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Review of Advanced Water Treatment for Removal of Nanoplastic Pollution

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ABSTRACT

Drinking water is a very important basic need for humans. One of the detected drinking water pollution that greatly affects the quality is the content of nanoplastics. In aquatic ecosystems, nanoplastics are materials that cannot be decomposed. Through this brief review, the efficiency of removing nanoplastics using various water treatment methods will be reviewed. Some of the treatment methods reviewed are nanoplastic removal using filtration, adsorption, coagulant and flocculant addition, and CFS (Coagulation/Flocculation Sedimentation). The research method used is a literature review related to drinking water treatment to eliminate pollution by nanoplastics. The conclusion from the literature review is that the process of treating drinking water by filtration with the addition of coagulants is the most efficient treatment for removing pollution by nanoplastics, reaching 99.9%.

Keywords: *Drinking water; Filtration; Adsorption; Coagulant; Nanoplastic*

INTRODUCTION

Nanoplastics are considered a risk to human health and the environment [1]. This is due to its small size, nanoplastics are smaller than 0.001 mm [2]. The presence of nanoplastics in all parts of the food chain in the biosphere [3]. The danger of nanoplastics to life both in animals, plants and humans is a hot issue in the modern era.

In aquatic ecosystems, nanoplastics are mentioned as white pollution, this is due to the residue of plastic films that cannot be decomposed, the cause is the excessive use of plastic and low recycling rates [4]. The literature shows that nanoplastics have many aspects of adsorption impact on processes such as growth, cellular mechanisms of neonate generation, and material behavior of concern [5]. A large amount of plastic accumulated in the aquatic environment results in the formation of nanoplastics after degradation, while their transportation through the food chain has a significant impact on the terrestrial environment by producing toxicity and disease [6]. The surface and charge functions of nanoplastics play an important role on ecotoxicological and ecological effects [7].

Water treatment technologies to remove nanoplastics are still very difficult, especially to quantify, analyze and identify nanoplastics. Removing Nanoplastics from drinking water can be through methods such as filtration, centrifugation and the use of membranes, where the removal efficiency shows a fairly high removal rate [8]. In addition, nanoplastics can also be removed through coagulants and adsorption processes. The type of nanoplastics, climate

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change, amount of water usage, method adopted, drinking water composition are important during the removal process.

Several studies have reported that nanoplastics in biofilms found in aquatic environments, also have organic matter, bacteria and other organisms. The biofilms formed change the characteristics of nanoplastics and then complicate the performance of drinking water treatment [9]. Another study explained that nanoplastic substrates are very specific and present in municipal water supplies.

METHODS

The research method used was a literature review on the topic of water treatment with various technologies for nanoplastic contaminant removal. Journals were collected from Google Schoolar with priority publications for the last 3 years (2020-2023).

Based on several journals reviewed related to the drinking water treatment process for nanoplastic removal, the activities carried out first are testing the nanoplastic content in the sample before the treatment process is carried out. Then the next step is to add coagulants and flocculants with a certain amount of dosage. The next process is the processing process for the removal of nanoplastics. The processing processes carried out include Adsorption, CFS (Coagulation / Flocculation Sedimentation), Filtration.

The output produced from the drinking water treatment process is carried out laboratory testing to compare the content in drinking water before treatment and after treatment. The results of the comparison will determine the level of efficiency of water pollution removal by nanoplastics with different processing methods.

RESULTS AND DISCUSSION

Nanoplastic Polystyrene (PS) Removal Efficiency by filtration treatment using sand and GAC media

The study was conducted with natural surface water from Lake Geneva, which is currently used as a drinking water source for 500,000 consumers. Pilot-scale was conducted by pumping water from Lake Geneva at a flow rate of 1 m^3/hour. Then coagulant was injected at 0.36 mg/L Al using Polyaluminum Chloride (PACl). Filtration with sand media uses double media, namely pumice and quartz sand, while the GAC filter uses a mixture of 75% bituminous coal and 25% activated carbon from coconut shells. The filtration speed is the same at 5.5 m/h for sand and GAC filters [3].

