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Research on the application and effect of sewage purification technology in urban river pollution control

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ABSTRACT

Through the comparative test, the capacity and effect of four sewage purification technologies of fiber filtration (FBF), flocculation–precipitation (FP), flocculation–filtration (FLF), superconducting magnetic separation (SMS) to remove suspended substance (SS), nutrients and heavy metals in the urban river were studied, and the residues of chemical additives and the impact on water ecological security were analyzed. Among them, FBF is a physical purification method; FP, FLF, and SMS are all chemical purification methods with polyaluminum chloride (PAC) and polyacrylamide (PAM) added as flocculants, and magnetic powder (Fe_3O_4) is also added for SMS. The test results show that: (1) the removal efficiency of SS by FBF is lower than the other three chemical purification methods, especially when the concentration of SS is greater than 30 mg/L, the removal efficiency decreases significantly. FLF has the best removal efficiency and stability for SS. (2) The removal efficiency of total phosphorus (TP) and permanganate index (COD_{Mn}) by FP, FLF, and SMS is obviously better than that of FBF, and the purification effect of FP on TP and COD_{Mn} is the best. (3) FBF and SMS have a good purification effect on cadmium (Cd), and FP and FLF have a certain purification effect on arsenic (As). (4) In the effluent treated by chemical methods of adding PAC, PAM, and Fe_3O_4, the residues of additives are all within the standard range.

Keywords: Sewage purification technology; River treatment; Suspended substance; Eutrophication; Heavy metals; Flocculant residues

1. Introduction

As an important carrier of water resources, the river is an important part of the water environment and the foundation of social and economic development. With the development of industrialization and urbanization, the large-scale discharge of pollutants has led to the increasingly serious pollution problem of urban rivers. Especially in the Jiangnan area in China where the water network is interlaced, the self-purification ability of water is weak, and it is seriously polluted by surrounding non-point sources and point sources. The main purpose of traditional water pollution control, water environment governance, and water ecological restoration is to reduce the nutrient salt and toxic and harmful substances in water. There are no standard requirements for transparency, turbidity, and suspended substance (SS) in China's National standard of "Environmental Quality standards for Surface Water" (GB 3838–2002), which will lead to water purification projects underestimating the turbidity of the water. Water

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turbidity will change the underwater light field, restrict aquatic plant photosynthesis, reduce water dissolved oxygen, affect the respiration, growth, and reproduction of aquatic plants, and also affect the spatiotemporal transformation of nutrients in the water [1]. Therefore, water transparency is an important index of water quality measurement and water ecosystem assessment. While inorganic SS and non-ferrous dissolved organic substances are the direct influencing factors of transparency [2,3], total phosphorus (TP) and ammonium nitrogen (NH_3–N) can indirectly affect the transparency by affecting the growth and reproduction of planktonic algae [4]. The removal efficiency of SS and nutrients should be fully considered in the water purification method.

According to different principles, the methods used to purify polluted water can be divided into four categories: physical purification, chemical purification, biological purification, and natural purification [5]. At present, water purification methods usually use physical and chemical purification methods. The most commonly used water purification methods in China include fiber filtration (FBF), flocculation–precipitation (FP), flocculation–filtration (FLF), superconducting magnetic separation (SMS), etc., which are mainly used in sewage treatment. For example, FBF is used to remove SS [6], chemical oxygen demand (COD), and TP in sewage [7]; FLF is used to remove SS in sewage [8]; FP is used to reduce wastewater turbidity [9], remove SS, TP [10], total suspended substance (TSS), COD [11] and heavy metals in wastewater [12] or algae in tap water treatment [13]; SMS is used to remove turbidity [14], COD [15], arsenic (As)/antimony (Sb) [16] and other harmful substances in sewage. It has also been applied in the treatment of other water bodies, such as using FLF to reduce the turbidity of reservoir water and remove organic substances [17], using FP to treat cyanobacteria in eutrophic lakes [18], combined with media filtration and microflocculation to treat particulates and dissolved pollutants in urban road flow [19], combined with microflocculation and large gradient magnetic filtration technology to reduce the turbidity of Pearl River water and remove organic substances [20]. In chemical purification methods, the different types of coagulants and the amount of dosage have great differences in the removal efficiency of turbidity and organic substances [21–23]. Usually, polyaluminum chloride (PAC) is used as a coagulant, and polyacrylamide (PAM) is used as a coagulant aid. The two are mixed and adjusted to achieve the best flocculation effect. In addition, if the effluent quality requirements are high, a combination of various technologies will be used, such as a novel biofilm-micro flocculation and high-density sedimentation-fiber carousel filtration process [24], the combined process of AAO-oxidation ditch, secondary sedimentation tank, coagulation sedimentation tank, and fiber turntable filter [25].

