staff are key Yi learning, research, disease diagnosis, disease prevention, healthcare, and public health (Tadesse, & Admassu, 2006; GESAMP, 2019).

Historically, the role of plastics in the entire healthcare system could not be overstated. Plastics in the laboratory are in several forms such as disposal gloves, syringes, burette, food containers, cleaning supplies, trash bags, protective clothing, IV bags, laboratory equipments, appliances, beakers, pipette, tape, funnel, test tubes, rack, retort, thermometer, goggles, barometer, stop watch, stirrer, centrifuging machine, forceps, pH meter, desiccator, tongs, dropper, etc (Seyoum, 2006; Fikri et al., 2017; Center for International Environmental Law, 2019).

Figure 1: Some laboratory items that may contain plastics

Mismanagement of plastic waste encourage food chain plasticization

Plastics are ubiquitous in the environment we live, and in the laboratory space. This factor encourages incorporation of plastics into food chain by one way or the other. Fragmentation of plastics through deliberate, mechanical, microbial, and photo-based actions bring about tiny plastics (micro plastics) that readily get into water (may be due to bottles, pipes, containers, etc) for human or other biota consumption (Pathak et al., 2024). Plastic polluting aquatic medium results in uptake by specific plants such as lettuce, apple, carrot and animals such as fishes, shrimps, mussels, oyster; and in turn the ultimate consumers take up the plastics along their foods. However, humans can also inhale plastics or chemicals, contact plastics through the skin and effects may resurfaced (Deji-Oloruntoba et al., 2024).

Impacts of plastic pollution on water resource

Water is an essential part of biota. The effects of plastic pollution on water is an alarming. Mismanaged plastic waste finds it's way into the water resources and cause effects. Likewise, incineration of plastics release carbon dioxide, carbon monoxide, heavy metals, and other harmful pollutants leading to contamination of water resources. Plastics in the form of macro plastics could easily release additives or turn into micro plastics that are taken up by aquatic animals which are ultimately consumed by human and other related biota (de Souza Machado et al., 2019; Doyan et al., 2024). This could elicit harmful effects consequently. Nevertheless, plastics have the ability to host microbes, and chemicals which are transported and dissipated along the water medium depending on certain environmental conditions at different points. For instance, chemicals such as nonyphenols, insecticides, fertilizers, etc easily cling into plastic in water medium for further dissipating and shuttling. Regards to aquatic biota, plastics polite animals with harmful chemicals therefore affect food chain. Sometimes, the affected animals are injured or killed due to poisoning instigated by plastics or additives or chemicals as a result of ingestion, trapping and entanglement. For instance, fishes (such as *Acipenser sinensis*, *Pangasianodon gigas*, cartilaginous fish), other mammals (such as dolphin, porpoise), reptiles (example, saltwater crocodile, gharial), are easily ingesting plastics. Likewise, aves such as black kite, satin bowerbird, osprey chicks, etc are affected by plastics in the water habitat (Horton & Blissett, 2021).

Effects of Plastic waste on Soil Environment

Some laboratories or relations especially in poor settings have their waste which is significantly plastic in nature been buried in soil or allowed to rot on the open. However, there are studies that confirmed that plastics in soils change plant traits (generally), alter physical properties of soils, change root traits, change leaf traits, change plant biomass, change soil microbial activities or actions, etc (de Souza et al., 2019). On a similar vein, plastics contaminating soil serve as major pollution source for underground water, and aquatic waterbodies as well (Iwuoha et al., 2013; Takada & Bell, 2021). The presence of waste in the soil environment has been an issue of concern around various parts of the world. Waste debris presence in the terrestrial (soil or land) environment is a great source that facilitates shuttling of harmful chemicals into the fresh water sources, surface water, underground water, and ultimately the marine. For instance, there are several sources of plastics to the soil such as mulching, mismanagement, greenhouse, landfilling, etc(Ryan, 2015; Sidi & Yahaya, 2022). However, waste is greatly containing plastics, the major waste concern of present day world. Plastic contains harmful additives (such as Bisphenol A, flame retardants, etc), harmful monomers (such as styrene, vinyl chloride), and is lovable to many chemicals and microbes; therefore, it is just shuttle of harmful chemicals into the soil for further transport, transformation of soil properties to bad (in most often), absorption by plants into the food chain, and for persistence. Evidence had collected that waste interactions in soil with soil organisms shows that uptake, injuries, and death are possible (Jambeck et al., 2015; Magami et al., 2017; Magami et al., 2018; Nasir & Ibrahim, 2022; Umar et al., 2022).

