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Phosphorus in Drinking Water And It's Removal in Conventional Treatment Process

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Abstract: Chemical forms of phosphorus in source and treated drinking water were studied in this paper. Removal of total phosphorus (TP) and microbially available phosphorus (MAP) by conventional treatment process of drinking water was examined. The results showed that particulate phosphorus constituted of most TP in source water. Content of total soluble phosphate (TSP) was about 30% of TP. Soluble reactive phosphate (SRP) can be measured in a few months during a year and its content was very low. Content of MAP was higher than content of TSP in source water, which showed that microbe can also use particle phosphorus. Ratio of TSP to TP increased evidently in treated water. This demonstrated that removal of TSP was more difficult than particulate phosphorus in conventional treatment process for drinking water. Removal of TP and MAP in conventional treatment process of drinking water was effective, with averaged removal efficiency of 66% and 69%, respectively. Coagulation-sedimentation and filtration removed TP efficiently. Enhanced coagulation may increases removal efficiency of MAP. Lower content of MAP can control biostability of drinking water.

Introduction

For a long time, organic carbon had been considered as the most primary nutrients to control heterotrophic bacteria to grow in drinking water. Especially the assimilable organic carbon (AOC) which was prone to microbial degradation was considered as the main index of evaluating biological stability of drinking water. But in recent years, some research indicates that in the northern hemisphere (such as Northern Europe, Russia and North America), natural water (e.g. lakes, rivers, and even groundwater) contains a lot of organic carbon as the forest and peat exist .and the microbial growth in drinking water was not restricted by AOC ,but the Inorganic element phosphorus.

Phosphorus exists with a variety of forms in the water. Based on the physical properties of phosphate it can be divided into solubility and granularity. According to the chemical characteristics it can be divided into orthophosphate, polymerization phosphate and organic phosphate. Microbial can only use part of that. Generally speaking, soluble orthophosphate (SRP) are most easily available by microorganisms. While domestic research on the form of existence of phosphorus, and the content of microbially available phosphorus (MAP) in drinking water sources has not been reported . This paper studies source water of J Water Supply Plant and the form of existence of phosphorus in out water in T city .combining the waterworks process, we studied the conventional process on the removal of the total phosphorus (TP) and microbially available phosphorus (MAP), and discussed the feasibility of controlling biological stability by phosphorus in drinking water.

The form of existence of phosphorus in source water and out water

According to the physical properties, phosphate in drinking water can be divided into solubility and granularity. According to whether it can be used by microbial, it can be divided into microbially available phosphorus and microbially unavailable phosphorus. This study measured source water of J Water Supply Plant , TP, TSP, SRP in out water and MAP respectively in February, March , July , August and September in T city.(Table 1and2)

Table 1 Different phosphorus in source water of J Water Supply Plant

Sampling time	TP (μg P/L)	TSP		SRP		MAP	
		TSP (μg P/L)	TSP/TP (%)	SRP (μg P/L)	SRP/TP (%)	MAP (μgPO_4^{3-}-P/L)	MAP/TP (%)
2-25	33.00	—*		—		—	
3-26	28.05	—		—		21.22	75.7%
7-4	68.38	8.15	11.9%			11.44	16.7%
8-28	92.58	39.64	42.8%	3.25	3.5%	38.21	41.3%
9-23	83.00	7.38	8.9%			8.17	9.8%

The data of total phosphorus in source water fluctuated greatly, TP in raw water was respectively 33.00 and 28.05μg P/L in February and March. However, it was respectively 68.38, 92.58 and 83.00μg P/L in July ,August and September. It can be seen from this that total phosphorus in source water changed obviously with the season, namely the content of phosphorus in source water in summer increased obviously compared with it in spring. That means that the phosphorus pollution source was mainly non-point pollution, stormwater runoff was small in winter and spring, phosphorus of non-point pollution into water decreased. And stormwater runoff was large in summer, phosphorus of non-point pollution into water increased. From the form of existence of phosphorus source water, phosphorus mainly existed in the form of insoluble granule. The proportion of TSP to TP in July and September was respectively 8.9% and 11.9%, but in August this figure rose to 42.8%.It was unclear that what led to the proportion of TSP in water source significantly rose. The content of SRP in source water was much smaller and only in August it was 3.25μg P/L. It was below detection limit both in July and September. Therefore the phosphorus existed mainly in the form of insoluble granule in source water, the concentration of SRP was very low.The proportion of MAP to TP was not related to seasonal change. It could be seen that the content of MAP in source water was relevant to the content of TSP. The higher the content of TSP in water was, the higher the content of MAP was. This showed that soluble phosphate was the phosphorus source that microbial could make use of easily. But microbial not only could use soluble phosphate (MAP in July and September were higher than the TSP incurrent month) and this showed microbes could also use other forms of phosphorus (for example organophosphate, etc.).