Although FBF, FLF, FP, and SMS are widely used in the sewage treatment process, they are rarely used in urban rivers. In particular, there are few studies on the purification capacity and effect of micro-polluted flowing water, and there are no large-scale promotion cases. It is not clear the relationship between the treatment capacity of the four methods and the particle size of suspended substance (PSOSS). And there is a lack of research on the residues and impact of chemical additives in the water. If these methods are widely used in urban river water purification engineering, it is difficult to ensure a safe and effective role. Therefore, this study carried out research on river water diversion purification technology in the open area of the south bank of Yaojiang River in Jiangbei District, Ningbo City (29 54′ 26″ N, 121 31′ 53″ E, Fig. 1), to explore the applicability, efficiency, and safety of different purification methods to urban river pollution control, to obtain the best treatment method for SS, eutrophication, and heavy metal indexes in water. The main stream of the Yaojiang River has a total length of 104.5 km and a total basin area of 2,940 km^2. It is an important local water system integrating drinking, water conservancy, agricultural irrigation, fishery, shipping, and other functions, and it is also the main water source of the inland river network in Haishu District. Diversion of water from the Yaojiang River can improve the water quality of the river network, which plays a very important role in the economic and social development and the living life of the people in the coastal cities. According to the “Environmental Quality standards for Surface Water” (GB 3838-2002), the current water quality of the Yaojiang River is generally class III water, in which the TP, total nitrogen (TN), permanganate index (COD_{Mn}), and NH_3–N occasionally exceed the standard. The main problems of the Yaojiang River are low water transparency and high turbidity, which affect the growth of aquatic plants in the diversion channel.

2. Materials and methods

2.1. Test method

Four methods of FBF, FP, FLF, and SMS were used to carry out a water purification comparative test. The method process is shown in Fig. 2.

- *Fiber filtration*: A physical filtering method. The river water is pumped into the filter tank through the pipeline, and the filter tank has a turntable wrapped with fiber filter cloths. During the filtration, the SS in the water is filtered through filter cloths with a pore size of 5 μm, the filtered water is discharged through the pipeline, and the sludge retained by the filter cloths is discharged by negative pressure reverse suction.
- *Flocculation–precipitation*: The river water is pumped into the sedimentation tank through the pipeline, and the PAC and PAM that have been adjusted to the optimum ratio and dosage are continuously added to the pumping pipeline to form sedimentable flocs. Micro-sand (Actiflo sand, particle size is 80~100 μm, the main component is SiO_2) is added to the sedimentation tank to promote the flocculation binding and settlement. The effluent is subjected to solid-liquid separation in the sand-water separator to achieve micro-sand recovery and sludge separation, and the filtered water is discharged through the pipeline.
- *Flocculation–filtration*: The river water is pumped into the filter tank through the pipeline, and the PAC and PAM that have been adjusted to the optimum ratio and dosage are continuously added to the pumping pipeline to aggregate the SS in the river water. The SS in the water is

filtered through a stainless steel filter screen with a pore size of 10 μm, the filtered water flows out through the filter screen, and the sludge retained by the filter screen is discharged after backwashing.

- *Superconducting magnetic separation*: The river water is pumped into the mixing tank through the pipeline, and the PAC and PAM that have been adjusted to the optimal ratio and dosage are continuously added to the pumping pipeline, and magnetic seeds (Fe_3O_4) are added to the mixing tank to form a suspension of the magnetic medium. After stirring, the mixed liquid enters the sedimentation tank for solid-liquid separation by the super-magnetic separator, the filtered water is discharged through the pipeline, the magnetic flocs are broken up by a high-speed separator, and the magnetic seeds and sludge are separated by a magnetic drum and then discharged separately.

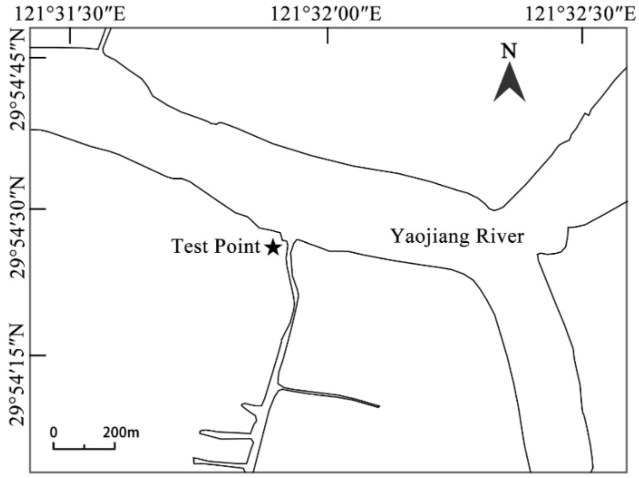

Fig. 1. Test point location.

