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Water: Impacts of plastic pollution on human health and biological systems

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ABSTRACT

Current spare of human development consisting of advancements in science and technology that led to the synthesis of plastics, polymers with diverse benefits in human endeavours; and on the other hand, the need for quality water is more intensified nowadays. Plastics pollution is rising due to mismanagement, and inturn causing contamination of water bodies and ultimately affecting biological systems. A review of literatures pertaining water, plastics and water pollution was done to fulfill the objective of this study. This study examines the harmful effects of plastics in water on human health and biological systems. Plastics, widely used in daily life, contaminate water sources, posing significant health risks. This review explores the role of water in biological systems, types of plastics, sources of plastic pollution, harmful chemicals conveyed by plastics, and management strategies.This paper concludes that behavior change, effective waste management, effective water supply and treatment, awareness creation may contribute greatly in controlling water pollution caused by plastic pollution.

Keywords: Plastics, foods, water, contamination, additives, recyling.

INTRODUCTION

Plastics, made from monomers like ethylene and propylene, are versatile but polluting. Their widespread use and improper disposal have contaminated water bodies, releasing toxic chemicals and harming humans and ecosystems. This study examines the impacts of plastics in water on human health (Abdullahi et al., 2023; Abubakar et al., 2018).

Plastics, synthesized from monomers like ethylene and propylene, are widely used due to their durability, moldability, and affordability. They are employed in various applications, including water and food storage. However, the rapid generation of plastic waste poses a significant concern, as it often ends up in water bodies, leading to pollution (Avio et al., 2017). This pollution can harm humans and the environment when plastics release toxic chemicals into water sources. The improper disposal of plastics, exacerbated by lack of awareness and mismanagement, has turned water bodies into plastic reservoirs (Alabi et al., 2019). The interaction between plastics and water facilitates the leaching of harmful additives, posing risks to human health and ecosystems (Adekomaya, 2020; Alabi et al., 2019). This study aims to investigate the adverse effects of plastics in water on human health and relationships.

RESEARCH METHOD

A comprehensive review of existing research on the effects of Heavy Metals (HMs) on nutrition and cognition is essential for informing the public and the academic community. This review aims to synthesize findings from various studies to provide insights into the relationships between water, plastics and plastics pollution and effect on human or biological system. By analyzing and correlating existing literature, this review seeks to identify areas for further research and contribute to the development of theoretical frameworks and conceptual models. In today's fast-paced and

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interdisciplinary research landscape, literature reviews have become increasingly important for advancing knowledge and facilitating theory development. A well-conducted review can integrate findings from multiple studies, address complex research questions, and highlight areas where further research is needed.

RESULT AND DISCUSSION

Water: The Crucial Biochemical Compound in Living Systems

Water is the most abundant chemical compound in living organisms, playing a vital role due to its unique properties. As an ideal solvent, water's molecular structure enables it to form dipoles, allowing it to interact with charged and polar species. This property, combined with its high dielectric constant, facilitates the dissolution of various substances (Stenesh, 1998). Water also forms hydrogen bonds, promoting self-association and ordered arrays. This bonding contributes to water's distinct properties, such as high surface tension, viscosity, and boiling point. Hydrogen bonding enables water to dissolve organic biomolecules, including aldehydes, alcohols, and carboxylic acids (FAO, 2019; Kershaw, 2015). Water's biochemical significance extends to:

1. Stabilizing molecules through covalent and non-covalent bonding.
2. Interacting with amphipathic biomolecules, such as proteins and lipids.
3. Encouraging hydrophobic interactions, reducing unfavorable interactions.
4. Acting as a nucleophile, facilitating hydrolysis and condensation reactions (Stryer, 1988).

The Nature and Types of Plastics

Plastics are synthesized from small units called monomers, which combine to form longer chains known as polymers (Lusher et al., 2017; Sarkingobir et al., 2020). There are two primary categories of plastics: 1. Thermoplastics: These plastics soften when heated, can be reformed, and harden when cooled. Examples include polypropylene, polyamides, polystyrene, and polyethylenes, which can be recycled with proper management. 2. Thermosets: These plastics do not soften when heated due to permanent polymer bonds. Examples include epoxy resins, acrylic resins, and polyurethane (Soumiya et al., 2018; Sripada et al., 2022; Verma et al., 2016). Plastics are widely used in water and food storage due to their:

- Inertness
- Flowability
- Resistance
- Moldability
- Cost-effectiveness
- Lightness (Umar et al., 2022)

Common applications of plastics in water and food industries include:

- Packaging materials (jars, caps, bottles, trays)
- Storage containers (tubs, sachets, bags, films)
- Food wrap and containers (waddings, lids, packs, bins, sacks) (Giacovelli, 2018; Yahaya et al., 2019).

Types of Plastics Used in Contact with Water and Food

Plastics, derived from polymerization of monomers, offer desirable properties such as:

- Chemical resistance
- Heat and electrical insulation
- Light weight
- Processability (Alabi et al., 2019; Tait et al., 2020; Umar et al., 2022).