Waste Incineration Effects

The practice of open burning of waste, which is a widely done practice among many countries, is a disastrous norm because it emits hazardous chemicals to the environment including fine chemicals, carcinogens (poly aromatic hydrocarbons), furan, soot, etc(Mainsalidis et al., 2020; Tait et al. 2020). The practice cause settling of toxic chemicals on crops, lakes, streams, rivers, and ultimately affecting fishes, plants, mammals, as well as livestock. This significantly affect food chain. Mostly, younger ones, older people and sick people are more affected by respiratory disorders such as asthma, chronic obstructive, pulmonary disease. Exposure to chemicals released due to waste burning spur effects on liver, hormonal system, development, reproductive system, and growth. However, nonspecific effects of burning waste include nausea, dizziness, fatigue, headache, allergy, and burning eyes (Mbue et al., 2015; Olugbemiga et al., 2017; Obebe & Adamu, 2020).

Open dumping Effects

Open dumping can be located in roadways, fields, river, abandoned sites, etc. Dumpsites contain mixture of times such as plastics as major portion, tires, hazardous waste, etc (Washam, 2010; Shamaki & Shehu, 2017). Physical injuries could occur due to items like metals, needles, appliances, while chemical substances in the waste could cause impactful hazard. This practice instigate soil, water, air, plant contamination because of leaching and uptake. Open dumps serve as breeding ground for mosquitoes, diseases, animals, unpleasant odour, soil and water contamination, fire outbreak, and threats to wild life and plant biota (Singh et al., 2018; Singh & Raj, 2018; Sripada et al., 2022).

Harmful Nature of Plastic Waste

Burning of plastics could spur emissions of additives such as flame retardants, antioxidants, fillers, impact modifiers, etc; unintended chemicals that got adsorbed unto the polymer; and monomers or the likes such as catalysts, dimers, oligomers (Velis & Cook, 2022). Fires act upon plastics due to heat to cause volatization, bond fission, and new bond formation or transformations (Ryan, 2015; Ngeno et al., 2022; Velis & Cook, 2021).
Incineration (burning)
Waste incineration has been defined as "combination of solid or liquid waste in incineration facilities." Open burning of waste is " the combustion of waste materials in the open, " a condition that elicit uncontrolled release of emission products into the environment (especially the air). Mostly, open burning or incineration is carried out either using machines or in the field in a manner that support incomplete combustion, irregular temperature, and incomplete time for the better combustion and definitely leading to harmful emissions such as carbon dioxide, nitrous oxide, carbon monoxide, methane, furans, heavy metals, gases, dioxins, etc. 1.4 metric ton carbon dioxide equivalents in every one metric ton of plastic burnt (incinerated) (Alabi et al., 2019; Nnebu & Abubakar, 2023; Pathak et al., 2024). Some instances whereby plastic burnt released harmful chemicals are enumerated below:

Polyvinyl chloride - PVC burnt released carbon monoxide, chlorinated furans, dioxins. These chemicals are causing birth defects, respiratory abnormalities, cancer, etc

Polystyrene (or styrene)- PS or derivatives are releasing styrene, hydrogen cyanide, and acrolein. The released emissions cause necrosis, death, cancer, eye and mucous membrane defects (Avio et al., 2016; Abubakar et al., 2018).

Polyurethane - This plastic releases carbon monoxide, phosgene, and hydrogen cyanide and cause death (Pathak et al., 2024).

Pthalates- Pthalates are usually applied as plasticizers in plastics, but their sensitivity to changes such as temperature, pH etc allow them to readily leach. To they are of the potential of forming bond with fats in the body for easier absorption, and upward transformation to form endocrine disruptors, metabolic inhibitors, and thyroid disruptors (Koushal et al. 2014; Karhsima, 2016; Hayes, 2019).

Brominated flame retardants (BFR)- BFR are popularly found in plastics as additives for reducing fire risk. Some of the members such as bromophenols, polybromnitaed diphenyl ethers, tetrabromobisphenol A, hexabromocyclododecane are toxic in nature. When the host plastic is incinerated, these additives quickly get out as gases acting in ash and airborne particulates (Wagner et al., 2014; Velis & Cook, 2021).

Dioxins- There are morethan 419 polychlorinated aromatic chemical compounds termed as dioxins, out of which presently about 40 of them are significantly regarded as harmful to human biological system ensuring effects such as cancers, developmental, neurological, immunological, and hormonal defects. Most of the dioxins are made after incomplete combustion of chlorine containing substances and they are persistent in nature (Prakash, 2017; Verma et al., 2016; UNEP, 2018; Shehu et al., 2020).