Table 2 Different phosphorus in out water of J Water Supply Plant

Sampling time	TP (μg P/L)	TSP		SRP		MAP	
		TSP (μg P/L)	TSP/TP (%)	SRP (μg P/L)	SRP/TP (%)	MAP (μgPO_4^{3-}-P/L)	MAP/TP (%)
7-4	23.01			—		3.19	13.8%
8-28	25.02	20.49	81.9%	—		3.87	15.5%
9-23	6.87	5.36	78.0%	—		2.28	33.2%

Through comparing the proportion of TSP to TP in out water, we could see that it increased. This showed that it was easier to remove the insoluble phosphorus by conventional process, and the removal of soluble phosphate was relatively difficult. According to the conclusion that soluble phosphate was the phosphorus source that microbial could make use of , when the proportion of TSP increased, the proportion of MAP to TP also should increase. But the test results did not coincide with the conclusion, this may be because the conventional process was easier to remove MAP in water.

Conventional process of removal of total phosphorus

The effect of conventional process on the removal of total phosphorus is good. The removal rate of TP in July, August, September was separately 66.1%, 69.5%, 89.5%, average removal rate was 75.0% (Table 3.) From the conventional process unit for removal of total phosphorus, it was 27.1%~77.1% by coagulation and precipitate unit, and 37.1%~72.5% by filtering units. This explained that coagulation precipitate and filtering units on the removal of total phosphorus had better effect. This might be relevant to the effect of coagulation, concerning that which played a greater role for coagulation precipitate and filtering. Generally, phosphorus in drinking water was removed mainly through forming precipitation with coagulants and forming floc with insoluble phosphorus. If the effect of coagulation was good and it formed big floc, most phosphorus would comes down in leaking precipitation and a small percentage would go into ponds to be removed; If the effect of coagulation effect was poor and form small floc, a small part of phosphorus would comes down in leaking precipitation and most would go into ponds to be removed. In July and August there was a case that the content of TP in out water was higher than the content of phosphorus in filters water. If we exclude sample pollution, and add chlorine from the filter water to out water, through clean-water reservoir, it generally won't cause phosphorus pollution. This phenomenon was difficult to explain. It might be because the phosphorus which was intercepted by filter passed through the filter again and entered into the clean-water reservoir.

Table 3 Removal of total phosphorus (TP) in J Water Supply Plant

Sampling time	7-4		8-28		9-23	
	Sampling points TP (μg P/L)	Unit removal (%)	Sampling points TP (μg P/L)	Unit removal (%)	Sampling points TP (μg P/L)	Unit removal (%)
In water	67.88		81.99		65.36	
Coagulating sedimentation	38.64	43.1%	59.81	27.1%	14.94	77.1%
Filter water	19.98	48.3%	16.45	72.5%	9.39	37.1%
Out water	23.01	-15.2%	25.02	-52.1%	6.87	26.8%
Total removal rate		66.1%		69.5%		89.5%
Average removal rate						75.0%

Conventional process of removal of MAP

Conventional process for the removal rate of the MAP in raw water was respectively 80.9%, 87.3% and 70.0% in July, August and September. The average removal rate of the three months was 79.4% (Table 4.). Compared to the conventional process for the removal of total phosphorus, the removal rate of MAP was slightly better than that of total phosphorus. This matched the deduction in 2.1. Concerning coagulating precipitation and filtering units for the removal of MAP, coagulating precipitation for the removal of MAP was 27.8%～76.1%,and filtering units for the removal of MAP was 8.6%～50.7%,so the effect of coagulating precipitate is better than that of filtering units .