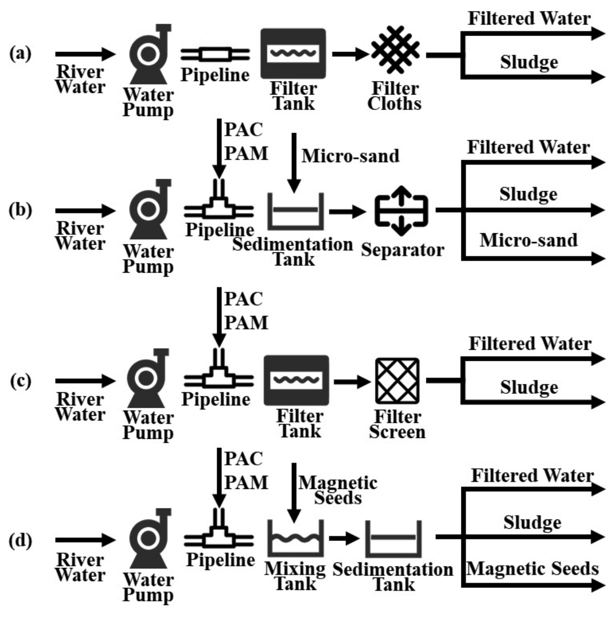

Fig. 2. Water purification process: (a) FBF, (b) FP, (c) FLF, and (d) SMS.

2.2. Test scheme

The test was conducted from June 12 to July 20, 2021. Water samples were collected from the water inlet and outlet of each test equipment to analyze the SS, PSOSS, eutrophication indexes (TP, TN, COD_{Mn}), heavy metal indexes (plumbum (Pb), hydrargyrum (Hg), chromium (Cr), cadmium (Cd), arsenic (As)), additive residues indexes (acrylamide (AM), aluminum (Al), ferrum (Fe)). The SS was tested once a day, the PSOSS was tested once (on June 24), and eutrophication indexes, heavy metal indexes, and additive residues indexes were tested three times (on June 13, June 20, and July 18). The purification effects of the four methods of FBF, FP, FLF, and SMS on SS, eutrophication indexes, heavy metal indexes, and residual conditions of the corresponding indexes of additives were compared and analyzed. The amount of flocculant applied for each purification method is shown in Table 1.

2.3. Sample analysis

All samples were collected on site and sent to the laboratory for testing. Among them, the use of PAC will bring a certain amount of aluminum ions (Al^{3+}) to the water, and there is a risk of pollution. Therefore, the residues of PAC are mainly determined by the concentration of Al^{3+}. PAM itself and its hydrolyzate have no toxicity, and its toxicity mainly comes from the residual monomer AM, so the residues of PAM are mainly determined by the concentration of AM. The composition of magnetic seeds is Fe_3O_4, its use will bring a certain amount of iron ions (Fe^{3+}) to the water, and there is a risk of pollution. Therefore, the residues of the magnetic seeds are mainly determined by the concentration of Fe^{3+}. The measurement indexes and analysis methods are as follows.

Water sample monitoring indexes: SS is determined by gravimetric method (GB 11901-89); TP is determined by ammonium molybdate spectrophotometric method (GB 11893-89); TN is determined by alkaline potassium persulfate digestion UV spectrophotometric method (HJ 636-2012); COD_{Mn} is determined by permanganate index method (GB 11892-89); Pb and Cd are determined by graphite furnace atomic absorption method ("Water and Wastewater Monitoring and Analysis Methods" (4th Edition Supplementary Edition, 2006)); Hg and As are determined by the atomic fluorescence spectrometry (HJ 694-2014); Cr is determined by inductively coupled plasma optical

Table 1
Concentrations of PAM and PAC for each purification method

Purification method	PAM (ppm)	PAC (ppm)
FBF	0	0
FP	3.0	6.0
FLF	0.7	5.0
SMS	2.0	5.8

emission spectrometry (HJ 776-2015); PSOSS is determined by Microtrac laser particle size analyzer (S3500SI).

Additive residues monitoring indexes: Al is determined by inductively coupled plasma optical emission spectrometry (HJ 776-2015); Fe is determined by flame atomic absorption spectrometric method (GB 11911-89); AM is determined by gas chromatography method (HJ 697-2014).

2.4. Index standard

The test indexes and their standard values are shown in Table 2. The standard value of SS is based on the Class I quality standard of surface water resources in "Quality standards for Surface Water Resources" (SL 63-94). The standard values of TP, TN, COD_{Mn}, Pb, Hg, Cr, Cd, and As are based on the Class III water standards in "Environmental Quality standards for Surface Water" (GB 3838-2002), and the residual standard values of Al, Fe, and AM in water are based on the general indexes and limits of water quality in "Standards for Drinking Water Quality" (GB5749-2022).