Common plastic types used in water and food applications include, the famous thermoplastics such as the followings:

1. Polyethylene Terephthalate (PET): Soft drink bottles, mouthwash bottles; recycled into hiking boots, furniture, tote bags.
2. High Density Polyethylene (HDPE): Milk containers, water bottles, toys; recycled into bins, bird feeders, benches.
3. Polyvinyl Chloride (PVC): Clear food packages; recycled into film, road gutters, play equipment.

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4. Low Density Polyethylene (LDPE): Grocery bags, frozen food bags; recycled into trash cans, floor tiles, bins.
5. Polypropylene (PP): Yogurt containers, medicine bottles; recycled into bicycle racks, brushes, cables.
6. Polystyrene (PS): Coffee cups, cafeteria trays; recycled into concrete, rulers, thermometers.

Nevertheless, Other Plastics are:

1. Polycarbonate, Polylactide: Baby bottles, medical containers, compact discs.
2. Thermosets: Urea formaldehyde, casein, vinyl ester, silicone resin, polyimide.
3. Elastomers: Polybutadiene, polydimethylsiloxane, polyurethane rubber, neoprene.
4. These plastics are used in various applications, including packaging, containers, and utensils, due to their unique properties (Sarkingobir et al., 2020, 2022; Sidi & Yahaya, 2022).

Sources of Plastic Pollution in Water

Plastic contamination in water originates from two primary sources:

1. Transport of plastic waste from external environments (land, air, and soil), with land being the major contributor.
2. Plastic materials used directly in aquatic mediums.

Specific sources include:

- Run-off water from land, carrying bulk and microplastics into water bodies.
- Improper waste disposal into water mediums.
- Plastic containers used for water storage, pumping, transportation, and consumption, which can leach plastics into the environment environments (Prakash, 2017; Shamaki & Shehu, 2017; A. Singh & Raj, 2018).

Once in water, plastics can exist as:

- Macroplastics: large entities that break down into harmful microplastics.
- Microplastics: tiny, toxic particles easily absorbed by plants and animals, entering the food chain.
- Key factors contributing to plastic pollution in water include:
- Inadequate waste management
- Uncontrolled run-off
- Direct plastic use in aquatic environments (Prakash, 2017; Rasul et al., 2021; Shamaki & Shehu, 2017; J. Singh et al., 2018; Wali et al., 2022).

Plastics as Vectors of Harmful Chemicals

Plastics can leach harmful chemicals into food, water, and the environment, posing health and ecological risks (Alabi et al., 2019). These chemicals fall into three categories:

1. Monomers: Unbonded or partially polymerized compounds, such as propylene oxide, acrylamide, ethylene oxide, and vinyl chloride, which are hazardous to human health.
2. Additives: Intentionally added chemicals that are not covalently bonded to the polymer chain, making them prone to migration. Examples include plasticizers, flame retardants, and UV stabilizers.
3. Sorbed chemicals: Hydrophobic pollutants, such as persistent organic pollutants (POPs) and heavy metals, that accumulate on plastic surfaces.

Plastics' potential to convey harmful chemicals is exacerbated by:

- Incomplete polymerization (4% of monomers remain unbound)
- Biodegradation, photodegradation, or fragmentation, releasing monomers and oligomers
- Ability to attract and transport microbes, including pathogens (e.g., *Pseudomonas spp, Campylobacteraceae*)
- Contribution to antimicrobial resistance
- The "plastisphere" – the community of microorganisms on plastic surfaces – facilitates the transport of harmful microbes, including viruses and protozoans (Ryan, 2015; Sabo et al., 2022; Sidi & Yahaya, 2022).

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Emerging Innovations in Plastics

In response to growing concerns about traditional plastics, new trends are emerging to develop more sustainable alternatives (Mbue et al., 2015). Some notable innovations include:

1. Oxodegradable additives: Enhance plastic degradation, reducing pollution.
2. Biobased plastics: Derived from renewable resources like corn, sugarcane, and other biomass, offering eco-friendly alternatives, such as:
   - Rayon
   - Polylactic acid (PLA)
3. Biodegradable plastics: Designed to be broken down by microorganisms into harmless products, including:
   - Water
   - Carbon dioxide
   - Methane
   - Energy
   - Biomass

These innovative plastics aim to mitigate environmental impacts and offer more sustainable solutions (Ngeno et al., 2022; Obebe & Adamu, 2020; Otitoju et al., 2023).

The Harmful Impact of Plastics on Animals and Humans

Plastics attract animals due to their scent, color, size, and ubiquity, leading to devastating consequences throughout the food chain. Animals ingest plastics, which can cause harm and eventually reach human consumers.

Plastics affect various species, including:

Wildlife:

- Birds: injuries, blockages, starvation, ulcers
- Fish: death, injury, infection
- Turtles: internal blockage, perforation, starvation, death, ulceration, deformation, poor growth (Ibrahim, 2017; Manisalidis et al., 2020; Mbue et al., 2015).

