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THE IMPACT OF HIGH WATER LEVEL INFLOW IMPACT LOAD ON THE OPERATION EFFICIENCY OF WATER TREATMENT PROCESSES

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Taking a water plant in Chongqing as the research object, this paper explored the impact of the water influent impact load on the process operation effect of the water plant during the high and low water level survey period of the Jialing River, which is the source water of the water plant. The results shown that under the constant changes of high and low water level influent impact loads, the structures of the water plant had strong impact load resistance. Under high water levels, the water plant had a strong impact on dissolved organic carbon (DOC), total nitrogen (TN), ammonia nitrogen (NH_4^+−N) and dissolved organic nitrogen (DON) increased by 5.91%, 16.35%, 2.34%, and 9.67% respectively compared with the low water level period; the effluent concentration of pollutants in each structure increases with the increase of influent concentration, and there was a significant linear relationship between the two; under high and low water levels, the pollutants gradually decrease along the treatment process of water plant. In addition, the study found that for water plants with large changes in influent load, high-density clarifier technology can be used to effectively remove pollutants.

Keywords: water level; influent shock load; DOC; TN; NH_4^+−N; DON

In China, due to the climatic conditions, geographical location, and other factors in the north and south, the time and duration of the flood season in the north and the south were quite different. The flood season in the south mainly refers to the seasonal rainfall which caused the period when the water level of the river was regularly and significantly increased. The flood season was an important reason for the large changes in the water quantity and quality of the river systems in the south. The changes in river water levels not only change the bottom quality of the river, increase the influent load of the water plant, but also increase the impact load on the structure of the water plant, which affected the treatment effect of water plant technology on raw water[1-3].

The impact load of influent is during the process of water plant operation and treatment, when the quality and quantity of influent water change greatly, the influent load will change significantly, which will cause a certain impact on the process structures of the water plant. The study found that with the increase in water influent load, the hydraulic residence time in the constructed wetland shortens, and the nitrification of ammonia nitrogen in the water was inhibited, so that the removal rate of ammonia nitrogen decreases with the increase influent water[4]. As well as, in the traditional activated sludge methods, the impact load resistance of the system was poor, while the influent water quality suddenly deteriorates, it will cause the effluent water quality to decrease[5]. Some literature pointed out that with the constantly increase of the ammonia nitrogen influent concentration, the nitrification of the activated sludge system has become significantly worse, the ammonia nitrogen impact load has caused a short-term inhibition of nitrification. At the same time, the ammonia nitrogen impact load will seriously affect the system's phosphorus release and phosphorus absorption process, resulting in poor phosphorus removal effect[6]. The surface water source in Jiangyin area located in the south was affected by changes in annual runoff, which had a greatly impact on the treatment process of the water plant, resulting in the deterioration of the effluent quality of the water plant, which did not meet the demand for water supply[7]. The research results of Liu[8] showed that when the ammonia nitrogen in the active anthracite filter exceed 3 mg/L, and the dissolved oxygen content was not increased, the microorganisms in the filter were restricted and cannot process high-concentration ammonia nitrogen in time, leading to effluent did not standard. It can be seen that, the impact load has a greater impact on the existing water plant technology, and it was difficult to ensure the safety of the water quality of the water plant.

Studying the impact load of incoming water can not only improve the resistance of water plants to high loads of incoming water, but also effectively improve the quality of effluent water and enhance the reliability and safety of drinking water for residents. Currently, most of the research on impact load is still in the field of sewage plants and artificial wetlands, with little research on the impact load of water plants on inflow. This article takes a waterworks in Chongqing as an example, which uses the Jialing River as its source water. The water level changes greatly in summer and autumn. The study investigates the impact of influent impact load on the operation efficiency of the waterworks under high and low water levels. The evaluation indicators are dissolved organic carbon (DOC), total nitrogen (TN), ammonia nitrogen (NH_4^+-N), and dissolved organic nitrogen (DON), and the correlation analysis between pollutant influent concentration and effluent concentration is conducted, To provide scientific basis for waterworks that respond to significant changes in influent load.