3. Results

3.1. Physical purification test

3.1.1. Purification of SS

Among the four purification methods, only FBF does not add flocculants and only relies on filter cloths for physical filtration. It can be seen from the variation curves of SS concentration in the influent and effluent of FBF with time (Fig. 3) that the range of SS concentration in the influent is 12~45 mg/L, and the range of SS concentration in the effluent is 7~48 mg/L. The compliance rate of the SS concentration in the effluent is greatly affected by the SS concentration in the influent. When the SS concentration in the influent is greater than 23 mg/L, the SS concentration in the effluent will not meet the standard, especially when the SS concentration in the influent exceeds 35 mg/L.

To compare the removal efficiency of FBF for different SS concentrations, the SS concentration in the influent is divided into 3 intervals (10~20, 20~30, and 30~50 mg/L) from low to high for comparative analysis. The results are shown in Fig. 4. It can be seen that FBF has little difference in the removal efficiency of SS when the range of SS concentration in the influent is 10~20 mg/L and 20~30 mg/L, but the SS removal efficiency decreases significantly when the SS concentration in the influent is greater than 30 mg/L.

3.1.2. Purification of eutrophication indexes and heavy metal indexes

The TN concentration range of the effluent by FBF is 3.04~3.23 mg/L, the TP concentration range is 0.01~0.12 mg/L, the COD_{Mn} concentration range is 3.3~5.3 mg/L, the As concentration range is 0.3~1.1 μg/L, the concentrations of Pb, Hg, Cr, and Cd are all lower than the minimum detection limit. According to the water quality standards, the concentrations of TP, COD_{Mn}, Pb, Hg, Cr, Cd, and As in the effluent are not exceed the standard, the concentration of TN exceeds the standard. Combined with the test results of the influent water quality, FBF has no obvious effect on the removal of TP and As. From the removal efficiency of TN, $COD_{Mn,}$ and Cd

Table 2
Water indexes and standard values

Index	Standard value
SS, mg/L	20
TP, mg/L	0.2
TN, mg/L	1.0
COD_{Mn}, mg/L	6
Pb, μg/L	50
Hg, μg/L	0.1
Cr, μg/L	50
Cd, μg/L	5
As, μg/L	50
Al, mg/L	0.2
Fe, mg/L	0.3
AM, μg/L	0.5

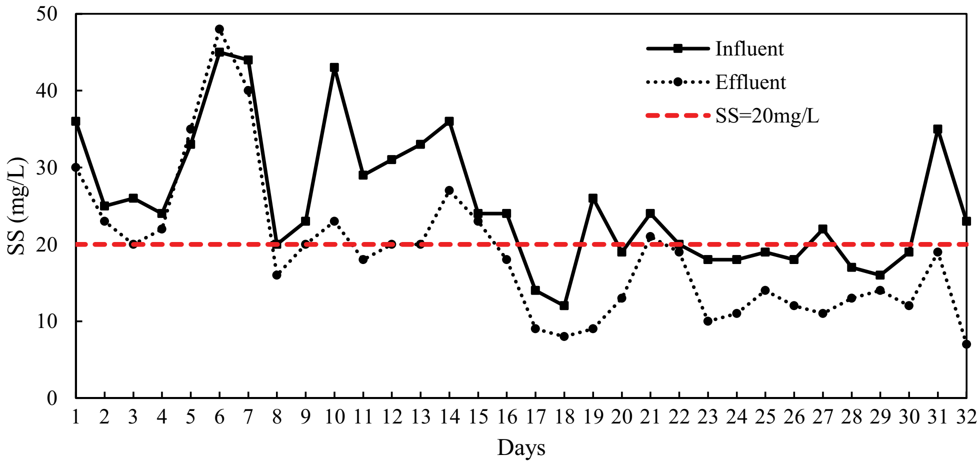

Fig. 3. Variation curves of SS concentration in the influent and effluent of FBF with time.

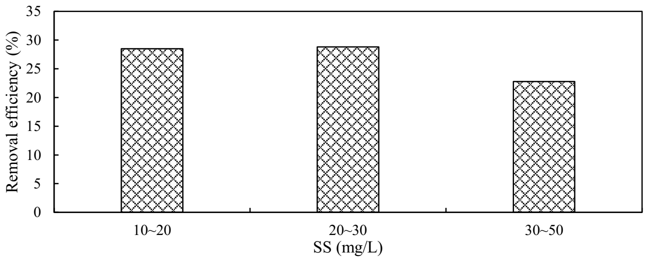

Fig. 4. Removal efficiency of SS by FBF in different SS concentration ranges.

by FBF (Fig. 5), it can be seen that it has a certain purification effect on TN and COD_{Mn}, but they are all lower than 5.0%, and only the removal efficiency of Cd is significant, reaching 97.3%.

