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Plastic in Water and Its Implications in Human and Biological Systems

Yusuf Sarkingobir, Ummu Tukur*

Shehu Shagari University of Education Sokoto, Nigeria
*Correspondence: E-mail: superoxidedismutase594@gmail.com

ABSTRACT

The objective of this work is to explain the harms of plastics present in water as they affect humans and relations. Plastics are major polymers in contemporary dealings of human endeavors. They are synthesized through the addition or condensation of monomer units and serve humans with their distinguishing benefits such as the ability to be processed to various things by molding. Extensive uses of plastics show that all human activities use plastic for one purpose or the other. Water utilized by humans is in constant contact with plastics indicating a probable pollution that affects human health. This paper reviews the role of water in the body (systems), types of plastics, types of plastics, harm to animals, concerned behaviors of plastics, harmful contents, and management. There is a need for enlightenment, and strict laws (policies).

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1. INTRODUCTION

Plastics are polymers made through a combination of certain monomers such as ethylene, propylene, vinyl chloride, etc. Plastic polymers are easy to buy, durable, and applicable in almost entire human endeavors due to their being moldable. Some plastics are used to store water and food, and some are utilized for other purposes (Wagner *et al*., 2014; Verma *et al*., 2016). A great concern about plastics is, the increasing plastic waste being generated every day in both developing and developed countries, forcing plastic waste to be inappropriately dumped in water bodies and elicit pollution. In the end, humans would be more harmed when plastics in stored water or waterbodies dissipate harmful chemicals into the human biological system (Sarkar & Bhuyan, 2018; Sarkingobir *et al*., 2020). Due to several activities, misappropriation, and poor knowledge or awareness waterbodies (that support human life in agriculture, foods, etc) are becoming the reservoir of plastics (Park *et al*., 2013; Nasir & Ibrahim, 2022; Otitoju *et al*., 2023). Any contact of plastics with water will be susceptible to the migration of harmful additives to harm the human biological system or other biota (Tait *et al*., 2020; Ngeno *et al*., 2022; Umar *et al*., 2022). The objective of this work is to explain the harms of plastics present in water as they affect humans and relations.

2. METHOD

This study is a literature survey. Data was taken from internet sources, specifically articles published in international journals. Data was taken from Google Scholar. Data was analyzed and summarized to get a review study.

3. RESULTS AND DISCUSSION

3.1. The Biochemical Role/Status of Water in the Biological Systems

Water is the most dominant chemical compound in living systems. Water has certain peculiar properties that influence its purpose. Water molecule is an ideal solvent for biological systems. The property of being a great solvent is achieved by the features:

Formation of dipoles- Indeed water molecules make dipoles. In this vein, the water molecule's nature of irregular, and highly skewed tetrahedron possessing a centered oxygen is appreciable, because the strong electronegative oxygen attracts electrons away from the hydrogen nuclei, so that the partial positive charge goes for hydrogen, and local negative charge is ensured. This is a dipole because it exists as an electrical charge distributed asymmetrically. The dipole of the water molecule ensures its high dielectric constant, thereby ensuring that water decreases the force of attraction between charge and polar species related to a water-free environment possessing a lower dielectric constant. The property of water of being of strong dipole, and elevated dielectric constants encourage its capacity to dissolve large quantities of charge substances or compounds (Labbo *et al*., 2021; Wali *et al*., 2022).

Water makes hydrogen bonds as well. When a partially unshielded hydrogen nucleus is covalently linked to electron-withdrawing nitrogen or oxygen, an interaction with an unshared electron pair of nitrogen or oxygen is encouraged. This is a hydrogen bond and is the real nature of water molecules, therefore, hydrogen bonds in water encourage the self-association of water molecules to make ordered arrays (Magami, 2013). The hydrogen bond of water makes many of its properties such as high surface tension, high viscosity, and high boiling point. In turn, hydrogen bond allows water to dissolve organic biomolecules that are involved in hydrogen bonds, for example, the case of aldehydes, alcohols, ketones, amides, amines, carboxylic acids, etc.

