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Cover Page Footnote

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Microplastics in water, their effects on the aquatic ecosystem and human public health, and the proposed solutions

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Abstract

We could be swallowing a credit card's weight in plastic every week. Microplastic water pollution is becoming a threat to both humans and aquatic creatures. In this research, microplastic water contamination is discussed, and divergent solutions are proposed. This paper attempts to investigate the causes and effects of such pollution and analyze the current solutions for this issue. The adopted research method is secondary research, where several studies are explored and analyzed. This study explains numerous causes for this issue like cosmetics, cleaning products, factories, and sewage. Consequently, this contamination can negatively impact the organs and metabolisms of the living organisms due to either physical or chemical exposure to the microplastics. The solutions mentioned in the paper were divergent and span across various fields, including electrocoagulation (removing microplastics using electricity), chemical coagulation (removing microplastics using chemicals), and magnetic removal (removing microplastics using magnetic force). In fact, the findings were promising, and many solutions were found, with removal efficiency reaching more than 90%. Those solutions were eco-friendly and could be applied to real life and in different countries. Egypt is one of those countries in which the solutions can be constructed. Egypt has enough resources, labor, and experts to adopt such projects. Over and above, this will cope with Egypt Vision 2030. It was realized that microplastic pollution is a disastrous global matter that needs more attention and steps toward reducing its dangers to the existence of human beings.

Keywords: Microplastics; Polymers; Human health; Aquatic ecosystem; Cosmetics; Cleaning products; Electrocoagulation; Chemical coagulation; Magnetic removal

The world faces many grand challenges that affect its development process and its sustainability, and water pollution is one of the major obstacles . Industry, agriculture and livestock farming, rubbish and fecal water dumping, and maritime traffic are key factors that play a role in the country's water insecurity, which causes the contamination of the water. One of the significant pollutants of the water that many people ignore is microplastics. Recently, microplastics have been detected in drinking water supplies, seas, and oceans. This presence of microplastics has sparked debates about possible human health implications and is considered as a danger to aquatic life as well. As a result, several prior solutions have been attempted to solve this disastrous problem. Increasing awareness and overcoming such an issue will be an excellent step towards achieving the United Nations Sustainable Development Goals (SDGs). After looking into microplastic contamination, it is found that it is related to two essential SDGs: clean water and sanitation (Goal 6) and life below water (Goal 14). Solving the problem of microplastics will contribute in a significant way towards reaching the goal of clean water and sanitation because microplastics are

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one of the most dangerous pollutants the world needs to prevent. Besides, microplastics negatively affect aquatic creatures, and in many scenarios, it leads to their death. Microplastic contamination is a severe worldwide complication that adversely influences both human health and that of aquatic animals, and people and the scientific community need to adhere to such an affair. After investigating the prior solutions proposed by the scientific community, some great ideas have been found, including electrocoagulation (removing microplastics using electricity), chemical coagulation (removing microplastics using chemicals), and magnetic removal (removing microplastics using magnetic force).

1. Problem analysis

Microplastics are solid polymer organic particles that are less than 5 mm. Microplastics are small plastic particles used in beauty products and hand cleansers. These contaminants can now be detected in almost all marine habitats. Because of their extended lifespan, plastics are significantly impervious to degradation, and they wind up in the aquatic ecosystems as a result of indiscriminate dumping (Sharma & Chatterjee, 2017). This definition is similar to that found in Duis & Coors (2016), who wrote: synthetic organic polymer particles with a diameter of less than 5 mm are known as microplastics. What's new is that in Duis & Coors (2016), the solid microplastics particles which are between 100 nm and 5 mm are referred to as microplastics due to the notion of nanoscale (1–100 nm).

Noteworthy is that microplastics have been detected in water, and they present a significant amount. According to Shen et al. 's study (2021), they have measured the number of microplastics in the number of particles per liter over four months. The mean values for raw freshwater in the four months were: 2173 ± 112 (no. of particles L-1) for April, 2258 ± 172 (no. of particles L-1) for May, 2584 ± 113 (no. of particles L-1) for June, and 3998 ± 246 (no. of particles L-1) for July. So, this will affect aquatic creatures. Then, they investigated the amounts after the filtrations to see the effects on humans. The mean values for the treated water in each month were: 282 ± 13, 338 ± 21, 388 ± 14, and 400 ± 13 number of particles per liter. The results imply that the microplastics in water are very high, and the filtration systems cannot eliminate the presence of microplastics in water. This is strong evidence for the profusion of microplastics in water.