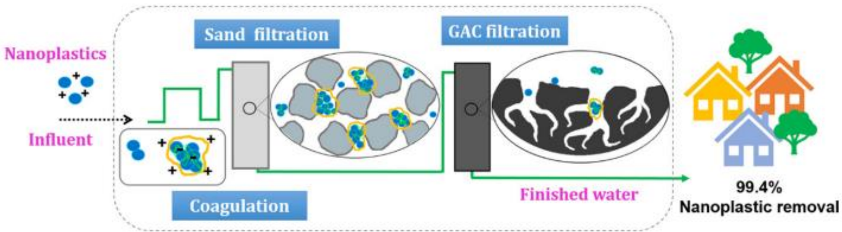

Figure 1. Removal efficiency of PS Nanoplastics by Filtration Treatment (Sand and GAC)

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The results showed that the removal efficiency of PS nanoplastics using sand and GAC media filtration treatment, if not coagulated, would reach 88.1%. The removal efficiency with filtration treatment is mainly due to physical retention and adsorption mechanisms. Due to its high porosity and adsorption capacity, the removal efficiency with GAC filtration is higher than sand filtration. In addition, coagulant addition was shown to increase the removal efficiency of nanoplastics. The coagulant PACI was shown to be able to remove nanoplastics during the drinking water treatment process up to 99.4%. Effective removal efficiency with sand media filtration increased from 54.3% to 99.2% when coagulant was added. The high removal efficiency when coagulant is added is due to the formation of large nanoplastic aggregates that increase retention in the filter media. In addition, the addition of coagulants can reduce the surface charge of PS nanoplastics even to neutralization conditions. This can reduce the repulsive force between nanoplastics and filter media, so as to increase retention and removal. The results showed that positively charged nanoplastics were almost completely removed during the drinking water treatment process including the coagulation process, sand media filtration and GAC filtration [3].

Adsorption Efficiency and Removal of Nanoplastics by Granular Activated Carbon (GAC) in Drinking Water treatment process

The study was conducted with purified water and natural surface water from Lake Geneva, which is currently used as a drinking water source for half a million consumers. To quantify the adsorption process, different adsorption models were applied to the experimental data to evaluate the adsorption capacity and removal efficiency of the adsorbent [10]. The water in Lake Geneva was collected at the inlet of the drinking water treatment plant in Geneva. Water from Lake Geneva was filtered using a membrane filter with a pore size equal to 0.2 μm (Merck Millipore Ltd., Swiss). The adsorption capacity of GAC and the removal efficiency of nanoplastics in this study were based on turbidity measurements (nephelometric). Turbidity measurements are commonly used in drinking water treatment plants as a regulatory parameter for particulate contamination in water and play an important role in water quality monitoring [11]. The suspended turbidity of nanoplastics was measured in experiments using a Hach Turbidimeter TU5200 with an infrared emitting laser at 850 nm (Hach Lange, Switzerland).

PS nanoplastics and activated carbon characterization

The surface charge value and stability of PS nanoplastic particles were characterized in pure water by measuring the ζ-potential and the variation of z-averaged hydrodynamic diameter as a function of pH. It was found that GAC has a significant number of pores with different sizes and shapes. The pores of GAC are relatively large with sizes varying between 15 μm and approximately 10 μm, providing additional surface so that PS nanoplastic particles can settle and penetrate. Smaller pores were also found with sizes ranging between 100 nm and 1 μm [10].

Batch Adsorption Study on Pure Water

The effect of adsorbent concentration on PS nanoplastic adsorption was investigated at different GAC doses (from 3 to 15 g/L) and a fixed PS nanoplastic concentration (30 mg/L). From the results, the adsorption of PS nanoplastics is fast at the initial stage then the adsorption becomes less efficient especially at high adsorbent concentration. When the adsorbent concentration is low, particles can easily access the adsorption. On the other hand, the removal efficiency of PS nanoplastics increased with increasing adsorbent concentration due to the increase in surface area and adsorption amount with GAC dosage The removal efficiency of PS nanoplastics increased rapidly to 38% up to a dose of 7 g/L then increased slowly to 15 g/L GAC with 50%

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removal. All PS nanoplastic suspensions were stable during all experiments and no aggregation and pH modification were observed with different GAC doses [10].