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Covalent and non-covalent bonding make molecules stable. Biomolecules are mostly amphipathic, that is, they behave in such a manner that charged or polar entities are released outwards. Proteins store amino acids with R-groups (for example serine, glutamate, arginine) inside. While polar groups are held outwards to interact with water. This is a situation of the lipid bilayer of the biological system that sets the polar heads, the phosphatidyl serine, and phosphatidyl ethanolamine outwards, while the fatty acids are kept away from water. This is favorable dealing with a lot of biochemical benefits.

Water encourages hydrophobic interactions, whereby, the non-polar units "self-associate" when on a water medium, a behavior that reduces non-favorable interactions in water. Moreover, water is an exquisite nucleophile. The ability of water molecules to react as nucleophiles with other molecules is an enormous thing that for example facilitates hydrolysis of many compounds such as amides, glycosides, and esters. Similarly, condensation reactions release water as byproducts, such as in the case of peptide bond formation. Many reactions involve the transfer of groups to water; therefore, water facilitates many reactions.

3.2. Plastics Nature and Types

Plastics emerged through a synthesis process that involved reacting small units called monomers to make longer chains called polymers. Generally, on many occasions, two types of plastics are recognized, viz, thermoplastics and thermosets. Thermoplastics are the type that soften when heated, potentially have the ability to be reformed, and harden when subjected to cooling. This category of plastic is potentially recycled when managed properly, such as in the cases of polypropylene, polyamides, polystyrene, and polyethylenes. Thermosets, the second type of plastics do not soften when heated owing to the permanent bonds made in the polymer, for example, epoxy resins, selected acrylic resins, and polyurethane. Nevertheless, plastics have been widely utilized in water and food storage because they are believed to be inert, flowable, resistant, moldable, cost-effective, and lightweight. Many uses of plastics in water and food industries could be traced to jars, caps, bottles, trays, tubs, sachets, bags, films, waddings, lids, packs, bins, sacks, etc (Avio *et al*., 2017; Fikri *et al*., 2017; Bas & Nzewi, 2018).

3.3. Role of Different Types of Plastic in Contact with Water or Food

Certainly, while plastics are polymers, polymers are a product of a combination of "poly" and "mers" meaning "many" and "units or monomers." A polymer is just a product of polymerization of smaller units (monomers) made through processes such as addition and condensation polymerization. The polymers are ideally resistant to diverse chemicals, resistant to diverse compounds, resistant to heat, and electricity (act as insulators), light-weighted, and processable into disparate entities (Chitaka & Goga, 2023). Different common types of plastic resins are useful in many ways and come in contact with foods or water as mentioned below:

(i) Polyethylene Terephthalate (PET). PET polymers are present in soft drink bottles, and mouthwash bottles. When recycled PET is found in hiking boots, furniture, picnic tables, tote bags, fencing, cartridges, etc.

(ii) High-Density Polyethylene (HDPE). HDPE is present in milk containers, juke containers, water containers, toys, detergent bottles, and grocery bags. HDPE when recycled is found in items such as bins, bird feeders, benches, clipboards, vitamin bottles, and laundry bottles.

(iii) Polyvinyl chloride (PVC). PVC is present in clear food packages. When recycled, PVC is allowed in film, road gutters, play equipment, panels, flying discs, cushions, etc.

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(iv) Low-density polyethylene (LDPE). LDPE is commonly traced to grocery bags, frozen food bags, and bread bags. However, some recycled products including trash cans, floor tiles, bins, mud flaps, panes, etc

(v) Polypropylene (PP). PP is a popular polymer resin present in yogurt containers, medicine bottles, ketchup bottles, and margarine tubs. Nevertheless, recycled PP could be present in bicycle racks, brushes, cables, ice scrapers, funnels, brooms, etc

(vi) Polystyrene (PS). PS is often used in coffee cups, cafeteria trays, grocery bags, and sandwich containers. Recycled PS forms include concrete, rulers, thermometers, switches, egg cartons, desk trays, insulators, etc

(vii) Polycarbonate and polylactide are used as baby bottles, medical containers, and compact discs.

(viii) Thermosets include Urea formaldehyde, casein, vinyl ester, silicone resin, polyimide, bismaleimide, melamine formaldehyde, Formica, and Thiourea formaldehyde.