3.2. Chemical purification test

3.2.1. Purification of SS

Fig. 6 shows the SS concentration in the influent and effluent of different chemical purification methods. It can be seen that the influent SS concentrations of the three methods are roughly the same, ranging from 25.3 to 26.1 mg/L, all exceeding the standard limit; the effluent SS concentration ranges from 12.8 to 16.2 mg/L, all lower than the standard limit. The removal efficiency of SS by the chemical purification method is FLF, SMS, and FP in descending order.

To compare the removal efficiency of different chemical purification methods for different SS concentrations, the influent SS concentration is divided into 3 intervals (10~20, 20~30, and 30~50 mg/L) from low to high for comparative analysis. The results are shown in Fig. 7. It can be seen that the chemical purification method still has a good purification effect when treating the influent with an SS concentration greater than 30 mg/L. Among them, the SMS purification effect is the best when the influent SS concentration of 10~20 mg/L is treated, and the FLF purification effect is the best when the influent SS concentration of 20~50 mg/L is treated.

3.2.2. Purification of eutrophication indexes

The TN concentration range in the effluent of three chemical purification methods is 2.90~3.30 mg/L, the TP concentration range is 0.01~0.08 mg/L, and the COD_{Mn} concentration range is 2.1~4.2 mg/L. According to water quality standards, the concentrations of TP and COD_{Mn} in the effluent of each purification method do not exceed the standard, while the concentration of TN exceeds the standard. Fig. 8 shows the removal efficiency of TN, TP, and COD_{Mn} by different chemical purification methods in this test. It can be seen that the three methods have lower and roughly the same removal efficiency of TN, ranging from 2.9% to 4.8%, in which SMS is relatively high and FP is relatively low. The TP removal efficiency of the three methods ranges from 51.8% to 80.8%. Among them, FLF and SMS have better and roughly the same efficiency, and the efficiency of FP is remarkable. This is consistent with the comprehensive

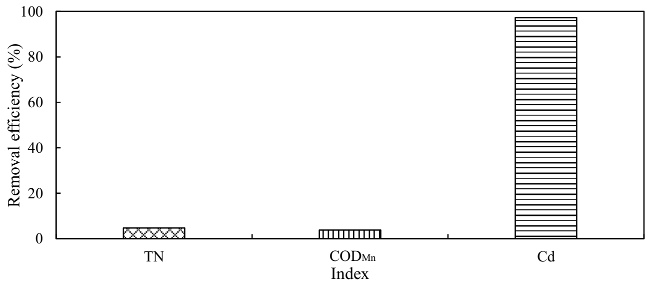

Fig. 5. Removal efficiency of TN, $COD_{Mn,}$ and Cd by FBF.

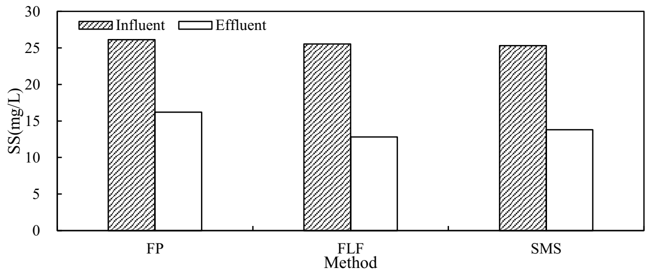

Fig. 6. SS concentrations in the influent and effluent of different chemical purification methods.

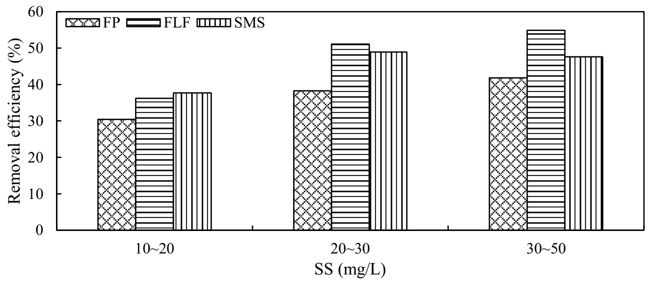

Fig. 7. Removal efficiency of SS by different chemical purification methods in different SS concentration ranges.

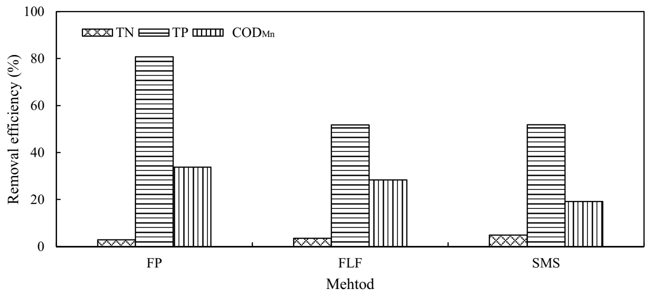

Fig. 8. Removal efficiency of TN, TP, and COD_{Mn} by different chemical purification methods.

test results of Plum on primary rain pollution and confluent sewage overflow pollution, that is, the removal efficiency of TP is 85% [12] and Guibelin et al. [11] test results on rainwater pollution, that is, the removal efficiency of TP is greater than 80%. The removal efficiency of COD_{Mn} is also different among the three methods, ranging from 19.1% to 33.8%, and the removal efficiency is FP, FLF, and SMS in descending order.