1.1. Characteristics of microplastic particles

1.1.1. Origination

According to their origination, there are two main types of microplastics: primary and secondary. Primary microplastics are the microplastic particles manufactured and produced by factories in a micro-size range like the particles found in cosmetic products. On the other hand, secondary microplastics are formed from the fragmentation of larger particles of plastics like the particles formed from throwing plastic bags after their degradation in water (Duis & Coors, 2016). This view is supported by Lassen et al. (2015), who wrote that primary microplastic particles are utilized as exfoliants in several personal care product categories, such as hand cleaners, face cleansers, and toothpaste. Other studies have been found supporting the same findings of Duis & Coors (2016) and these studies noted that it is expected that 75–90% of the plastic waste in the marine environment comes from land-based sources (secondary microplastic particles), with the remaining 10–25% coming from ocean-based sources (Andrady, 2011; Mehlhart et al., 2012). Now we can say that either the particles of microplastics are produced in micro-size from the beginning, or they degrade from larger pieces of plastics.

1.1.2. Shape

Microplastics appear in different shapes. The three main shapes that have been found for the particles are fibers (8.0 μg/mg), fragments (1.7 μg/mg), and beads (0.5 μg/mg). According to Gray & Weinstein (2017), the geometries of microplastics (beads, fragments, and fibers) have a major impact on their absorption in grass shrimp, with fragments accumulating substantially more in the stomach than beads and fibers and being more toxic than the other types. In contrast to Gray & Weinstein (2017), Qiao et al. (2019) argued that microplastic fibers buildup in the gut of fish generated several harmful consequences, including mucosal injury, increased permeability, inflammation, and metabolic disturbance, and microplastic fibers caused more severe intestinal toxicity than microplastic fragments and beads. As a result, we can see that the level of toxicity and accumulation of different shapes of microplastics is a controversial topic in the scientific community.

1.1.3. Polymer type

There are several types of polymers of microplastics. Fischer & Scholz-Böttcher (2017) claimed that there are about 8 types of polymers with varying percentages: Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), Polyvinyl chloride (PVC), Polyamide 6 (PA6), Poly(methyl methacrylate) (PMMA), Polyethylene terephthalate (PET), and Polycarbonate (PC). A study looked into the same characteristics by using samples from the Atlantic Ocean to discover that about 48% of the microplastic particles found in the samples were polyethylene (PE) and polypropylene (PP) (Enders et al., 2015). If we investigated those results, we could come up with a convincing conclusion. PE is used in the manufacture of soft drinks, milk, and juice bottles and is used in cosmetic products. In addition, PP is mainly used in producing toys, plastic containers, and reusable plastic water bottles. Since all these products are daily use ones, either humans or factories of these products are the primary source for microplastics dumping in the water. Those previous studies focused on water in general, but Xu et al., 2021 were more concerned about wastewater treatment plants (WWTPs). They discovered that the main polymers found in WWTPs are polystyrene, polyethylene, and polyvinyl chloride. Hence, polymer's types depend on many factors like the location, the nature of the water, and the environment around this water.

1.2. Causes of spreading microplastics in water

Many studies dived into exploring the causes of microplastics pollution but from different aspects and considerations (Carr et al., 2016; Claessens et al., 2011; Fendall & Sewell, 2009; Lechner et al., 2014; Leslie & Vethaak, 2014). For instance, Leslie & Vethaak (2014) investigated the sewage and treated effluents. On the other hand, Carr et al. (2016) and Fendall & Sewell (2009) investigated cosmetics and cleaning products. From a different point of view, Claessens et al. (2011) and Lechner et al. (2014) focused more on the industrial causes and factories.According to Leslie & Vethaak (2014), plastic sources are generally found on land because it is man-made commodity; however, because many plastic particles may be found in both sewage sludge and treated effluents, they end up building up in aquatic systems. Following up the same approach, Carr et al. (2016) discovered that cosmetics and cleaning products, which are released in home wastewaters, are the primary culprits of polymeric micro-and nano-sized plastic particles in aquatic systems. Before the previous study, Claessens et al. (2011) argued that spills of plastic resin powders or pellets used in air blasting contribute to microplastic pollution. Lechner et al. (2014) further confirmed this by arguing that industrial sources, such as feedstocks used in the manufacture of plastic goods, are also considered a major source for the contamination. An investigation in the past used a similar approach to that used by those previous researchers but with more specifications (Fendall & Sewell, 2009). The authors demonstrated that facial cleansers act as a source to be reckoned with. We can realize that there are a variety of sources of microplastics, and we need to eliminate as they continue to pose a greater threat to various systems