(ix) Elastomers include polybutadiene, polydimethylsiloxane, polyurethane rubber, neoprene, and chlorosulfonated polyethylene (Alam & Ahmade, 2013; Ibrahim *et al*., 2021).

3.4. Sources of Plastics in the Water

Plastics in water (aquatic medium) are either due to the transport of plastic waste from other habitats (such as land, the major source, and air or soil), and plastic materials used in the aquatic medium (Yahaya *et al*., 2019). Parable, run-off water from land carries bulk and minute plastics into soils and water mediums; waste materials disposal into water mediums also contributes significantly to plastic pollution of water mediums. However, the plastic material in water medium could exist as large entities called macroplastics that can further be acted upon to give out many harmful entities called microplastics. It is also important to stress that the plastics containers used for storage, pumping, transport, hand drinking of water are good sources of plastics that can easily be taken up by plants or animals into the food chain (Kajoe *et al*., 2017; Ibrahim *et al*., 2019; Irianti & Prasetyoputra, 2019; Malami *et al*., 2022; Nasir & Ibrahim, 2022).

3.5. Plastics as Conveyers of Chemicals That Are Potentially Harmful

The chemicals in the plastic folds are divided into several types (**Figure 1**). They can either be monomers, additives, and sorbed chemicals. Concerns about the ability of plastics to convey harmful chemicals that affect health and the environment can be identified severally. Monomers are not ideally completely bonded (polymerized) in the chain (Rasul *et al*., 2021). Likewise, biodegradation by microbes, photodegradation, fragmentation, or otherwise easily loose polymers into oligomers, and monomers, that leach into the food, water, and environment. Indeed, about 4% of the monomers are redundant in a polymer chain at the halt of polymerization. The most common monomers of concern could be propylene oxide, acrylamide, ethylene oxide, and vinyl chloride are significantly hazardous. Additives added to plastics on purpose are mostly hazardous. They behave as not covalently bonded entities in polymer chains and, therefore, migrate easily (Soumiya *et al*., 2016). Because plastics are ideally hydrophobic, they can gather hydrophobic chemicals such as persistent organic pollutants (POPs), heavy metals, etc; the chemicals could be disposed of or consumed by organisms as well. Formation and transportation of plastisphere rampantly occur in plastics. Plastics can attract microbes, as well as convey them to a distance. Thus, sewage microbes, and harmful microbes (such as viruses and protozoans) could be transported or ingested

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along with plastics. Microbes, such as *Pseudomonas spp* and *Campylobacteraceae* could be found in plastics. Likewise, plastics have been reported to increase antimicrobial resistance.

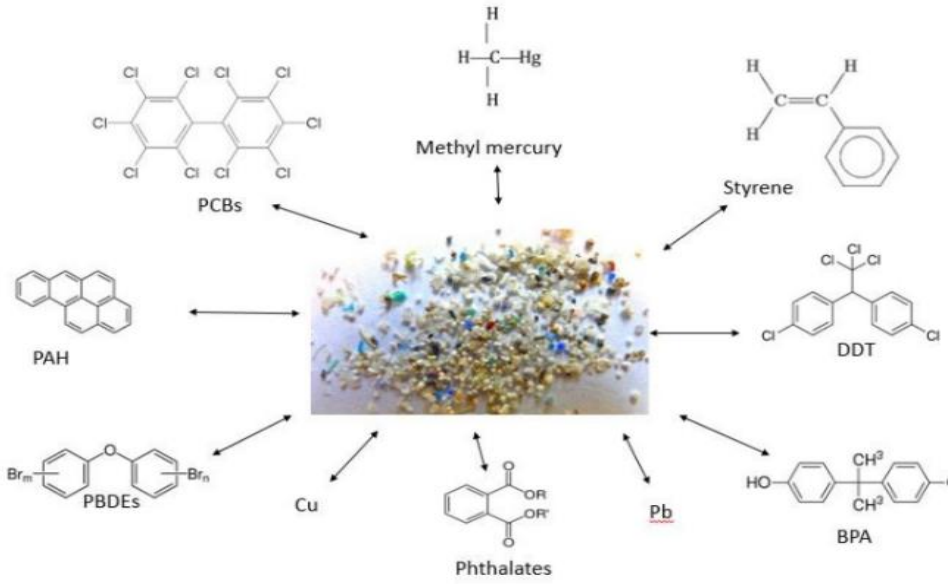

Figure 1. Examples of dangerous chemicals in plastics (Bas & Nzewi, 2018).

