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The adverse effects of dissolved organic matter on water bodies and in-depth exploration of management methods

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Abstract:

Dissolved organic matter (DOM) accounts for a great proportion of organic carbon in all aquatic ecosystems and is often a vital carbon resource for heterotrophic microorganisms. According to the Wet-chemical analysis and 1 H- and 13C-NMR spectra, it is clearly showed that both DOM fractions from the urban waste compost were low in neutral, acidic and amino sugars as well as in lignin derived compounds. In this article, directly or indirectly impacts of the human activities on water bodies are mentioned and the eutrophication, a common and harmful phenomenon of pollution, is introduced as one of the well-known results of concentrated DOM. As a result, human found several methods to remove the DOM. The most likely treatment to be implemented 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.

Keywords: Dissolved organic matter, water bodies, Granular Activated Carbon, membrane materials.

1. Introduction

With the rapid development and progress of science and technology, human environmental problems are becoming more and more serious. Especially in aquatic environments, dissolved organic matter (DOM) is a very serious problem. DOM can be seen as 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 [1]. DOM can be understood like a kind of colloidal suspension and it is the main component of organic matter in water. The common range of molecular weights of the DOM is between 100 to 100000 Dalton (Da) [2]. The composition of DOM of low weight molecule(LMW) and high weight molecule (HMW) can be seen in fig. 1. The LWM and HWM parts are respectively take the proportion of 43% and 57% of DOM. The proportion of large molecules in water is even higher than that of small molecules. HWM is more difficult to naturally degrade than LWM because the intermolecular forces are stronger.

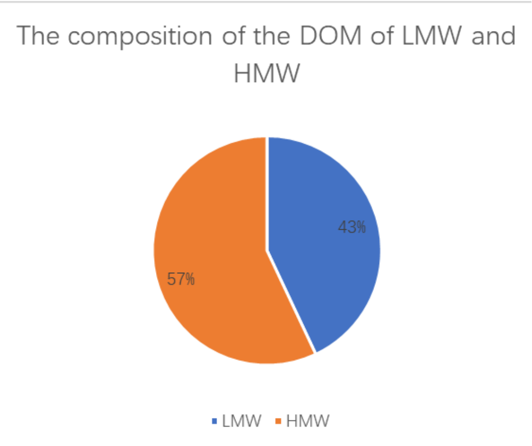

Fig.1 The composition of the DOM [3]

Regardless of whether there is human intervention in this outcome, the high rate of large molecules means that DOM is more difficult to decompose, and the required time will be longer, ultimately leading to a series of potential threats to the surrounding environment. There is another content called particulate organic matter (POM). DOM and POM can be classified in nonliving organic matter. There is not a serious distinction between DOM and POM, which is mainly based on the separation technology. POM can pass through a 0.2 μm filter while DOM can pass through a 0.45 μm filter. However, this distinction could not show the chemical and biological origins and ecological functions of POM and DOM [4]. Nowadays a huge amount DOMs from are carried into the ocean and other aquatic systems. Around 55% to 80% of the component of DOM is humic substance in aquatic system which at least 85% is fulvic acid (FA).[5] FA are soluble in both acid and alkaline solutions while the humic acid (HA) is soluble in alkaline but insoluble in acid solutions which the pH is below 2 [5]. Because of the agriculture runoff and the urban runoff, the aquatic system is polluted by some metal oxides The metal oxide in aquatic system will react with the DOM and then some toxic complexes will be formed which are both harmful to the human and environmental health [6]. Moreover, eutrophication is another huge problem caused by DOM. Eutrophication is usually caused by the accumulation of excess organic molecules in calm water and harmful algal blooms become more and more frequent. In the long run, eutrophication might deteriorate the local aquatic biosphere and even the climate system. This will accumulate the inland water algal biomass which in turn can cause the increase in the autochthonous biological DOM thus increase the concentration of the DOM in water column [7]. Nowadays, the most practical method human used is granular activated carbon filtration (GAC), a kind of popular and low-cost treatment. Human are searching for some other useful treatments, and there are two other treatments people can be used to solve the DOM problem. The first is the using of membrane materials and second one is using water-soluble polymers, while both have the same problem-high cost. This article will describe how granular activated carbon works in eliminating DOM in details and find the most practical method among the above technologies by comparing the advantages and drawbacks.