3.2.3. Purification of heavy metal indexes

The concentrations of Pb, Hg, and Cr in the influent and effluent of the three chemical purification methods are all lower than the minimum detection limit, the concentrations of Cd and As are lower than the minimum detection limit in some test results, and the concentration range of Cd in the effluent is 0.1~0.3 μg /L, the concentration range of As is 0.3~1.2 μg/L. According to the water quality standards, the concentrations of Pb, Hg, Cr, Cd, and As in the effluent of each method are all lower than the standard limit. Fig. 9 shows the removal efficiency of Cd and As by different chemical purification methods in this test. It can be seen that SMS has a significant effect on the removal of Cd, and the removal efficiency is 95.3%. FP and FLF have a certain removal effect on As, among which the effect of FP is better with the removal efficiency of 56.6%, and the effect of FLF is poor with the removal efficiency of 10.3%. FP and FLF have no obvious effect on the removal of Cd, and SMS has no obvious effect on the removal of As.

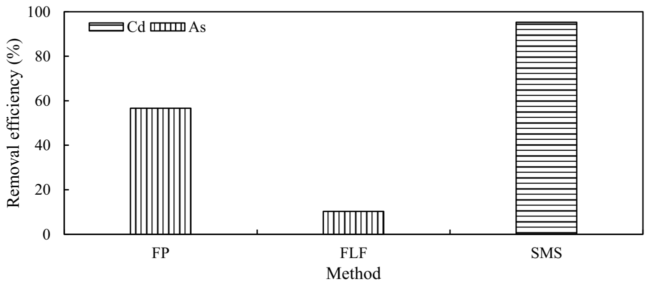

Fig. 9. Removal efficiency of Cd and As by different chemical purification methods.

3.2.4. Analysis of additive residue indexes

The concentration of AM in the influent and effluent of each chemical purification method is lower than the minimum detection limit, indicating that the concentration of AM produced by each method will not cause negative effects. The concentration range of Al in the effluent is 0.01~0.10 mg/L, and the concentration of Fe is lower than the minimum detection limit. According to the water quality standards, the concentrations of Al, Fe, and AM in the effluent of each method are all lower than the standard limit. Fig. 10 shows the removal efficiency of Al and Fe by different purification methods in this test. It can be seen that although each chemical purification method adds PAC in the purification process and SMS also adds Fe_3O_4, the contents of Al and Fe in the effluent of the three chemical purification methods are much lower than that in the influent, and the removal effect is remarkable. Among them, the removal efficiency of Fe by each chemical purification method has little difference, all higher than 90%; the removal efficiency of Al is FLF, SMS, and FP in descending order.

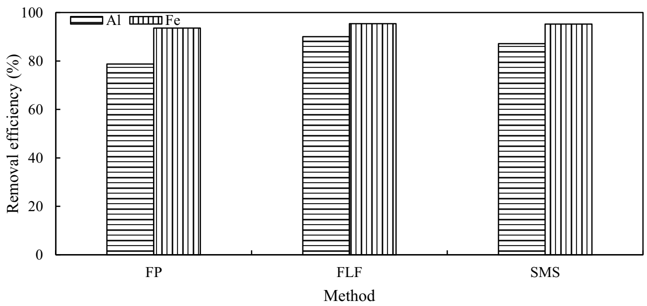

Fig. 10. Removal efficiency of Fe and Al by different chemical purification methods.

4. Discussion

It can be seen from the research results that different methods have different purification effects for SS, eutrophication, and heavy metals in river water, and the possible harm caused by the addition of flocculants needs to be further explored.