Humans:

Consuming plastics-contaminated food exposes humans to risks, including:

- Cancers
- Diabetes
- Heavy metal poisoning
- Infertility
- Birth problems
- Poor immunity
- Developmental and growth issues
- Liver and kidney problems

The ingestion of plastics has severe and far-reaching consequences for animal and human health (Nasir & Ibrahim, 2022; Olugbemiga et al., 2017; Yusuf Fardami et al., 2023).

Concerning Behaviors of Plastics

Plastics exhibit several troublesome behaviors (Alabi et al., 2019):

1. Microplastic formation: Plastics <5mm in diameter, including nanoplastics, can be primary (industrially produced) or secondary (degraded from macroplastics).
2. Biomagnification: Toxic chemicals in plastics accumulate in organisms' tissues, increasing concentration as they move up the food chain.
3. Bioaccumulation: Plastics persist in organisms' bodies, reducing excretion rates and posing health risks.
4. Persistence: Plastics resist degradation due to their inert nature, remaining in the environment for extended periods.

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Migration: Chemicals from plastics contaminate water, food, or waste through contact.
Permeation: Plastics allow water or food absorption, diffusion, and desorption, compromising quality and organoleptic properties.
Key characteristics of microplastics include:

- Primary microplastics: pellets, abrasives, films, powders
- Secondary microplastics: degraded from macroplastics

These behaviors contribute to plastic pollution's far-reaching consequences (U. Kaoje et al., 2018; Karshima, 2016; Labbo et al., 2021; Liboiron, 2016; Lovo & Rawlings, 2021; Lusher et al., 2017).

Harmful Constituents and Additives in Plastics

Plastics contain various harmful additives that pose health risks to humans, animals, and plants (Alabi et al., 2019). Key concerns include:

1. Metals: Cadmium, chromium, aluminum, iron, lead, nickel, etc., which can be toxic.
2. Pathogens: Plastics harbor pathogenic microbes, facilitating disease transmission.
3. Flame Retardants: Toxic, persistent, bioaccumulative substances that leach into environments.
4. Phthalates: Plasticizers disrupting endocrine systems, particularly affecting testosterone.
5. Styrene (Polystyrene): Acute exposure causes eye irritation, gastrointestinal issues; chronic exposure leads to central nervous system problems, weakness, hearing loss.
6. Nonylphenols: Proven to reduce fertility, disrupt endocrine systems; banned in Europe.
7. Bisphenols: Cause reduced fertility, altered behavior, hormone disruption.
8. Vinyl Chloride (PVC): Acute exposure leads to drowsiness, dizziness; chronic exposure causes liver damage, cancer.
9. Perfluorinated Chemicals: Accumulate in organs, causing cancer, endocrine disruption, delayed development, reproductive issues.

These hazardous additives contaminate environments, compromising ecosystem and human health (Ibrahim et al., 2019; Irianti & Prasetyoputra, 2018; Jambeck et al., 2015; A. U. Kaoje et al., 2017).

Effective Plastics Management Strategies

To minimize harm to humans and the environment, plastics can be managed through various lifecycle stages: production, consumption, and disposal. Key strategies include:

1. Multiple Use: Refillable, returnable, and reusable plastics reduce waste disposal.
2. Energy Recovery: Incineration generates electricity, producing heat for various uses.
3. Recycling:
   - Mechanical Recycling: Sorting, drying, granulating, shredding, and compounding.
   - Chemical Recycling: Pyrolysis, depolymerization, and other processes.
4. Bans: Restrict single-use plastics, microplastics, PVC, and PS in food and water contact.
5. Information Accessibility: Educate the public on plastic chemicals and associated harms (Sarkar & Bhuyan, 2018; Sarkingobir et al., 2020, 2021, 2023; Shehu et al., 2020).
6. Water Treatment: Remove microplastics and impurities through:
   - Coagulation
   - Membrane filtration
   - Flocculation
   - Flotation/sedimentation
   - Chlorination
   - Advanced oxidation
   - Ozonation
   - Turbidity control (FAO, 2019; Wali et al., 2022; Yahaya et al., 2019).

Advanced methods for detecting plastics/additives include chromatographic and spectroscopic techniques.
Additional strategies:

- Reduce plastic use
- Refuse harmful plastics

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- Recycle/compost plastics
- Implement policy changes

By adopting these strategies, individuals, communities, and policymakers can mitigate plastic pollution's environmental and health impacts (Dauvergne & Islam, 2023; Fikri et al., 2017; Hamid & Asghar, 2018; Reza & Yousuf, 2016).

CONCLUSION

Water is vital to all biological systems, and plastics have become ubiquitous in human activities. However, plastics' widespread use has led to reckless mismanagement, resulting in pollution of drinking water and water bodies. To mitigate this issue: 1.) Effective plastics management is crucial; 2.) Proper water treatment is essential for safe domestic use; 3.) Cleaning water bodies is imperative. Raising public awareness through education and enlightenment can: 1.) Encourage responsible behavior; and 2.) Prompt policymakers to address plastic pollution decisively.

Collective action is necessary to protect water resources and prevent plastic pollution's harmful impacts on human health and the environment.

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