1.3. Effects of plastics on ecosystems, aquatic creatures, and human health

Now, after investigating the causes, we need to look into the impacts, which is a widely studied field(da Costa et al., 2016; Duis & Coors, 2016; Dimitriadi et al., 2021). da Costa et al. (2018) and Dimitriadi et al. (2021) gave attention to the biological effects on different organs and metabolisms of aquatic life creatures, but Duis & Coors (2016) considered closely the way of the microplastics from the moment they enter the body till the excretion. da Costa et al.'s study (2016) introduced a well-structured model for the impacts. They divided the impacts into two main categories: physical and chemical exposure. The physical exposure is due to macro-plastics, meso-plastics, microplastics, or nano-plastics. Macro-plastics and meso-plastics cause starvation, reduction in food consumption, and digestive tract internal injuries or even blockage to aquatic life creatures. Micro-plastics and nano-plastics are more dangerous. They can lead to behavioral effects like harmful mobility effects and reduced vigor, morphological effects like inhibiting the formation of fat deposits and effects on enzyme secretion, and reproductive effects like delayed ovulation.

Chemical exposure has two forms that impact aquatic life: sub-lethal and lethal. The sub-lethal chemical exposure has behavioral effects similar to nano-plastics, morphological effects like the changing heart rate and neurotoxicity, and reproductive effects like delayed maturity and growth inhibition. Lethal chemical exposure leads to death. In the same vein, these results are like those reported by Duis & Coors (2016), who clearly explored the process of microplastics movements in the body of sea life. The authors claimed that the journey starts with the ingestion. After the animals ingest the microplastics, they exist in considerable amounts in their bodies. The following stage is the transfer of the microplastics from the intestinal tract to the surrounding tissues or circulatory system. There are two ways for microplastics after ingestion. One way is to remain in the intestinal tract and then excreted or be absorbed by body tissues. The second way is to transfer to any circulatory organ or even to the blood. In the end, if the particles remain in the intestinal tract, it will take hours or a few days for most of them to be excreted. If the particles are transmitted to the circulatory system, the excretion will have a lower possibility to occur and will be much slower. This was an interesting journey and at the end of the day they asserted the same negative effects on human and aquatic creatures as da Costa et al. (2016). These views of harmful effects are supported later by Dimitriadi et al. (2021), who wrote an article studying the impacts of microplastics of polystyrene on zebrafish hearts. Zebrafish were fed a diet high in polystyrene microplastics (PS-MPs) (particle sizes 3–12 μ) for 21 days. Exposure to polystyrene microplastics PS-MPs resulted in a considerable reduction in heart function and swimming ability. DNA damage was more sensitive to the action of PS-MPs than the other impacts. The authors added the following:

> Our results provide evidence on the multiplicity of the PS-MPs effects on cellular function, physiology, and metabolic pathways, and heart rate of adult fish and subsequent effects on

> fish activity and fish fitness thus enlightening MPs characterization as a potent environmental pollutant (Dimitriadi et al., 2021, p. 1).

Thus, it can be easily seen that the three studies agree that microplastics have catastrophic consequences on the health of the living organisms.

The characteristics and types of microplastics have been studied, and it is clear how microplastics are a threat to almost all living organisms on the planet after looking into microplastic pollution causes and effects. Now, the research will proceed to the suggested solutions to eliminate this issue and how those solutions are practical, efficient, and reliable.

2. Solution analysis

2.1. Conceptual framework

Sustainability and sustainable development have become more important in a scientific study on challenges of environment, environmental legislation, and agricultural and industrial output, among other things. Despite the fact that these two notions are mostly used interchangeably, they are the subject of serious conversations about their meaning and applicability to real-world situations (Ruggerio, 2021). For governments all around the world, the topic of sustainable development has become a major focus of policy research and formation. The changes that have occurred in both developed and developing countries over the last few decades have made it necessary for them to take on the development challenge of sustainability. Both developed and developing countries must improve their sustainability. The United Nations (2020) stated that "sustainable development has been defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs." It implies that the countries should work on improving and enhancing the sustainability of their different sectors not only for the present but for the future generations as well. In the same vein, Harrington (2016) wrote that sustainability involves goals and visions which are interconnected with long-term conditions and targets. It can be seen how both sources agree on the crucial role of sustainability in eliminating various issues and securing sources and nature's bounties for future generations. This research shows a consensus on sustainable solutions for microplastic pollution using physical, chemical, and even electrical techniques.