SS in water not only affects the transparency and turbidity of the water, and then reduces the primary productivity of aquatic organisms, and can adsorb and desorb toxic elements, organic substances, and microbial bacteria in water, thus causing poisoning to fish and other aquatic organisms. From the detection results of PSOSS in the influent, FBF is mainly concentrated in the range of 12~60 μm, and the median particle size is 25.702 μm; FP is mainly concentrated in the range of 8~50 μm, and the median particle size is 19.535 μm; FLF is mainly concentrated in the range of 10~50 μm, and the median particle size is 22.553 μm; SMS is mainly concentrated in the range of 90~450 μm, and the median particle size is 192.682 μm. Therefore, the filter cloths with a pore size of 5 μm in FBF can theoretically filter most of the SS in water, but it can be seen from the test results that the removal efficiency decreases significantly when the influent SS concentration is greater than 30 mg/L. That is because, on the one hand, the purification effect is affected by the PSOSS and the pore size of the filter cloths, and effective purification can only be achieved when the pore size of the filter cloths is smaller than the PSOSS; on the other hand, the purification effect is also affected by the SS concentration and treatment capacity, and it is difficult to ensure the removal efficiency of SS when the influent SS concentration is high. In addition, the larger the PSOSS is, the easier it is to be filtered or precipitate. However, combined with the results of different ranges of influent SS concentration, the median particle size of FBF is larger than FP and FLF, but the removal efficiency of SS by FBF in each interval is relatively low. This shows that water purification methods with the addition of flocculants have a significantly better removal efficiency on SS than the pure physical filtration method, especially in the treatment of high SS concentration influent. The median particle size of SMS is larger than that of FLF, but when treating the influent with higher SS concentration, the removal efficiency of FLF has increased while that of SMS has decreased, and FLF is always higher than that of SMS. Therefore, it is difficult for the physical purification method to meet the standard requirements when dealing with influent water with high SS concentration, and chemical purification methods adding flocculants have better purification effects, which are common practices at present. Overall, the removal efficiency and stability of FLF for SS are the best among the four methods.

From the perspective of the mechanism of removing SS by different methods, FBF in this test only relies on filter cloths for pure physical filtration, while the flocculants added by other methods can destabilize the SS in water and then aggregate and become larger, forming coarse flocculent agglomerates [26], achieving the purpose of solid-liquid separation and easier to remove SS. FP provides the contact area required to enhance the flocculation through the use of micro-sand. Small flocs increase the probability of collision, thus helping the formation of flocs, and act as ballast or aggravating to speed up the sedimentation rate. While FLF retains the SS through the filter screen. From the perspective of the purification effect, FP has a lower removal efficiency of SS than FLF, because the purification effect of FP is greatly affected by the sedimentation time. Short sedimentation time cannot effectively remove SS, while if the sedimentation time is too long, although the purification effect is improved, it will greatly reduce the purification efficiency. Therefore, in practical work, it is necessary to combine the filtration method after FP to have a better purification effect on water. SMS by adding magnetic medium (Fe_3O_4), based on flocculation, increases the proportion of flocculation to strengthen the flocculation effect and then separates through the superconducting magnet attraction. If the magnetic separation is not complete, the concentration of Fe may increase, and then the water chromaticity and odor will change. In addition, in practical applications, FBF can also be combined with flocculation to enhance the purification effect.

For the eutrophication indexes, the purification effect of the four methods on TN is poor, but chemical purification methods with flocculants have a better purification effect on TP and COD_{Mn} and are obviously better than FBF of pure physical purification. From the perspective of the purification mechanism of adding flocculants by chemical purification methods, the main functions of PAC in phosphorus removal are as follows: on the one hand, after PAC is added, it will be hydrolyzed to form Al^{3+}, which combines with soluble phosphate to form insoluble $AlPO_4$ precipitation, thereby removing PO_4^{3-} in water; on the other hand, by compressing the twin electrical layer, carrying out a series of actions such as adsorption bridging and net capture, the SS and organic pollutants in water are coagulated into agglomerates, after bonding into flocs precipitation through solid-liquid separation to achieve phosphorus removal. The addition of PAM rapidly flocculates small flocs into large and compact flocs through the adsorption bridging effect of its macromolecules or charge neutralization, thereby accelerating the precipitation of particles. The combination of PAC and PAM can not only achieve the best treatment effect but also reduce the amount of the two flocculants, thereby reducing the cost of water treatment. The flocculants also have a certain purification effect on COD_{Mn}, which is also removed by precipitation of particles, so it only has an effect on COD_{Mn} caused by SS.

For heavy metal indexes, FBF and SMS have a significant removal effect on Cd, and FP and FLF have a certain removal effect on As. From the perspective of the purification mechanism, the use of PAC can remove heavy metals such as manganese (Mn), Cd, Cr, and Pb in water [27], mainly by reacting with salt substances in the water to generate large precipitates to achieve water purification. The As removal mechanism of PAC [28] is a combination of co-precipitation and adsorption, mainly removing As^{5+} in water, which usually exists in the form of $H_2AsO_4^-$ or $HAsO_4^{2-}$. Before the $Al(OH)_3$ flocs become larger, the adsorption sites on the surface form covalent bonds with As^{5+}. Within a few minutes, the flocs grow up and continue to adsorb As^{5+} in water. At the same time, As^{5+} and Al^{3+} in water undergo precipitation reaction to form $AlAsO_4$, which is finally removed by precipitation and filtration. The mechanism of Cd removal by PAC [29] is that the $Al(OH)_3$ flocs generated by its hydrolysis and Cd $(OH)_2$, Cd CO_3 have the effects of electric neutralization, sweeping, co-precipitation, etc., forming large flocs and then gradually precipitation, thereby removing Cd^{2+} in the water. Therefore, the removal of Cd is mainly through physical filtration of flocs, and the effective removal of As also requires chemical precipitation, which leads to the fact that FBF, a pure physical purification method, only has a good removal effect on Cd.

