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Original Research Paper

Study on the Molecular Weight Distribution in Ganjiang River

Zhengong Tong
School of Civil Engineering of East China Jiaotong University, Nanchang, Jiangxi Province, China, 330013

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ABSTRACT

Using the method of ultrafiltration, the raw water of the Nanchang section of Ganjiang River and the water after conventional treatment was estimated to determine the molecular weight distribution. The results showed that the raw water of Ganjiang River has a molecular weight distribution with large edges and small middle parts, which meant that the organic matter of the water mainly centralized in a scope where the molecules were larger than 30ku or less than 1ku, and the middle size matter occupied a relatively small proportion. In winter low-water season, there was little organic matter in the river and the small organic matter molecules played the dominant role. Meanwhile, in the season of high-water, the amount of organic matter increased, whereas the small organic matter molecules decreased and the large organic matter molecules became dominant. The ordinary water purifying process of Nanchang city was just to remove the large molecules of the organic matter mainly, which led to an unsatisfying result where the small molecules were barely removed.

INTRODUCTION

As the worldwide water pollution is becoming more and more serious, and the types and amount of the organic matters in raw water are increasing at an amazing speed, traditional water treatment processes become less effective, and the health of human beings is severely threatened. Studies show that dissolved organic matter (DOM) is the main precursor of trihalomethanes (THMs) and other desinfection byproducts (DBPs), which have a carcinogenic effect deriving from the chlorination of the water supply plants (Djamel Ghernaout 2009). A great number of tests have been performed by many researchers for the molecular weight distribution of the organic matter in different water and the results generally show that the molecular weight distribution of raw water varies with time and place within a great range. The generating capacity of chloroform is closely related to the molecular weight distribution of humic acid. Molecular weight distribution shows strong regional characteristics, and different water purifying methods demonstrate different removal characteristics of the segments of molecules (Wen Tian-hong 2008). Knowing the molecular weight distribution of the organic matter in raw water shall offer a theoretical reference for the selection of water treatment methods and the removal of the organic matter to the highest degree. Therefore, based on the characteristics of the organic matter in raw water and the characteristics of the molecular weight distribution of the removed organic matter under different water treatments, a comprehensive analysis would be conducive to the improvement of the water treatment efficiency, the searching for better water supply plans, and the guarantee of the safety of water (Zhang Yajun et al. 2010).

MATERIALS AND METHODS

Experimental Materials

Experimental equipment and materials: MSC ultrafiltration cup produced by Mo-su Scientific Equipment Co, Ltd. in Shanghai and microporous membrane with maximum pressure edge of 0.22Mps and diameter of 0.45μm were employed in this experiment. The ultrafiltration membrane is also made by Mo-su Scientific Equipment Co, Ltd. with material of PES and diameter of 80mm, and the molecular weights of organic matter that it is able to intercept are 30ku, 10ku, 3ku, and 1ku.

The pretreatment of the membranes: The microporous membranes were pretreated by being boiled in purified water for three times (smooth side down, 30mins each time) and then stored in icebox. The ultrafiltration membranes were pretreated by being immersed and rinsed in pure water for three times (smooth side down, 30mins each time) and then stored in icebox.

The cleaning of the membranes: While using the membranes, the major problem encountered is the contamination from the particles, colloid, or solute molecules in the processing liquid; they are absorbed and deposited on the membranes' surface or inside the membrane hole which would cause irreversible flow decay of the membranes. Humus is the major component of the organic matter in natural water, and low-molecular weight dissolved organic matter, and humic acids are considered as the leading factors resulting in membrane fouling. Liu found out that organic matter plays a role of "adhesives" in forming process of the filter cake on the surface of membranes (Zhenhua Liu 2012). Filter cake

has great influence on the water producing ability of membranes. Cleaning is one of the most effective ways to slow down the membrane fouling; in general, washing, anti-washing, physical method, and acid washing will be employed. For a hydrophobic membrane, the polyphenol film is difficult to be cleaned, however, it is suitable for us to employ alkaline cleaning solutions for it (Dong et al. 2003); considering the suggestion of the manufacturer, NaOH was applied.