2.2. Research Method

In this research, the case analysis method has been adopted and various scenarios have been examined. Different papers and articles that have tried to address the problem of microplastics pollution have been investigated. Some of these solutions were effective and others were unsuccessful. Failed solutions have been disregarded and this research delves deeper into the successful ones. The three solutions that will be introduced have been conducted in five different countries: USA, Turkey, China, Finland, and Canada. The solutions' mechanisms, scientific approach, and effectiveness will be explored. Consequently, the results of each study will be analyzed to decide if those solutions are successful, sustainable, and whether they can be generalized or not.

2.3. Recommended solutions

2.3.1. Electrocoagulation (EC)

Despite the fact that electrocoagulation (EC) has become a profitable business, it has gotten very little scientific attention. This technique has the potential to greatly reduce the drawbacks of traditional treatment methods. Furthermore, the processes of EC are still unknown, and little attention has been paid to the parameters that impact the efficient removal of ionic species (Mollah et al., 2001). This view is supported by Hakizimana et al. (2017) who argued that in the last decade, the electrocoagulation process (EC) has brought the attention of many scientists, and it is still a vital field of research. The majority of published work focuses on applications for treating drinking water and agricultural, urban, or industrial wastewaters in order to improve simultaneous soluble and colloidal pollutant removal (Hakizimana et al., 2017). This category contributes to theoretical knowledge, electrode materials, process parameters, reactor design, and even techno-economic analysis (Hakizimana et al., 2017).

Coagulation occurs when charged particles in colloidal solution are neutralized by mutual interaction with opposite charge and agglomerate, followed by sedimentation. The lowering of the net surface charge to a degree where the colloidal microplastic particles, earlier "stabilized by electrostatic repulsion,"can come closely enough for "van der Waal's forces" (weak intermolecular forces that result from temporary fluctuations in electron density and can cause attraction between molecules) to keep them together and allow aggregation is widely acknowledged (Mollah et al., 2001). Claiming the same approach, Hakizimana et al. (2017) explained the idea of electrocoagulation by saying that in electrocoagulation, coagulants are produced electrically by using metal electrodes. The metallic ions are liberated from the anodic reaction, and the hydroxide ions (formed by electrolysis) are produced from the cathodic reactions.

Many studies explored the area of usage of Electrocoagulation to remove microplastics from water (Akarsu & Deniz, 2020; Elkhatib et al., 2021; Raza et al., 2016; Shen et al., 2022). Microplastic particles are considered colloidal fragments. Microplastic particles usually become partially negative charged particles because of the friction between them and the water surface tension. Furthermore, an electrical double layer that consists of two layers is formed by the partially charged particles. The maximum potential is found at the colloidal particle surface (known as Nernst potential), and the major cause for colloidal system stability is the Zeta potential measured at the surface of shear, which comes from the dropping of potential all across the stern layer, which is attributed to the prevalence of oppositely charged particles. The larger the magnitude of Repulsion between particles, the more stable the colloidal system becomes. When metal coagulants are polymerized, they can aggregate microplastic pollutants together. This destabilization of microplastic particles, by charge-charge interactions or by forming hydrogen bonds with them, results in the particles clinging together. This phenomenon occurs due to the reactive groups that polymers have, which can adsorb to the surface of the microplastic particle. Meanwhile, a sludge blanket is formed by the coagulants, where the suspended solid particles are trapped.

The results of the removal for this solution were very good. For Elkhatib et al.'s (2021) study which was conducted in the USA, the microplastics removal efficiency was 96.5%. Similarly in Turkey, the removal efficiency of the elimination of microplastics for Akarsu & Deniz (2020) reached 98%. The results of Shen et al. (2022) experiment, which was carried out in China, were close to the previous studies, and the best removal rate was "93.2% for PE, 91.7% for PMMA, 98.2% for CA and 98.4% for PP at pH 7.2". As a result, it can be said that electrocoagulation is an efficient solution, which can be applied in real life and it will impact the field of water treatment positively.