1 Test conditions

1.1 Test process

A water plant in Chongqing uses Jialing River as raw water, the construction scale of the first and second phases are both 200 thousand m^3/d, and the long-term construction scale is 1.2 million m^3/d. The treatment process that combines conventional treatment and advanced treatment is adopted in the water plant.

The process flow chart of the water plant is shown in Fig.1.

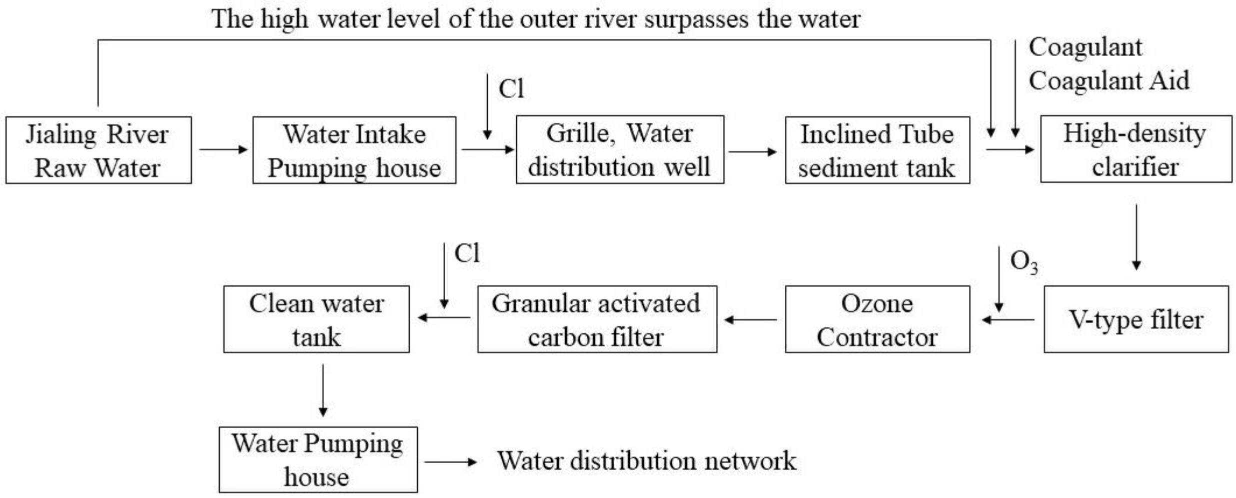

Figure 1 - Process flow chart of a water plant in Chongqing

There is also a heating water and backwashing pool system in the water plant, the system collects heating water and backwashing wastewater in the granular activated carbon filter and the backwashing water in the V-type filter, and after proper treatment sends it to a high-density clarifier for further recovery, treatment, and utilization.

1.2 Analysis items and methods

During the survey period, samples were taken in two periods of high water level and low water level of the Jialing River. Sampling starts on September 8th and ends on September 19th, once a day, sampling the effluent water from various structures in the water plant. After sampling, use a brown reagent bottle to seal and store it in the laboratory. After filtering with a 0.45μm filter membrane before use, the analysis items were measured.

These experiments were carried out according to the Chinese National Standard Methods (SEPA of China, 2002). Total nitrogen (TN) was determined by alkaline potassium persulfate digestion UV spectrophotometry; NO_3^-−N was determined by UV spectrophotometry; NO_2^-−N was determined by N−(1−naphthyl)−ethylenediamine photometric method; and the NH_4^+−N was measured by the Nessler's reagent photometric method; since DON cannot be directly measured, the concentration of DON was determined by the difference method: DON=TN − NO_2^-−N − NO_3^-−N − NH_3/ NH_4^+−N; DOC content was determined by combustion oxidation method, using an Elementar Vario TOC analyzer (high–temperature combustion at 850 °C, nondispersive infrared detection; Elementar Analysensysteme Gmbh, Germany).