3.6. Innovations in Plastics

Nowadays, due to concern about ideal plastics, new innovative trends are emerging intending to bring more opportunities better than ideal plastics (Mbue *et al*., 2015). Oxodegradable additives are added to plastics to reduce pollution. Biobased plastics that are made from corn, sugarcane, and relations are intended to make better alternatives; for example, Rayon, and polylactic acid. Utilization of plastics that are "biodegradable" capable of being degraded by microbes partially or completely to give out water, carbon dioxide, methane, energy, and biomass, is a good Innovative idea to reduce plastic effects haply (Manisalidis *et al*., 2020; Sarkingobir *et al*., 2021).

3.7. Plastics Are Harmful to Animals

Because of scents, colors, size, conspicuousness, and ubiquitousness, many animals are attracted to plastics on land or water mediums (**Figure 2**). Therefore, plastics affect animals and are found along the food chain; because the consumers while eating animals are possibly ingesting plastics as well. Parable, some of the animals reported to be affected by plastic consumption are as follows:

(i) Birds- Affected by injuries, blockage, starvation, and ulcers
(ii) Fishes- Effects include death, injury, infection
(iii) Turtles- Affected by blockage internally, perforation, starvation, death, ulceration, deformation, and poor growth.
(iv) Humans- Cancers, diabetes, heavy metal poisoning, infertility, birth problems, poor immunity, development and growth problems, liver problems, and kidney problems (Hamid & Asghar, 2017; Magami *et al*., 2017; Alabi *et al*., 2019; Adekomaya, 2020; Malami *et al*., 2022).

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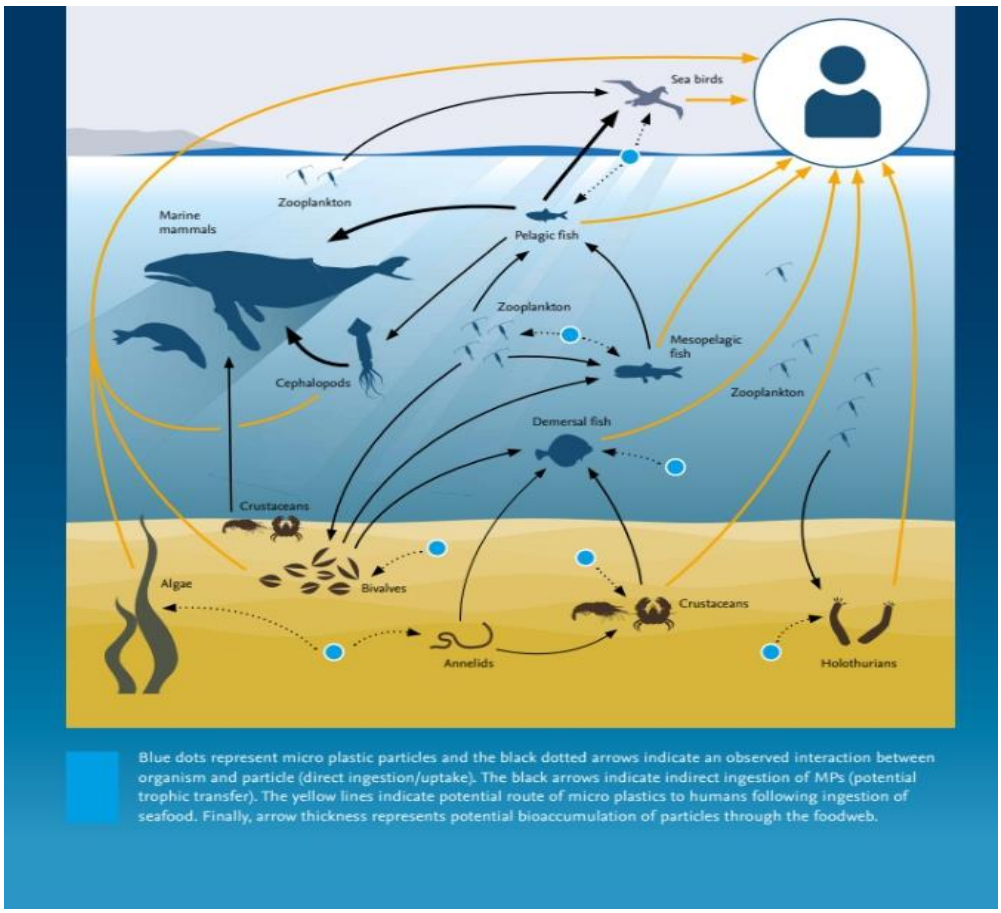