Batch Adsorption Study on Surface Water

To see the effect of initial PS nanoplastic concentration and contact time, the study was conducted in Lake Geneva water at pH 8.4 ± 0.1 and GAC fixed at 5 g/L concentration, as well as increasing PS nanoplastic concentration from 5 to 40 mg/L. Results showed an increase in adsorption capacity with increasing PS concentration and contact time. The removal efficiency of nanoplastics increased from 78% to 90% with increasing concentration from 5 mg/L to 20 mg/L [10].

In pure water the adsorption and removal efficiency of nanoplastics is dominated by electrostatics between positively charged nanoplastics and negatively charged GAC. n the surface water of Lake Geneva the adsorption process was influenced by aggregation. The adsorption capacity was found to increase significantly with increasing PS nanoplastic concentration. Higher removal efficiencies were also found in Lake Geneva water especially at higher nanoplastic concentrations (10 to 40 mg/L), with removal reaching 90% at a concentration of 20 mg/L [10].

In Lake Geneva water the adsorption capacity and removal efficiency of PS nanoplastics were found to be three times higher than ultrapure water and increased significantly as the concentration of PS nanoplastics increased with a maximum adsorption capacity of 6.33 mg/g. This increase in adsorption capacity is due to the presence of Dissolved Organic Matter (DOM), which results in modification of the PS surface charge, the presence of divalent ions allowing adsorption of PS-DOM complexes, and, aggregation of PS nanoplastics. For the removal of nanoplastics in conventional drinking water treatment plants, this study showed that GAC produced from renewable sources can be considered as a moderate adsorbent for the removal of positively charged PS nanoplastics [10].

Removal efficiency of micro and nanoplastics (180 nm-125 m) in drinking water treatment using CFS and Filtration

This study investigated the removal efficiency of micro- and nanoplastics (180 nm-125 μm) in drinking water treatment, using coagulation/flocculation combined with sedimentation (CFS) and granular filtration under typical working conditions at a water treatment plant (WTP) [13]. Bench-scale treatment for CFS and filtration was conducted to mimic the working conditions at the Detroit WTP operated by the Great Lakes Water Authority (GLWA).

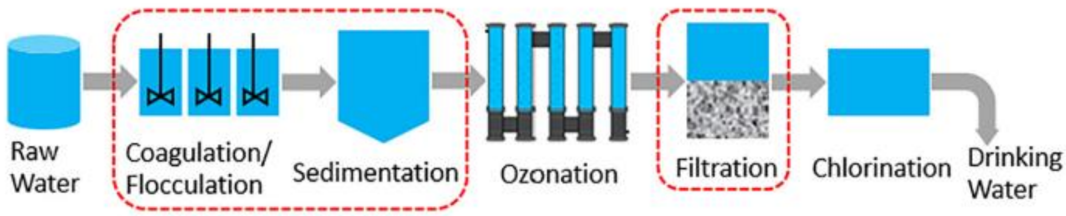

Figure 2: Drinking water treatment process adopted in Detroit WTP. Coagulation/flocculation combined with sedimentation (CFS) and filtration were selected to study the removal efficiency of micro- and nanoplastics.

From the results of a study conducted by Yongli Zhang et al in 2020, in general, the removal of microplastics and nanoplastics using the CFS (Coagulation / Flocculation and Sedimentation) treatment method is very low. Without a coagulant, the removal rate for particles measuring 45-53 μm only ranges less than 2%. Meanwhile, if a coagulant is applied, the removal rate that can be done is 16.5%. Meanwhile, if the removal of micro and nanoplastics uses the Filtration processing method, the removal efficiency is much higher than CFS. The removal efficiency using filtration can reach 86.5% to 99.9%. Particles larger than 100 μm can be removed up to 99.9% [13].