The flocculation method is widely used in water purification, but there is little research on its residual amount and the harm to water quality. People tend to pay more attention to the effect of water purification and despise the potential harm caused by the flocculant added to the method. PAC is the most commonly used water flocculant, widely used in drinking water, industrial water, and sewage treatment. However, the Al carried by PAC may bring pollution risks to water. It is neurotoxic and can accumulate in the nervous system of aquatic vertebrates [30], thereby affecting human health and causing serious neurological diseases, such as Parkinson's dementia, amyotrophic lateral sclerosis, and Alzheimer's disease [31]. PAM itself and its hydrolyzate have no toxicity, and its toxicity mainly comes from residual monomer AM. Its wide application also inevitably remains in environmental water, resulting in potential risks, which will inhibit algal growth [32] and have the risk of neurotoxin to humans. PAM is classified as a carcinogenic and mutagenic compound [33]. If the magnetic medium used in SMS is not completely recovered, it will lead to an increase in Fe concentration in water. Although Fe, a heavy metal, is necessary for normal physiological processes of human bodies, it is toxic at high concentrations [34], and excessive Fe can lead to tissue damage and the formation of free radicals [35]. At present, there is no standard for determining the content of AM, Al, and Fe in rivers, but the upper limits are stipulated in the "Standards for Drinking Water Quality" (GB5749-2022), which requires higher water quality. From the results of this test, the residual amount of AM and Fe^{3+} cannot be detected according to the standard detection method, and the concentration of Al^{3+} in the effluent is also within the standard range. It can be considered that the water purification method with the addition of flocculants will not have a negative impact on the concentration of AM, and will not cause excessive concentrations of Al and Fe. On the contrary, when the influent exceeds the standard, it will reach the standard after treatment, indicating that the precipitation reaction of Al and Fe in the water is relatively complete.

It is also important to note that seasonal changes can have an impact on the effectiveness of water pollution control. The Yaojiang River is one of the local drinking water sources and plays a very important role in the living life of people in coastal cities. The comprehensive water quality of the Yaojiang River during the wet season was inferior to the dry season, which was probably caused by the surface runoff carrying various pollutants [36]. This characteristic of water quality showing seasonal variations was reflected in both the Mudan River and the Songhuajiang River [37,38]. In general, the degradation of the chemical water quality was highest after overnight stagnation during the summer [39]. For example, summer stood out negatively for all tap water parameters such as odor, color, turbidity, and hardness from both Poland and Ukraine [40]. However, people may face certain carcinogenic risks in both dry and wet seasons in the use of terminal tap water or chlorinated water [41]. Therefore, water safety can only be ensured by reducing the concentration of contaminants at the source. This study was carried out in summer and the weather conditions were variable during the test period, but the water pollution purification effect was relatively stable. The test results are of reference significance for the selection of purification methods for urban river pollution control.

5. Conclusion

Water fluxes and stores regulate the Earth's climate and are critical to thriving aquatic and terrestrial ecosystems and water, food, and energy security, but humans are also altering the water cycle at an unprecedented scale and rate [42]. Moreover, the use of various chemicals can be harmful to humans and ecosystems while providing benefits to society [43]. The Earth is the common home of human beings, and many plants and animals live in water bodies such as rivers and lakes, and most water bodies on land eventually drain into the oceans, which can seriously threaten the health of organisms and humans if they are polluted. Therefore, water pollution is a global environmental problem. To build the consciousness of the Earth's life community is an inevitable choice to achieve sustainable human development. This study is carried out in the context of caring for the global planetary ecosystem. According to the test results of four water purification methods, the three chemical purification methods of FP, FLF, and SMS have higher removal efficiency of SS, TP, and COD_{Mn} in river water than physical purification methods, and different chemical purification methods have different purification effects on these indexes. FLF is preferred for the removal of SS, and FP is preferred for the removal of TP and COD_{Mn}. For the purification of heavy metal indexes, FBF and SMS are preferred for the removal of Cd, and FP is preferred for the removal of As. However, in practical applications, the water purification goals are multi-faceted, and the best selection should be made according to the comprehensive evaluation of the purification goals. In addition, the chemical purification methods of adding PAC, PAM, and Fe_3O_4 are safe for water quality, but the use of additives will increase the cost of water purification treatment. Therefore, in practical work, it is necessary to comprehensively consider various indicators such as purification goals, equipment prices, flocculant costs, electricity costs, and potential hazards. Drawing on the experimental results of this study, appropriate purification technologies are selected to carry out water pollution treatment, and to a certain extent, the sustainable stability of the planetary ecosystem is maintained.

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