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Research on pollution status of dissolved organic matter and treatment technologies development

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Abstract:

Dissolved organic matter is a kind of common water impurity that is very common in natural water bodies, such as lakes and rivers near urban areas. Although the activities of the biosphere produce some soluble organic compounds, human living also bring considerable amount of supernumerary compounds. Impurities that exceed the self-purification capacity of water bodies can cause water pollution, which in turn affects surrounding residential areas. Therefore, reducing the concentration of dissolved organic matter in water through filtration, or preventing the influx of artificial compounds into the water bodies has positive implications for urban ecology. This article proposes multiple feasible solutions based on the above two ideas, including the adapting and applying existing technologies, as well as involving high-tech that can be implemented in the near future. The paper focus on the filter materials such as granular activated carbon and graphene, also a more economic improvement of the application of water-soluble polymers.

Keywords: Dissolved organic matter; water pollution; water treatment.

1. Introduction

Dissolved organic matter (DOM) is the dominant form of organic matter which is as the fraction of organic matter in a water sample that passes through a 0.45 μm filter in the water bodies of inland water which has exceptions include running waters with very high concentrations of organic particles or extreme algal blooms [1, 2]. It is a kind of colloidal suspension and is the main component of organic matter in water. The common range of the DOM's molecular weights is between 100 to 100000 Da [3]. DOM is often the primary term for aquatic ecosystem carbon, energy and nutrient budgets due to its pervasive effects on food webs, secondary production and nutrient retention/release. DOM can also be defined as a heterogeneous mixture of complex organic matter, including humus, proteins, lipids, polysaccharides and amino acids. DOM plays a vital role in natural-water ecosystems, and it has a great influence on some metals' transport, solubility and toxicity. Human have found several methods to remove the DOM. The most likely treatment to be implemented

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at present is Granular Activated Carbon Filtration (GAC), but it has been narrowly defeated due to its inability to meet the demand for large-scale deployment. Other solution like membrane materials and water-soluble materials are also competitive for organic water pollution removement. The aim of this article is to review the processes or equipment currently used for treating soluble small particles, although they have not yet been used for purifying natural water bodies, and to discuss their development and applications in related fields soon.

2. Existing treatment

There is currently no water treatment solution specifically designed for DOM cleaning in natural water bodies that has been widely adopted. The main reason for this is that compare to the samples, natural water bodies in reality contain various impurities, not limited to soluble organic matter. Each impurity has different properties [4], and if multiple purification methods are used specifically, it will lead to low efficiency. In addition, a widespread application of water treatment plans have to consider cost issues, however, most existing DOM models have relatively high resource waste. The current mainstream purification methods are focus on cut off the transmission chain, such as using adsorbents and membrane materials to intercept impurities.

2.1 Granular activated carbon filtration

Activated carbon is a type of carbon particle with a well-developed pore structure, which significantly increases its surface area and brings about efficient material adsorption capacity [5]. Simple drinking water treatment facilities using activated carbon as the main raw material have been promoted to a certain extent in the market [6]. On this basis, there have been many advances in low-cost preparation technology for activated carbon, making this treatment method more popular [7]. Although activated carbon is very popular, it is more suitable to appear as part of purification equipment rather than as a separate filtering material. At present, most activated carbon purification devices used at the end of household water pipes or in factory sewage treatment on the market have multiple sections, including multi-layer cylindrical filtration systems composed of small particles such as sand or extending the contact time between water and adsorbates by placing a larger amount of activated carbon [8-10]. If the government wants to thoroughly purify lakes or rivers, it needs to build large facilities at the source to intercept DOM, or whimsically saying, pour a large amount of GAC into the water body. Both methods are unrealistic and more meaningful solutions in the field should continue to be studied.

An experiment was conducted on two types of granulated activated carbon adsorption of seven organic micropollutants (OMP) frequently detected in urban water bodies, and the results showed that activated carbon particles have the ability to remove artificial soluble organic matter from water. The OMP selected as the analysis object includes six over-the-counter (OTC) or common prescription drugs, as well as one pesticide, as shown in table 1. The measurement index for the experimental conclusion is Freundlich adsorption coefficient, with the unit of Kf, Represents the weight of OMP that can be captured by GAC per unit of mass. Note that the sorption capacity of GAC particles for organic micropollutants is positively correlated with the relative molar mass of the latter and is more pronounced on the second type of activated carbon. Cetirizine and Fexofenadine molecules have a large weight (388.9 and 501.7 g mol^{-1}), and their capture efficiency is also the highest (22 and 26 ng g^{-1}). The molecular weight of pesticides is the smallest (191.1 g $mol^{-}1$), and so is the value of Kf (4.6 ng g^{-1}). Relatively speaking, the first type of activated carbon is better at intercepting medium-sized molecules because for Lamotrigine, a chemical substance with a molar mass of 255 g mol^{-1}, the adsorption efficiency is relatively high (11 ng g^{-1}). In practical applications, it is possible to consider using multiple layers of activated carbon with different specifications and properties to increase adsorption efficiency and range.