Sedimentation of nanoplastics using a combination of Ca/Al flocculants

The study was conducted on water taken at an Agricultural University lake in South China. Removal of nanoplastics using flocculation process is an effective treatment for remediation of contaminated water [14]. Aluminum and calcium ions were used as flocculants for the flocculation and sedimentation treatment process.

During the sedimentation process, crystals are more easily formed by calcium and aluminum ions with an increase in pH, and crystals are formed at pH 10. The flocculant used can effectively precipitate nanoplastics after coagulation and stirring.

nder acidic conditions where the pH is below 5, the negative surface charge of nanoplastics is reduced due to the high concentration of hydrogen ions and the positive charges of calcium and aluminum ions. Under moderately alkaline conditions with pH above 5, calcium and aluminum ions gradually form crystals that can capture nanoplastics. Overall, electrostatic adsorption and molecular forces are the main mechanisms for the deposition of nanoplastics [14].

The efficiency of nanoplastic precipitation using calcium and aluminum ions as flocculants can reach 80%. The capture of nanoplastics with Ca/Al flocculants is a new method and insight that can be used in the drinking water treatment process [14].

Nanoplastic removal in drinking water treatment using filtration, ozonation, and activated carbon

The study was conducted on lake water in Zurich (a source of drinking water for the city of Zurich, Switzerland). The lake water was taken at a depth of 30 m from the DWTP entrance of Lake Zurich which was filtered using a 0.45 μm membrane filter. The treatment methods used in this study are ozonation and filtration with sand and activated carbon media. The average diameter of the sand media was 450 μm. The coefficient of uniformity ranged between 1.71 and 1.78 for all filtration media[15].

From the results of pilot-scale research and laboratory research, the ozonation process using ozone levels suitable for drinking water treatment has almost no effect on nanoplastic removal. From the results of laboratory research (column experiments), it is shown that there is an influence of operational conditions, water chemistry, and the type of filter media used on nanoplastic removal efficiency. Increasing the filter length and reducing the water flow rate was shown to affect nanoplastic retention [15].

In addition, the use of lake water as a material for research led to reduced nanoplastic transportation. This is likely due to the compression of the electric double layer and filtration media due to the high ionic strength of lake water. In addition, the formation of biofilm on filtration media is one of the important causes in increasing the removal efficiency of nanoplastics. In the study conducted using aged sand filter media, the nanoplastic removal efficiency increased from 43% to 77%. In the research conducted, it was seen that the removal of nanoplastics was quite efficient when using sand media as a filter, but there was a reduction in retention in activated carbon media [15].

A full-scale drinking water treatment system (DWTP) with fast and slow filtration (sand and activated carbon media) modeled in pilot-scale and laboratory experiments was shown to be able to remove high nanoplastics (> 3-log 10) in lake water. However, overall, the slow sand filter is more capable of retaining nanoplastics with a removal of about 3-log 10. The occurrence of biofilm growth on the slow sand filter results in a high nanoplastic removal efficiency (>99.9%) [15].

CONCLUSIONS

Nanoplastics are water pollutants that persist in the environment longer than other pollutants. The degradation process and removal efficiency of nanoplastics can be improved by various water treatment measures. Some of the most effective and efficient treatment methods to remove nanoplastics in drinking water treatment are filtration, coagulation, sedimentation with Al/Ca flocculant, and adsorption with GAC.

Nanoplastic removal by filtration process is very efficient, which can reach 99.9% removal if coagulant is added. Increased removal efficiency with coagulant affixation due to the formation of larger nanoplastic aggregates thereby increasing retention in the filter media. In addition, the sedimentation process is also very efficient if aluminum and calcium flocculants are added. Nanoplastic removal can reach 80% when Al / Ca flocculants are added. he nanoplastic removal method using Al and Ca ions is new knowledge that requires further research. For removal using the adsorption process, the added dose of GAC is also very efficient. The efficiency of nanoplastic removal in surface water using the adsorption process can reach 90% with the addition of a GAC dose of 20 mg/L.

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