2 Results and discussion

2.1 The impact of water plants on the removal of pollutants during high and low water levels

It can be seen from Fig.2 that during the investigation of the low water level of the source water, the removal rates of DOC, TN, NH_4^+−N and DON by the water plant structures were 32.38%~50.91%, −7.48%~13.19%, 89.39%~99.51, and 61.81%~99.15%, respectively, the average removal rates were 39.38%, 2.81%, 93.47%, 80.70%; during the high water level survey period, the removal rates of each pollutant were between 33.03%~62.50%, 10.22%~32.76%, 91.08%~99.12%, 77.53%~99.77%, the average removal rates were 45.29%, 19.16%, 95.81%, 90.37%, respectively. After the water level of the Jialing River increased, the influent load of DOC, TN, NH_4^+−N and DON increased significantly. In this case, the removal rate of various pollutants by the water plant were still increased by 5.91%, 16.35%, 2.34%, and 9.67% compared with the low water level period, which reflected the adaptability of water plant structures to fluctuations in water quality and quantity, and their strong resistance to water ingress impact load. Among them, the TN removal rate increased most significantly during the high water level, this is due to the abrupt rise of the water level, which caused the nitrogen in the sediments of the Jialing River to be washed into the water body, and at the same time, the increase of organic substrates in the influent water provides more carbon sources for denitrification and promotes the smooth progress of the denitrification reaction. This conclusion is consistent with the relevant research results of Wang [9].