Table 4 Removal of Microbially Available Phosphorus (MAP) in J Water Supply Plant

Sampling time	7-4		8-28		9-23	
	Sampling points MAP (μg P/L)	Unit removal (%)	Sampling points MAP (μg P/L)	Unit removal (%)	Sampling points MAP (μg P/L)	Unit removal (%)
In water	16.67		28.93		7.59	
Coagulating sedimentation	12.03	27.8%	6.92	76.1%		
Filter water	11.00	8.6%	4.72	31.8%	3.74	50.7%
Out water	3.19	71.0%	3.68	22.0%	2.28	39.0%
Total removal rate		80.9%		87.3%		70.0%
Average removal rate						79.4%

Lehtola et al. in Finland studied the impact of oxidation of ozone on the MAP, finding that the impaction can increase the mount of MAP, for that ozone could oxidate organic macromolecules into small molecules, and phosphorus were often combined with organic macromolecules, so the process of oxidation could increase the mount of MAP. In the convention process, the water from the filter must be disinfected by adding chlorine, which also could play the role of oxidation of organic molecules, but the MAP hadn't increased. Even though, the additional(a small amount of) chlorine after water passed through filter (residual chlorine to ensure that treated water> 1.0 mg / L) weaken the effect of oxidation ,the MAP couldn't be released.

Discussion

Biological stability problem in drinking water is currently a hot issue. Bacterial regrowth in the network will lead to chrominance and turbidity of drinking water increase, increasing their risk of pathogenic microorganism and pipeline corrosion and a series of problems. Now the controlling measures are increasing chlorine dosage and removing assimilable organic carbon (AOC) in drinking water .Increasing chlorine dosage will make produce disinfection by-products in drinking water increase, which pose a threat to human health. And at present, treatment process for high assimilable organic carbon (AOC) in raw water is not ideal.Generally it is believed that the carbon in drinking water (assimilable organic carbon AOC) is the nutrients to limit microbial growth. Miettinen et al in Finland and Japanese Sathasivan et al. and other researchers first discovered restriction of phosphorus in drinking water on bacterial growth. Under the condition that carbon is relatively rich, if the phosphorus content is low, then microbial growth may be constrained by phosphorus. After some research, Japanese Sathasivan et al. put forward, when the concentration of phosphorus was between 1-3μgPO_4^{3-}-P/L, the phosphorus in drinking water may become a limiting factor for microbial growth. For the conventional process in J water supply plant in T city, the effect of removal of TP and MAP was good, and MAP in out water basically can ensure below 5μg PO_4^{3-} -P/L. After the study, there was the condition of phosphorus limitation in J Water Supply Plant, phosphorus is the limiting factors r of bacterial growth in the network. If strengthen the control of coagulation process, it is likely to achieve higher removal rate, ensure biological stability of drinking water. If phosphorus is the limiting factors of bacterial regrowth in the network, it will be possible for providing an alternative way to control biological stability of our drinking water. Under the condition that concentration of assimilable organic carbon (AOC) was higher, low concentration of phosphorus limit the bacterial reproduce in the network, thereby ensuring biological stability of drinking water

Conclusions

Research on the existing form and treating process of phosphorus in source water and out water of J water supply plant, in addition, the removal of TP and MAP, we can come to the following conclusion:(1)Total phosphorus in source water changed obviously with the season, namely the content of phosphorus in source water in summer increased obviously compared with it in spring.(2)phosphorus mainly existed in the form of insoluble granule, the content of TSP was relative low, and the SRP were only detected in some month. The Soluble phosphate is easily made use of by microorganisms, generally the higher the content of TSP in water was, the higher the content of MAP was.(3)the proportion of TSP to TP in out water increased, that showed it was difficult to remove insoluble phosphate.(4)For the conventional process, the effect of removal of TP and MAP was good. The average removal rate was 75.0% and 79.4%. The effect of coagulating precipitate unit and filtering units on the remove of total phosphorus were both good.

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