2.3.2. Removing microplastics using magnet

Many studies have investigated the approach of removing microplastics using magnets, but each study discussed a different technique (Grbic et al., 2019; Scherer & Figueiredo Neto, 2005; Shi et al., 2022). Scherer & Figueiredo Neto's (2005)research in Brazillooked into the properties of ferrofluids and polarities of magnetic substances, but Grbic et al. (2019) modified the Fe nanoparticles to make them attach to microplastics, and the experiment was implemented in Canada. Seeking the same approach, Shi et al. (2022) carried out their experiment in China and gave attention to the adsorption properties of Fe3O4 to microplastics.

According to Scherer & Figueiredo Neto (2005), small amounts of oil and magnetite are added to a water sample with microplastics to mix with the microplastics forming the ferrofluid liquid. After that, a strong magnet is used to pull the magnetized mixture, and then a microplastic-free water sample can be achieved. The primary premise behind this concept is that like dissolves like, which means that substances with matching chemical properties dissolve in each other. Polar solvents dissolve polar solutes, while non-polar solvents dissolve non-polar solutes; on the other hand, non-polar and polar compounds are incompatible (immiscible or cannot dissolve each other). Oil, plastics, and magnetite are all known for being non-polar substances. Thus, they can never mix with water (polar substance). So, the method was to add oil and then, being a non-polar, it can float on top of the water without dissolving, and by stirring, the microplastics can dissolve in it, making a microplastic-oil mixture, like dissolves like. After that, the magnetite, being also nonpolar, can be added to mix with the microplastic-oil mixture to make the ferrofluid. As a result, the non-polar mixture becomes magnetized and thus can be extracted out of the water using a strong magnet.

Grbic et al. (2019, p. 1) wrote: "Hydrophobization of Fe nanoparticles facilitates sorption to MPs. This was done by surface modification with a silane to functionalize Fe nanoparticles with hydrophobic hydrocarbon tails." From this statement, it can be seen that the idea depends on the hydrophobic properties of Fe nanoparticles, and with some modifications, they become able to attach to the microplastics. After the attachment process, the bulks of microplastics and Fe nanoparticles are removed with strong magnets. This technique was very similar to the ones of Shi et al. (2022). This method used nano-Fe3O4 as adsorbents to magnetize MPs by mixing and oscillating, and it was based on physicochemical features of MPs, such as large surface area and exterior hydrophobicity. Magnetized MPs can then be pulled out of the water by the magnet's attraction. So, the significant difference is using the nano-Fe3O4 particles instead of the Fe nanoparticles.

The results reflect the high efficiency of this approach. For instance, Grbic et al. (2019) claims that 92% of 10-20 μm polyethylene and polystyrene beads and 93% of >1 mm MPs (polyethylene terephthalate, polyurethane, polyethylene, polypropylene, polyvinyl chloride, and polystyrene) were recovered from saltwater. They also recovered 84% and 78% of MPs (polyurethane, polypropylene, polyethylene, polyvinyl chloride, and polystyrene) from the fresh water and sediment samples, respectively, ranging in size from 200 μm to 1 mm. The results of Shi et al. (2022) were close to the previous ones, and they stated that polyethylene, polypropylene, polystyrene, and polyethylene terephthalate were found to have removal rates of

86.87%, 85.05%, 86.11%, and 62.83%, respectively, in a size range of 200–900 µm. So, removing microplastics with magnetics can be considered a reliable and sustainable solution.

2.3.3. Chemical Coagulation

Chemical coagulation is a water treatment method that removes particles by changing the electrical properties of the particles floating in water. Small, highly charged molecules are injected into water samples in order to disrupt the charges of the suspended particles, oil materials, or colloids. To enhance the filtration performance, the right and suitable coagulant for a system should be chosen carefully to improve the overall system performance, specifically particles removal efficiency (Bradley, 2022).