2.Source and negative impact of DOM

2.1 The source of DOM

Some terrestrial DOM can be produced by biological degradation and progressive concentration of organic compounds particularly resistant to degradation. Because of the degradation of vascular plants, DOM contains approximately 10 % proteins, 30–50 % carbohydrates (mainly cellulose), some lipids concentrated in the roots and leaf cuticles [8], 15–25 % lignin [9], and other biomacromolecules [10]. Some can be produced in a type of precipitation which will pass through the atmosphere, and then drops onto the vegetation. After that, rest of them will infiltrates into the soil organic layer, and continuous moving towards to the mineral soil layer. In addition, dissolved atmospheric dust and gases, throughfall, root exudate, litter of leaf and root, and the primary and secondary metabolites of microorganisms are also the typically sources of DOM. Until now, little is known about the chemical composition of DOM in compost and waste. Studies have found that DOM fractions in leaf litter, municipal solid waste compost, and soil water have similar characteristics. However, these studies also show that the composition of DOM varies in different types of compost and that long periods of composting can significantly change the composition of DOM. DOM from other wastes, such as sewage sludge and pig manure, is much less characterized than DOM in compost. DOM in sewage sludge and pig manure decomposes differently from DOM in green manure, which may be because of differences in chemical composition. In headwater catchments, DOM in rivers often originates primarily from exotic sources, such as organic soil layers. In contrast, in lake systems, native DOM often supports a large proportion of community respiration. However, the net ecosystem production (total primary production - community respiration) of lakes tends to be negative, suggesting that exotic DOM from surrounding watersheds is also an important source of respirable C in lake systems [11].

2.2 Negative impact caused by DOM

Nowadays DOM offer lots of negative impacts which is harmful to the living environment of humans. Among

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these effects, eutrophication is the most discussed one by scientists. Eutrophication is a huge word which describes a big problem in the nation's estuaries. Eutrophication often occurs when the environment becomes enriched with nutrients, increasing the amount of plant and algae growth to estuaries and coastal waters. As a result, there are lots of bad results may be caused like harmful algal blooms, dead zones and the collective death of fish. 65% of the estuaries and coastal waters in America that have been studied by researchers are moderately to severely degraded by excessive nutrient inputs. Algal blooms and low concentration of O_2 in water will not make aquatic animal and plants alive. Therefore, aquatic will lose room to survive. Eutrophication sets off a chain reaction in the ecosystem, starting with an overabundance of algae and plants. The excess algae and plant matter decompose, and then produce huge amounts of CO_2. This change will decrease the pH of seawater, a process known as ocean acidification. Acidification decrease the speed of the growth of fish and shellfish and can prevent shell formation in bivalve mollusks. Eventually, there is a large decline of the amount of catch for commercial and recreational fisheries, which means smaller harvests and more expensive seafood [12].

3.Granular activated carbon for DOM removal

3.1 Working principle

Granular activated carbon (GAC) is made from some raw organic materials like coconut shells or coal that are high in carbon. Some heat energy will be used to increase the surface area of the carbon in a condition without oxygen. As a result, these filters are sometimes called "charcoal" filters. The activated carbon removes certain chemicals that are dissolved in water and are widely used as adsorbents for removing organic chemicals and metal ions of environmental or economic concern from air, gases, potable water and wastewater passing through a filter containing GAC by trapping (adsorbing) the chemical in the GAC [13].

3.2 Main process and treatment performance

GAC is an effective and compared practical method to figure out the DOM problem. There are two typical GAC filter system now, and Whole-House Filters or Point of Entry is one of them. A whole-house filter is installed at a point on the home's water supply plumbing that will result in treatment of all water that travels to any faucet or fixture in the home (but typically will exclude outside faucets to prolong the life of the carbon). The main purpose that using this system is removing the chemicals before they can be ingested, breathed in, or absorbed by the skin during washing or bathing.

From fig.2, it is clearly seen that the filters are usually cylindrical in shape. The figure shows that is about 4-feet tall and 15 inches in diameter. The filters are usually installed as a pair, although more may be required in some situations. Two filters arranged in sequence ensure that any chemical that might get past the first filter is trapped by the second.

When the first filter is used up, the second filter is moved to the first position and a new filter is placed in the second position. Sample ports located before, between, and after the filters allow for testing of the water at each location. After these steps, people can use the water which has already been filtrated [14].