The polluted membranes shall be soaked first in 4% NaOH solution for one hour and then in ultra-pure water for one hour for three times, and then be stored in the 4% formaldehyde solution which should be placed in a refrigerator (Li et al. 2007).

Experimental Method

Specific filtering method is as follows and illustrated in Fig. 1. Fold the 0.45 μm microporous membrane to the pump filter, first filter 250 mL of high pure water to wash the membrane, then add the to-be-tested water sample, abandon 150 mL of the first-time filtrate, and then collect the rest for the filtration of the ultrafiltration membrane and the determination of TOC and UV_{254}. The filtering weights of the membrane are 30ku, 10ku, 3ku, 1ku respectively, followed filtration from large to small; this would produce a series of filtration elements which represent the composition of the molecules between the two ends of the membrane. Take the grade components from the two adjacent layers of the membrane and then measure the DOC and UV_{254} indicators, and the molecular distribution of the organic matter would be determined through margin calculations. When filtering, for each grade of ultrafiltration membrane, filter 100 mL of high water before the water sample, discard the first 50 mL of the filtrate and then collect the water sample, retain 30-40mL of the water sample and discard them before adding more water sample to ensure that the water does not press and dry in the UF cup and affect the performance of the ultrafiltration membrane. At last the values of the TOC and UV_{254} of the filtered liquid were determined.

RESULTS AND DISCUSSION

Molecular weight distribution of the organic matters in the winter raw water of northern Ganjiang River: In January 2011, samples of raw water were taken from the northern bank of Ganjiang River twice for the determination of the molecular weight of organic matter. TOC analysis (as presented by Fig. 2) shows that the raw water of Ganjiang River has a distribution with large edges and small middle part, where the organic matter with molecular weight of 0.45 μm ~30 ku accounts for 19.1~43.8% of the total amount, and the organic matter with molecular weight of less than 0.5ku accounts for 19.8~52.7%. Apparently, the organic matter of small and large molecular weight plays a dominant role while the middle takes a relatively small proportion; and the organic matter of molecular weight less than 1ku accounts for the largest proportion. As for UV_{254} (as presented by Fig. 3), the organic matter of low molecular weight takes the dominant role, where the molecules with weight less than 0.5ku account for 72~75%, comprising the majority of the organic matter.

Comparison of molecular weight distributions of the organic matter in the summer raw water of northern and southern Ganjiang River: Samples of raw water were taken respectively from the northern Ganjiang River on 17 July and southern Ganjiang River on 23 July to determine the molecular weight distribution of the organic matters. The results are as presented by Figs. 4 and 5.

By comparing Figs. 4 and 5 with Figs. 2 and 3, it could be found that in summer-wet period, the overall organic content is higher than in winter, where content of small molecular organic matter decreased and content of large molecular organic matter increased. In detail, the organic matter with UV_{254} of less than 1ku accounts for 15.4~18.2% of the total amount, and the organic matter with UV_{254} of more than 30k accounts for 51.6~56.8%; while for TOC, the organic matter of less than 1ku accounts for 32~35%, and the organic matter of more than 30ku accounts for 39~40%. The molecular weight distributions of the organic matter in raw water of both sides of the Ganjiang River are similar: the edges are high and the middle part is low; the differences are that the organic matter of molecular weight between 10ku and 30ku of the southern side is more than that of the northern side, while for the organic matter of molecular weight between 3ku and 10ku, the situation is just the opposite.