Figure 2. Plastics affecting animals in water medium.

3.8. Behaviors of Plastics of More Concern

Microplastics as a concern plastic entities is a common trend. Microplastics are types of plastics that are particle in nature, they are below 5 millimeters in diameter (they include nanoplastics). Microplastics can be made initially by the industries as primary microplastics, and be done through degradation of macroplastics as secondary microplastics. Primary microplastics include pellets, abrasives, films, powders, etc. Biomagnification is another behavior in plastics. Plastics tend to increase in concentration of their toxic chemicals while dwelling in organisms' tissue as they move to the top of the food chain. Therefore, the higher the level of organisms in the food chain (trophic level) the higher the potential risk due to plastic consumption. Bioaccumulation of plastics is noxious because plastics tend to stay in the body of the consuming organism by reducing its excretion rate. Persistence is an adamant feature of plastics; therewith, they stay for longer years before being completely degraded because they are mostly comparatively inert (Patel *et al*., 2016; Alabi *et al*., 2019; Sabo *et al*., 2022). Migration of chemicals into contact is common in plastics. Plastics in contact with waste, water, or food allow the migration of plastics and resultantly lead to contamination or pollution (Reza & Yousuf, 2016). Permeation is another feature of plastics. Plastic materials allow the solution or absorption of water (or food contact) into the surface of polymer plastics. They also allow diffusion or migration, desorption, or emergence of water (food or others) from the opposite surface. Consequently, the quality of water or food as well as organoleptic properties could be distorted by plastic medium (Obebe & Adamu, 2020; Dauvergne & Islam, 2023).

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3.9. Harmful Constituents or Additives of Plastics

There are several additives of plastics that are harmful to plants, humans, and animal's health. Some of them are itemized as follows:

(i) Metals- Plastics contain metals such as cadmium, chromium, aluminum, iron, lead, nickel, etc that could be hazardous to living organisms.

(ii) Pathogens- Plastics condone the growth of microbes that could be pathogenic and hence could harm the receiver organisms or humans. Mosquitoes and pests can utilize plastics as a hazard and ultimately affect human health generally.

(iii) Flame retardants- These are substances intended to curtail flammability, as well as the spread of fire. The concern is they are toxic, persistent, bioaccumulative, leach, and common in plastics.

(iv) Phthalates are common plastic plasticizers to aid plastic in becoming pliable. Many of them are endocrine disruptors (for example are known for affecting testosterone, a significant male hormone) (Sidi & Yahaya, 2022; Sarkingobir *et al*., 2023).

(v) Styrene of Polystyrene. Styrene acute exposure affects the human's mucus membrane and causes other effects such as eye irritation, and gastrointestinal effects. Chronic exposure effects include central nervous system problems, weakness, hearing loss, fatigue, headache, and peripheral neuropathy (Rasul *et al*., 2021; Sidi & Yahaya, 2022).

(vi) Nonylphenols are used in plastics and leach to the contacts. They are proven to reduce fertility, and destroy the endocrine system; therefore, prohibited in Europe.

(vii) Bisphenols are groups containing hydroxyphenyl functionalities proven to cause reduced fertility, altered behavior, and hormone disruption.

(viii) Vinyl chloride is present in PVC plastics. Acute exposure to this monomer causes drowsiness, dizziness, and headache; while chronic exposure can cause liver damage and cancer (Sidi & Yahaya, 2022; Sripada *et al*., 2022).