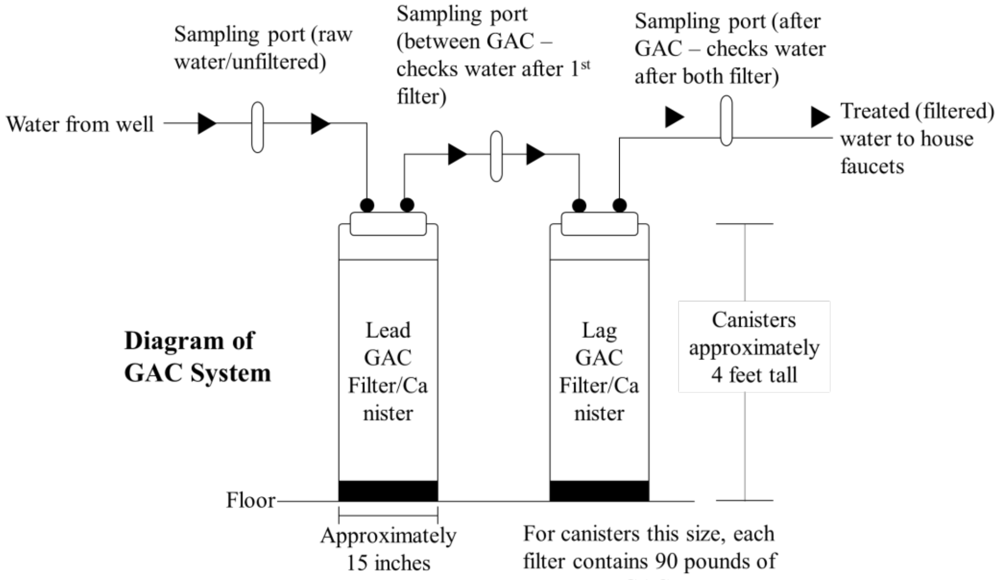

Fig.2 GAC system

From the figure, although activated carbon is popular, it is more suitable to appear as part of purification equipment rather than as a separate filtering material. If the government wants to thoroughly purify lakes or rivers, it needs to build large facilities at the source to intercept DOM, or simply pour a large amount of GAC into the water body, which both are unrealistic.

4. Other treatment technologies for DOM removal

4.1 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 [15]. 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 [16]. Membrane materials can filter microplastic particles to a certain extent, but nanoscale plastics (1-100 nanometers) may still pass through films [17]. 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.

4.2 Water-soluble polymers

Soluble polymers are a novel class of materials typically made from sugars and peptides, and they find extensive use in the packaging sector [18]. They are selected for their ability to decompose into smaller molecules through the action of natural decomposers, like bacteria [19]. This process helps mitigate the potential environmental or health risks associated with synthetic macromolecules. There are many water-soluble polymers, including uncharged linear homopolymers (e.g., polyethylene oxides) to branched and charged copolymers (e.g., polyacrylates, modified polysaccharides, and polyamino acids). Water-soluble polymers cover a wide range of properties and functionalities (e.g., thickening, stabilization, and emulsification) that are essential for their use in many applications because of their chemical diversity [20].

5 Comparison of different methods and further treads

For water-soluble polymers, the degradation process is influenced by multiple factors, leading to variable efficiency. These polymers are engineered to degrade at specific points, and if hydrolysis proceeds as intended, the product remains largely unaffected. However, if not, the resulting small molecules might still pose pollution risks. Additionally, environmental conditions impact degradation efficiency significantly, as factors such as water treatment facility effectiveness, soluble inorganic substance concentration, and bacterial colony presence vary across regions. In recycling facilities operating in challenging environments, waste from water-soluble polymers performs similarly to waste from other materials [21]. It is seemed that none of them has no drawbacks. The drawback of three of them is the high producing cost and GAC is still the most effective treatment among the three methods.

Although numerous effective methods for degrading or removing DOM exist, most remain in the experimental phase within laboratory settings. The primary barrier to their large-scale implementation is cost: the challenges in facility production and high operational expenses render them impractical for underdeveloped [22] regions or densely populated urban areas [23]. Below, two promising solutions, which face deployment delays due to these issues, will be discussed as examples. Under this condition, the most two practical and possible treatment the human may use are new-type materials and DOM degradation method based on photocatalysis

6 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 a 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 soon.

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