Molecular weight distribution of the organic matter in the raw water of Ganjiang River during rainy period: A thunderstorm came up on 27 July in Nanchang, therefore,

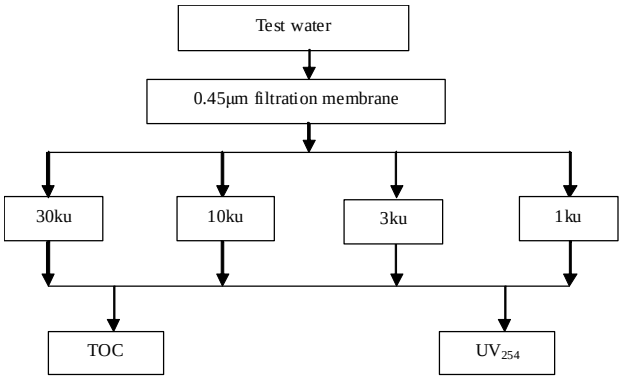

Fig. 1: Determining process of MV distribution of organic matters.

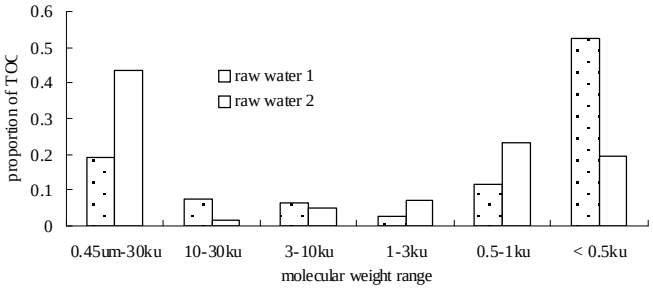

Fig. 2: MV distribution of TOC of Ganjiang River in January.

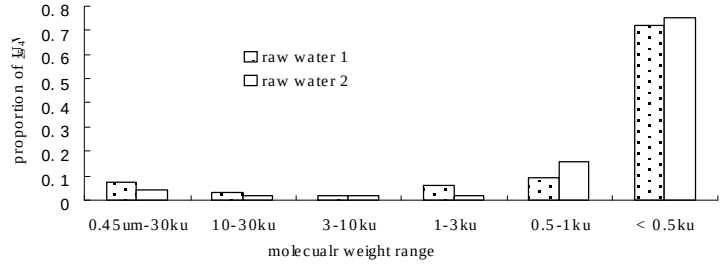

Fig. 3: MV distribution of UV_{254} of Ganjiang River in January.

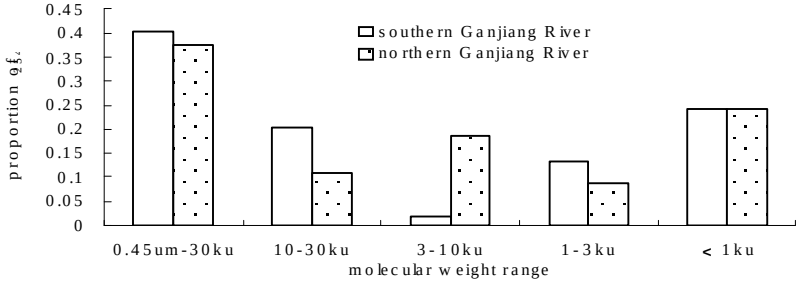

Fig. 4: MV Distribution of UV_{254} of Ganjiang River.

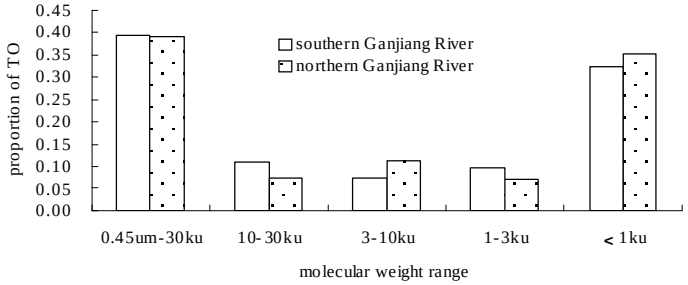

Fig. 5: MV Distribution of TOC of Ganjiang River.

samples of raw water were collected from southern and northern sides of Ganjiang River on 28 July for determination of the molecular weight distribution of organic matter in rainy season. The results are as shown in Figs. 6 and 7.