Table 1. Characteristics of selected organic micropollutants [11]

Compound	Molecular Formula	Molar Mass (g mol^{-1})	K*f* (ng g^{-1})	
			Norit 830W	Filtrasorb 400
Carbamazepine	$C_{15}H_{12}N_2O$	236	4.3	9.3
Cetirizine	$C_{21}H_{25}ClN_2O_3$	388.9	16	22
Fexofenadine	$C_{32}H_{39}NO_4$	501.7	9.3	26
Fluconazole	$C_{13}H_{12}F_2N_6O$	306.1	5.2	11
Lamotrigine	$C_9H_7Cl_2N_5$	255.0	11	10
Oxazepam	$C_{15}H_{11}ClN_2O_2$	286.0	6	11

DEET	$C_{12}H_{17}NO$	191.1	3.7	4.6

2.2 Membrane materials

Membrane materials are understood as one or more layers of composite network structures, which have a large number of pore structures at the microscopic level that allow water molecules to pass through and have the ability to intercept large molecules in water, such as DOM [12]. At present, membrane materials have achieved mass production because they cannot only be used to intercept organic macromolecules in artificial wastewater, but also purify freshwater resources from outdoor water storage facilities [13]. Membrane materials can filter microplastic particles to a certain extent, but nanoscale plastics (1-100 nanometers) may still pass through films [14]. The limitation of membrane materials is that they cannot remove organic molecules that already exist in large water bodies, nor can they intercept DOM that seeps into the water from the surrounding soil.

2.3 Water-soluble polymers in articles for daily use

Soluble polymers are an emerging product typically composed of sugars and peptides and have been widely used in some products in the field of packaging [15]. These substances are chosen because they can be broken down by decomposers, such as bacteria, from large molecules to small molecules that already exist in nature [16]. This method can avoid the potential harm caused by artificial macromolecules to the environment or human body.

However, as shown in fig.1, the degradation process is influenced by numerous factors, resulting in highly unstable efficiency. Degradable polymers are designed to tend to break at specific points. If hydrolysis proceeds normally, there is no significant harm to the product. Otherwise, uncertain small molecules may still cause pollution; Environmental constraints also affect degradation efficiency, as artificial or natural factors vary greatly in different regions, including the completeness of water treatment facilities, the concentration of soluble inorganic substances, and the number of bacterial colonies. For recycling facilities located in harsh environments, waste produced using WSP materials is no different from other materials.

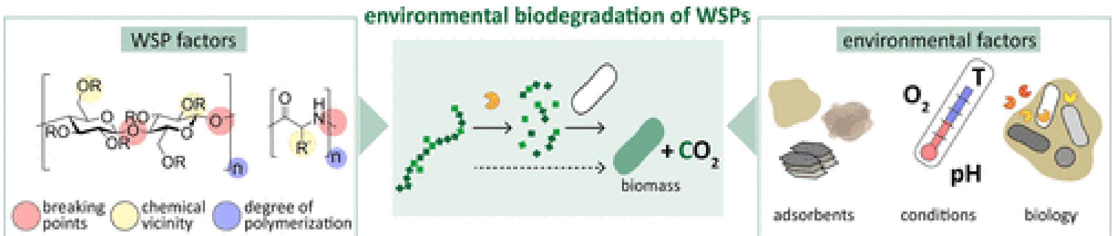

Fig.2 Factors affecting biodegradation of WSPs [17]

3. Future Perspectives

Although there are already many efficient solutions for degrading or removing DOM, the vast majority are still in the testing stage in laboratory environments. The cost issue is the main reason preventing the large-scale deployment of these measures: difficult to produce facilities and high operating costs make them unpopular in the un-developed regions or dense urban areas [17]. Below, two promising solutions that cannot be immediately put into use due to the above reasons will be given as examples.

3.1 Application of new-type materials in filtration

In order to address small molecule pollutants, including microplastics, adsorbents or membrane materials in water treatment systems should become more sensitive, more targeted towards small molecules, and not hinder the passage of water molecules. The solution includes the use of nanomaterials or graphene. Graphene, due to its properties, can be applied simultaneously in the fields of adsorbents and membrane materials [18]. Due to its application in other high-end manufacturing fields, the cost of obtaining materials is lower compared to other materials. However, the cost of maintaining graphene products in the water treatment industry is still unclear.

3.2 DOM degradation method based on photocatalysis

The application of photocatalysis is a completely emerging technology. By irradiating with ultraviolet light, organic macromolecules are charged and broken into smaller, more harmless molecules. Compared to the two mainstream purification methods mentioned earlier, the

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replacement cycle of the materials required for photocatalytic processes is much longer, resulting in relatively low labor costs. However, research has found that adding catalysts such as titanium dioxide to the sample can significantly improve the efficiency of photocatalysis. Consider that TiO_2 have become a cheap paint in manufacturing, some private companies who contracted to rectify pollution may illegally dump catalysts in the water to accelerate the decomposition of DOM, with the ignorance to the potential harm to local communities. The impact of high-power ultraviolet lamps on water treatment facility workers should also be taken into consideration. In addition, there is still a lack of research on the penetration of ultraviolet radiation into water bodies carrying impurities such as sediment.

4. Conclusion

Overall, it is clearly showed that human activities are an important factor affecting DOM enrichment, and excess DOM in turn affects the surrounding ecology, including nearby urban areas, through microbial or chemical disasters. In order to prevent DOM from being too concentrated in water, people have taken a series of measures, among which water-soluble polymer seems to be the most practical and widely used treatment. More and more new technology should be innovated so that human may use a higher efficiency and lower cost treatment method, which could improve the natural water condition around urban areas. Up to now, artificial DOM pollution is still an implicit but series problem which people suffer from in many suburbs around the world. Therefore, developing a more effective and more easily replicable method of governance is one of the important tasks of scientists. Humankind should be responsible for those vicious DOM, as they will ultimately harm the ecosystem, followed by urban itself. believing that by combining existing technologies and transforming them into feasible solutions, unnatural phenomena such as eutrophication will be curbed in the near future.

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