Several studies have discussed this solution, but each study used different chemicals and coagulants (Rajala et al., 2020; Xue et al., 2021; Zhou et al., 2021). According to Rejala et al. (2020), a known amount of polystyrene spheres of two distinct diameters (1 mm and 6.3 mm) were injected into WWTP effluent samples. Inorganic and organic coagulants usually applied with WWTPs, such as polyaluminum chloride, polyamine, and ferric chloride, were utilized to treat the samples. Following the same technique, Xue et al. (2021) pursued the coagulation-flocculation sedimentation (CFS) process and used alum-CFS coagulant in the removal of the microplastics.
The removal of carboxylated polystyrene (PS) microspheres in a broad range of sizes (90 mm, 45 mm, 25 mm, 6 mm, and mm) in two types of genuine surface waters (Grand River and Lake Erie water) that are supplied for full-scale drinking water treatment facilities were investigated using alum-CFS bench experiments. Similarly, Zhou et al. (2021) used chemical coagulation and examined the mechanism and the removal efficiency of polystyrene (PS) and polyethylene (PE) microplastics by using polyaluminum chloride (PAC) and ferric chloride FeCl3 coagulants.

The results were promising and indicated the positive impact of the chemical coagulation technique. The highest removal efficiency achieved by Rajala et al. (2020) was 99.4%, and this study was implemented in Finland. The numbers of Xue et al. (2021) in Canada were close as the highest removal rates reached were 96.1%, 85.2%, and 90.6% for 3 µm, 6 µm, and 25 µm particles, respectively. On the other hand, the results of the coagulants used by Zhou et al. (2021) in China were not as efficient as the previous ones. With FeCl3, the removal efficiency of PS was 63.94% and 17.4% with PE, while the efficiencies with PAC were 75.25% and 30.49% with PS and PE, respectively. However, by choosing the suitable coagulants for this process, we can consider chemical coagulation as an efficient solution that significantly contributes to the removal of microplastics.

3. Recommendations

The main objective of this study was to search for solutions that can be applied in Egypt to solve the problem of microplastic water pollution, as this problem is increasing significantly in Egypt, and Egypt is considered one of the largest sources of water pollution with microplastics in the Middle East. Several excellent and reliable solutions were discussed in this paper, like electrocoagulation, chemical coagulation, and magnetic extraction. From my point of view, the most reliable solution that can be applied in Egypt is electrocoagulation.

Chemical coagulation is a viable option for treating water contaminated with microplastics in Egypt. The use of chemical coagulants can effectively remove microplastics from water by adding chemicals to create tiny flocs that stick to microplastics and make them easier to remove through filtration. Egypt has already implemented chemical coagulation in some water treatment plants to remove suspended solids and turbidity, and it has been successful in producing high-quality drinking water. However, chemical coagulants have a serious environmental impact, such as the formation of disinfection byproducts and the disposal of waste generated during the treatment process.

Magnetic removal is another promising method for the removal of microplastics from water in Egypt. This method involves the use of magnetic particles that can attract and capture microplastics, which can then be removed from water through filtration. However, the application of magnetic removal in larger-scale water treatment systems in Egypt requires further research and development to optimize the process and reduce the cost as it is very expensive. Additionally, the disposal of magnetic particles after treatment is a crucial concern for the environment.

According to the International Energy Agency (IEA), in 2019, Egypt's electricity production was approximately 184 terawatt-hours (TWh), which is a significant amount. Egypt has diversified its electricity production sources, including natural gas, oil, hydropower, and renewables, such as wind and solar power. The country has been investing in expanding its electricity generation capacity to meet the growing demand for energy, and it has set ambitious goals to increase the share of renewables in its energy mix in the coming years. Consequently, Egypt produces a good amount of electricity, and part of it can be allocated to purify water from microplastics.

Electrocoagulation is an effective method for treating water contaminated with microplastics in Egypt. This method involves the use of an electrical current to remove contaminants from water by causing the formation of coagulant agents. These agents can then attract and capture microplastics, which can be removed from water through filtration. The potential for electrocoagulation in Egypt is significant, as the country produces a good amount of electricity, which can be used to power the electrocoagulation process. This method has been shown to be effective in removing microplastics from water in laboratory studies and has been successfully applied in some water treatment plants in Egypt to remove other contaminants. Moreover, electrocoagulation can be easily integrated into existing water treatment infrastructure and has lower operating and maintenance costs compared to other treatment methods.

There are many areas in which those filtration plants can be built, such as the New Administrative Capital, the desert areas of the Sixth of October City, and the desert roads between the governorates. There is something that must be mentioned, which is that the STEM schools in Egypt were encouraging their students to work on solving the issue of microplastic water contamination, and there are many students who developed the electrocoagulation system, which showed its effectiveness and how it is suitable for the Egyptian environment. Applying such a solution falls in line with Egypt Vision 2030 and with UN SDG#6 and SDG#14 as Egypt seeks a clean and sustainable environment.

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