By comparing Figs. 6 and 7 with Figs. 4 and 5, it could be found that the overall molecular weight distribution of organic matter hardly changed after rain and that the edges of the distribution are still higher and the middle is lower. The UV_{254} of the organic matter with molecular weight greater than 30 ku accounts for 36~39% of the total organic matter, while the TOC accounts for 37~42%; the UV_{254} of the organic matters with molecular weight less than 1ku accounts for 33~34%,

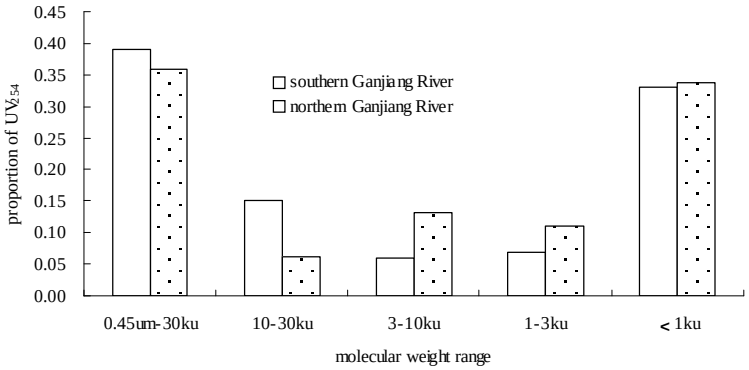

Fig. 6: MV distribution of UV_{254} in Ganjiang River when raining.

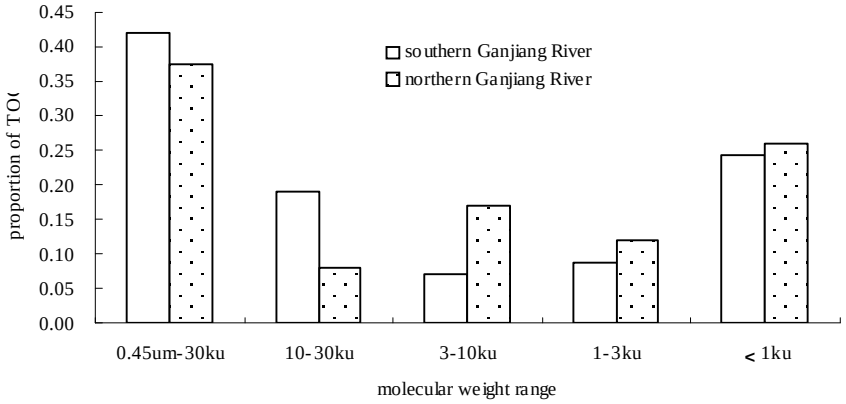

Fig. 7: MV distribution of TOC in Ganjiang River when raining.

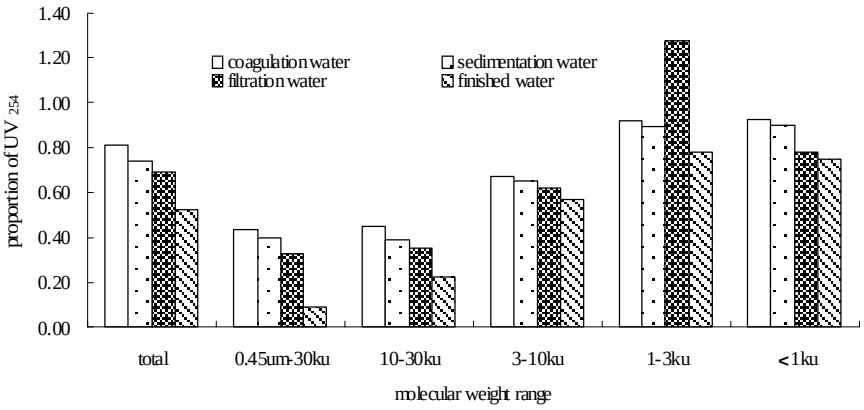

Fig. 8: The organic matter removal of the water of northern Ganjiang River on MV distribution of UV_{254}.

while the TOC accounts for 24~26%. Comparing the data, it can be seen that after rain the UV_{254} of the organic matter with molecular weight greater than 30ku decreased, and the UV_{254} of the organic matter with molecular weight less than 1ku increased to some extent. The TOC of the organic matter with molecular weight greater than 30 ku basically did not change, while the TOC of the organic matter with molecular weight less than 1ku decreased slightly.