Bisphenol A(BPA)- BPS is vastly used in the industry as antioxidants, reactants; and it is a popular endocrine disruptor, cytotoxic, and very ubiquitous additive (Velis & Cook, 2021).

Polycyclic aromatic hydrocarbons (PAHs)- PAHs contain aromatic rings and they are carcinogenic, emitted through open waste burning (Soumiya et al., 2018; Tait et al., 2020).

Particulate matter (PM)- PM is released after plastic burning. It affects visibility, respiratory system, and are deposited on housing and plants tissues (Obebe & Adamu, 2020).

Heavy metals - Heavy metals are found in plastics due to deliberate addition or adsorption. Heavy metals (HMs) are toxic at certain levels in the case of cadmium, arsenic, lead, mercury, etc. Arsenic (III) affects -SH group present in enzymes and proteins (such as pyruvate dehydrogenase) (Salau et al., 2022). Arsenic similarity to phosphorus elicit inhibition of biochemical ways that involved phosphorus. Cadmium is similar to zinc and therefore have the ability to affect enzymes requiring zinc even in plants. A renowned disease of cadmium is popularly called as Itai-Itai Disease causing fragile bones. Lead has the potentials to affect the bran and the entire nervous system, albeit children are affected more. Lead is well-known in it's ability to disrupt enzymes such as those that are responsible in hemoglobin synthesis and as well causing anemia in humans (Wagner, 2014; Sarkingobir et al. 2020; Sarkingobir et al., 2021; Sarkingobir et al., 2023).

Mercury is a major toxic metal albeit it's toxicity varied with speciation. Mercury binds with certain groups in hemoglobin, albumin, and in turn affecting the binded entities. Methylmercury is soluble in fat and can pass across brain, placenta. It inhibits active transport of sugars across the membranes. Chromium has several metabolic effects such as liver necrosis, death due to hexavalent chromium. Hexavalent chromium also causes nephritis, irritation of GIT, digestive tract cancer, nasal ulcers, cancer, and genetic damage. Albeit optimum copper is essential for biota, excess level of the element elicit genotoxicity, and it can accumulate in the brain, liver, in turn instigating liver damage, Wilson Disease, and mental disorders (Reza & Yousuf, 2016; Rasul et al., 2021).

Some Dangerous Behaviors of Plastics

Plastics can exist in certain behaviors that are very detrimental to the biota. Some of the consequential behaviors of plastics can be enumerated as follows:

Bioaccumulation - Plastics and their toxic substances have the ability to bioaccumulate in the biota (Kanweru & Tadibale, 2021).

Biomagnification- Plastics and their toxic substances have the tendency to increase in concentration while dwelling in the biota (Park et al., 2013; Patel et al., 2016).

Formation of fragments -Plastics easily firm smaller fragments such as micro plastics, nanoplastics, that easily enters the biota, environment, and food chain while eliciting deleterious effects. Actions affecting large plastics transformation to particulate include photo degradation, biodegradation, oxidation, thermo degradation, hydrolysis, pyrolysis, etc (Gazal & Ghewala, 2020; Lovo & Rawlings, 2021; Kour et al., 2023).

Persistence- Most of the plastics have along lifecycle ranging from at least 25 years to more; therefore stay much longer in the environment and continually serve as host to microbes and persistent harmful chemicals; while also acting as sour e of harmful toxicants (Libroin, 2015; Alabi et al., 2019).

Suggestions

Recycling utilization has been a proposed method of rightly disposing plastics, albeit most of the plastics are non-recyclable and even the recycling process is coupled with emission of toxic chemicals.

Legislative approach to phase-out the most toxic chemicals from plastics has been suggested severally. It is also important to calm on policy makers to formulate laws that may compel manufacturing companies to make biodegradable or biobased plastics.

Innovation should be encouraged to make new sets of polymers with improved sustainable degradation potential among plastics in use (Deji-Oloruntoba et al., 2024).

Educate the people at public levels and at schools on environmental sustainability especially methods of reducing dependence on plastics (Nnebue & Abubakar, 2023).

Education and awareness need to je strongly raised. The public and technocrats should be educated on sustainable disposal of plastics, ways of plastic use reduction, advocacy ways, dangers of plastics, in order to compel public officers to take right steps for sustainability (Prakash, 2017; Adekunmbi et al., 2024).

Conclusion

Plastics are considerably useful in the laboratory like other facets of human life. However, management of plastics is mostly mismanagement that affects health of humans through polluting (the environment). Behavioral change through awareness is important, innovation, laws, etc are important for remedy of the trend.

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