(ix) Perfluorinated chemicals are compounds added to plastics and the concern is their ability to dwell in the liver, spleen, kidney, and brain, in turn causing cancer, endocrine disruption, delayed development, and disrupted reproduction (Sidi & Yahaya, 2022).

3.10. Plastic Management

Plastics can be managed through various steps of its lifecycle, beginning from production, and buying to the disposal step (Liboiron, 2016; Shamaki & Shehu, 2017). The following points are some reiterated plastic management to minimize harm to humans and environmental consequences:

(i). Multiple uses of Plastics. The practice of refillable, returnable, and reusable plastics in many instances reduces plastic waste disposal to prevent water pollution (Singh *et al*., 2018).

(ii). Energy Recovering. Plastic is a material composing a huge amount of energy that should not be wasted. A strategy of utilizing plastics using incineration to generate electricity under controlled conditions is a proven strategy (Karhsima, 2016; Kingsley *et al*., 2016). Additionally, plastics could be used to produce heat for various home uses. Application of heat upon plastics instigates the divulgence of fuel gases that combine with air leading combustible mixture that gives out heat to facilitate cycle continuation. There is diverse recycling broken down to furnish materials utilized for making new plastics feedstock or products (Sarkingobir *et al*., 2022; Abdullahi *et al*., 2023).

(iii). Mechanical Recycling is a management tip that uses mechanical approaches (including sorting, drying, granulating, shredding, and compounding) to convert plastic waste items (Singh & Raj, 2018).

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(iv). Chemical Recycling utilizes chemicals means to decompose used plastics for further production or usage (such as the use of plastic as a fuel source) example pyrolysis (cracking) or depolymerization, Econyl process, and Vinylloop-process.

(v). Bans. Many plastics, at certain points, should be banned. Parable, single-use plastics, and microplastics should be banned (for example takeaways, bottles, bags, straws, and microbeads), and polymers like PVC and PS should not be allowed in contact with food and water. Likewise, PVC and PS should be taken away from children's contacts at all (Kajoe *et al*., 2017; Shehu *et al*., 2020; Sarkingobir *et al*., 2023).

(vi). Provide information Accessibility. There is urgent importance in providing information on chemicals contained in plastics and associated harms due to plastics to the environment and human health; so that the public makes the right decisions in exercising better preventive policies. This will impose behavior change so that, people reduce the use of plastics, refuse certain plastics, recycle certain plastics, and compost plastics; to the best of individual, cooperative, and policy maker's abilities. The availability of information instigates the public to seek the government to make law strategies that reduce plastic mismanagement (Kaoje *et al*., 2018; Magami *et al*., 2023).

(vii). Treatment of Drinking Water for Plastic Pollution Minimization. Certainly, sources of microplastics to water include plastic waste mismanagement (poor waste disposal strategies), water treatment apparatus, clothing through laundries, water bottles, agro-plastics, cosmetics, recreation, landfilling, bags, etc. (Verma *et al*., 2016; Abubakar *et al*., 2018; Iwuoha *et al*., 2013; Abdullahi *et al*., 2023). Usually, groundwater is naturally filtered and thus, is supposed to be maximally treated by natural actions to remove impurities. However, other forms of water such as tap water, bottled water, etc are expected to be subjected to treatment to remove impurities when quality standards are maintained. Ideal basic methods for water treatment include coagulation, membrane filtration, flocculation, flotation or sedimentation, chlorination, advanced oxidation, ozonation, and turbidity control strategies (Magami, 2013; Magami *et al*., 2017).

Other advanced methods that could be used to identify plastics or additives include, chromatographic techniques, spectroscopic methods, etc (Ibrahim *et al*., 2019; Ibrahim *et al*., 2021).

4. CONCLUSION

Water is naturally essential to all biological systems. Nowadays, plastics are useful in almost all human dealings. This essentiality of plastics in diverse uses spurred careless mismanagement and in turn, caused plastics to pollute drinking water and water bodies. It is important to manage plastics well, treat water well before domestic and related uses, and clean our water bodies. Education and enlightenment could help spur the public to act rationally and also force policymakers to tackle plastic pollution.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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