UV_{254} to a large extent can reflect the content of humic acids, and the organic matters in water are mainly humic acids. Organic matters in water increased because of the summer rainfall, coupled with vigorous growth of algae and its metabolites, resulting in higher UV_{254}. Since the organic matters and algae and their metabolites are mainly small molecules (Dong & Cao 2001), the UV_{254} of the organic matters with molecular weight less than 1ku increased.

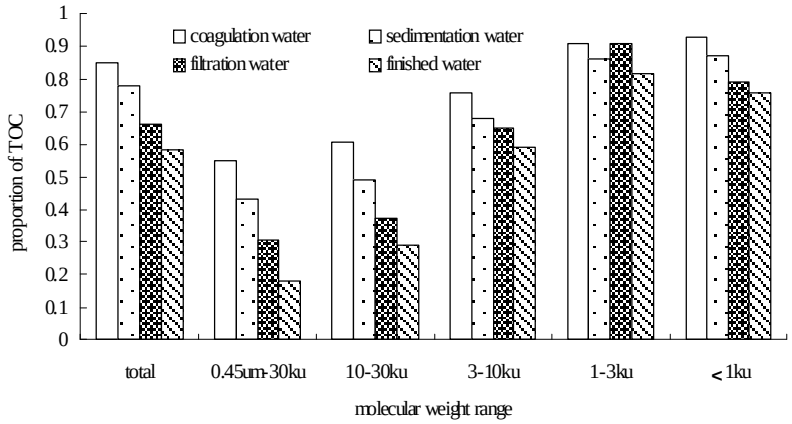

Fig. 9: The organic matter removal of the water of northern Ganjiang River on MV distribution of TOC.

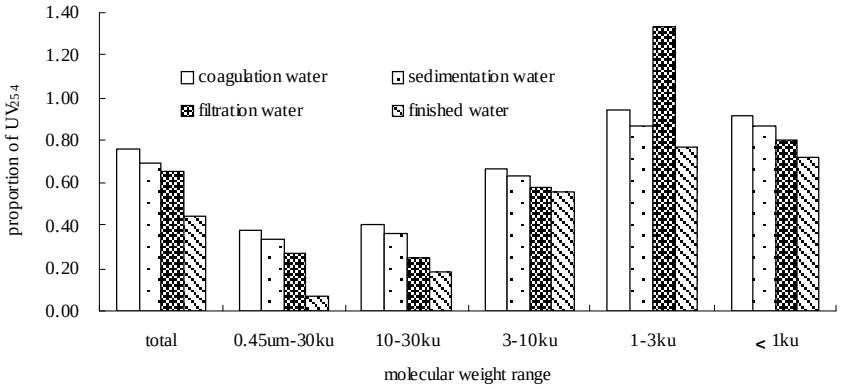

Fig. 10: The organic matter removal of the water of southern Ganjiang River on MV distribution of UV_{254}.

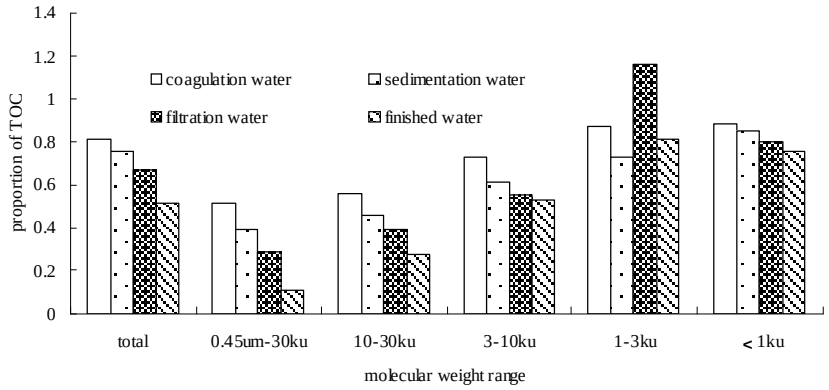

Fig. 11: The organic matter removal of the water of northern Ganjiang River on MV distribution of TOC.

Comparison of molecular weight distribution of the organic matter in water of northern and southern Ganjiang River after different water treatments: Samples of raw water were collected from the water plants on the northern and southern bank of Ganjiang River to measure the molecular weight of the organic matter. The water treatment processes of the water plants are basically the same, namely coagulation, sedimentation, filtration and watering. The samples were respectively taken on 17 July for the northern side and 23 July for the southern side. The test results and analysis are as shown in Figs. 8, 9, 10, and 11.

By comparing Figs. 8 and 10 with Figs. 9 and 11, it could be found that removal of the organic matter of the water of southern and northern sides of Ganjiang River are similar probably because of the similar molecular weight distributions of the organic matter in raw water and the

similar water treatment processes. In general, the content of organic matter decreases over time. The removal rate of UV_{254} is 48~56%, while that of TOC is 42~48%. The removed organic matters are mainly the organic matters with molecular weight greater than 10ku; the removal rate of the organic matters of small molecular weight is very small. After the reaction tank, the UV removal rate of the organic matters with molecular weight in the range of 0.45μm to 30ku reached 56~62% and the TOC removal rate reached 45~49%; such organic matters are almost all removed for the finished water, where the UV removal rate reaches 91~93% and the TOC removal rate is 82~89%. The UV removal rate of the organic matters with molecular weight in the range of 10ku to 30ku reaches 77~82% for the finished water, and the TOC removal rate reaches 71~73%. For the organic matters with molecular weight less than 1ku, after the reaction tank the UV removal rate was only 7~9% and the TOC removal rate only reached 12%; for the finished water the UV removal rate of such organic matters is 25~28% and the TOC removal rate is 24~25%. For the organic matters with molecular weight in the range of 1ku to 3ku, after the sand filters the content actually increase, after the clean water tank there is an apparent drop of the content; the overall removal rate for such organic matters did increase despite the increase through the sand filter. It was found that the conventional water treatment using aluminum coagulation can only remove organic matters with molecular weight greater than 4200μ. It is consistent with the conclusion derived from this experiment that the conventional treatment processes mainly remove the organic matters whose molecular weight is larger than 10ku (Wang et al. 2012).

CONCLUSIONS

1. In general, the raw water of Ganjiang River shows a molecular weight distribution where the edges are high and the middle part is low. To be exact, the molecular weights of most organic matters are larger than 30ku or less than 1ku, and the organic matter of medium molecular weight only accounts for a relatively small proportion.
2. In winter-dry season, the overall content of organic matter is low and the organic matter of small molecular weight accounts for a dominant ratio. For summer-wet period, the overall content of organic matter is higher than in winter, and the small molecule organic content decreased, the organic matter of large molecular weight taking a larger proportion.
3. The conventional water treatment processes of the water plants in Nanchang city mainly remove the organic matter of large molecular weight, while the organic matter of small molecular weight is barely removed.
4. The molecular weight distributions of the organic matter in the raw water of both sides of the Ganjiang River are similar, so are the removal performances of the conventional water treatment processes of the water plants on the two banks.
5. Taking into account the water quality of Nanchang city, on the condition that the current structure of the water treatment processes is not to be changed, iron salt and permanganate could be used to improve the removal efficiency of organic matter. If the structure of the water treatment processes can be changed, biological treatment could be added to the processes to enhance the removal efficiency of the organic matter of small molecular weight.

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