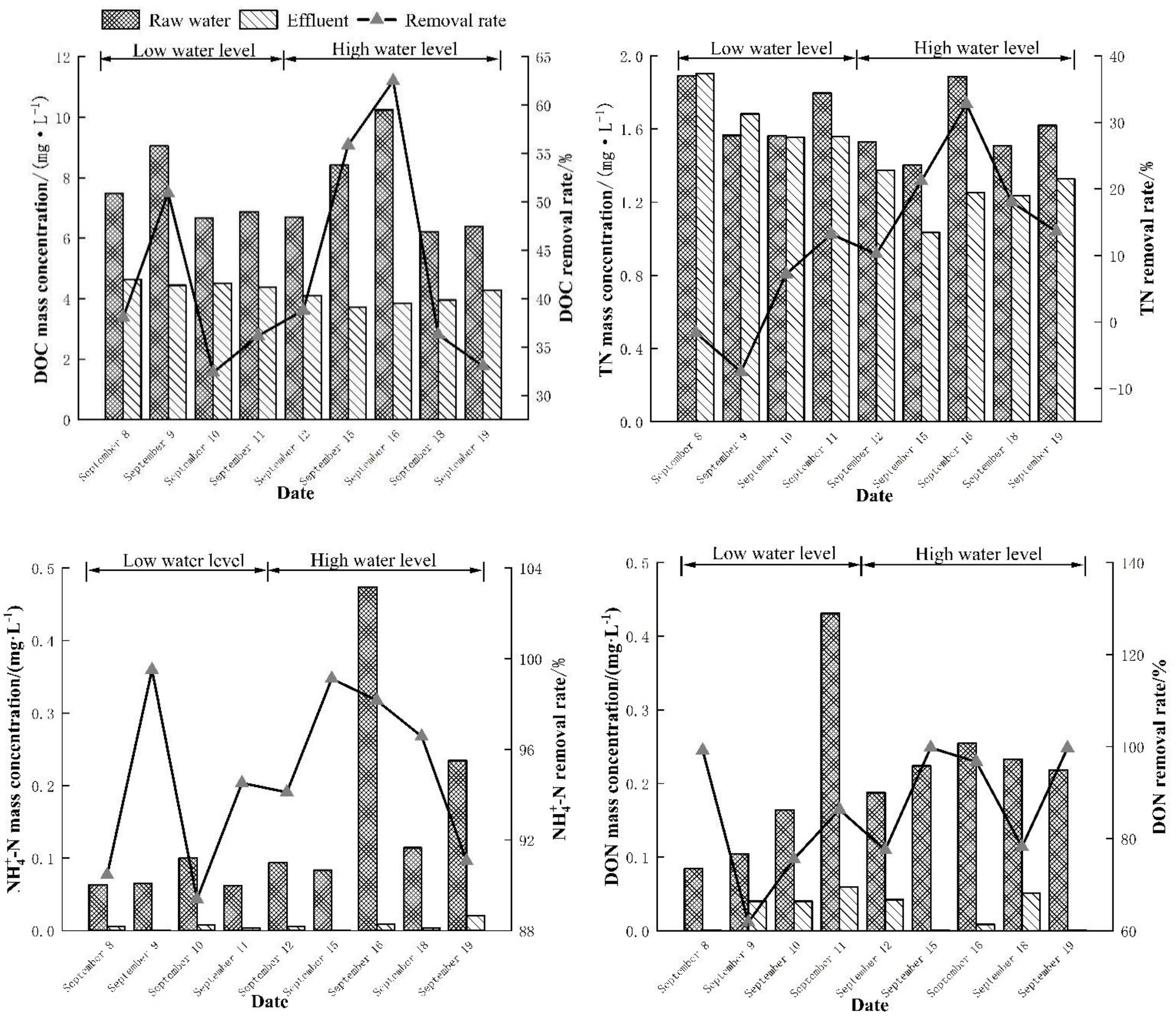

Figure 2 - Pollutant removal effect of water plant during high and low water level:(a) removal rate of DOC in water plant; (b) removal rate of TN in water plant; (c) removal rate of NH_4^+−N in water plant; (d) removal rate of DON in water plant.

During the investigation, the effluent concentration ranges of DOC, TN, NH_4^+−N and DON were 3.72~4.64mg/L, 1.04~1.90mg/L, 0.0003~0.0209mg/L and 0.0005~0.0591mg/L, respectively. The effluent concentration of NH_4^+−N was far less than 0.5mg/L, which meet China's "Drinking Water Sanitary Standards" (GB5749-2006); the DON concentration of effluent meet the EU drinking water quality standards for DON (<1mg/L); The DOC effluent was stable, and the concentration range meet the average TOC concentration range of the water quality data statistics of more than 30 domestic water companies in 1999-2000. Therefore, the water plant has a strong ability to resist impact load and runs well during the high water level of the source water.

2.2 The relationship between the influent concentration and the effluent concentration of pollutants in each structure

The relationship between the influent concentration and the effluent concentration of different pollutants were shown in Fig.3. There was a significant linear correlation between the influent concentration of DOC and the effluent concentration in the inclined tube sediment tank (R^2>0.9), the effluent concentration of DOC increases with the increase of influent DOC concentration. There was also a very significant linear correlation between the influent concentration and the effluent concentration of TN in the V-type filter and Granular activated carbon filter (R^2>0.9). In particular, because the V-type filter in the water plant has been put into operation for a long time, the regular backwashing effect of the filter has become poor, although the service life of the filter material was affected to a certain extent, the biofilm can remain on the filter material, it has good adsorption and conversion capacity for organic pollution such as NH_4^+−N in the water, which can effectively cope with the changes in the influent concentration of TN and NH_4^+−N, and ensure the stability of the effluent water quality. Therefore, TN has a better treatment effect in the V-type filter. This result was consistent with the research conclusion of Wang [10] on the water purification effect of residual biofilm in the filter. In addition, the effluent concentration of each pollutant in the granular activated carbon filter increases with the increase of the influent concentration, which shown that the activated carbon filter has a higher removal effect and reflects the activated carbon filter has a strong impact load resistance.

In general, for pollutants with a good linear relationship, according to the linear equation between the influent concentration and the effluent concentration in the structure, the water quality can be estimated from the influent water quality, and the results can be used to adjust the process parameters of the subsequent structure. Ensure that the effluent water quality meets the "Sanitary Standards for Drinking Water" (GB5749-2006).

The slope of the fitted curve can indicate the change of the effluent concentration under the condition of the pollutant influent change. The smaller the slope of the curve, the smaller the change in effluent water quality and the more stable the water quality under the same change in water inflow. It can be seen from the linear equation of the fitting curve in the figure that in the water plant process, the slope of NH_4^+−N is the smallest, indicating that the effluent concentration of NH_4^+−N after each structure changes the least, and the effluent quality is the most stable, especially after the V-type filter, the effluent performance of NH_4^+−N is significantly better than the other three structures.

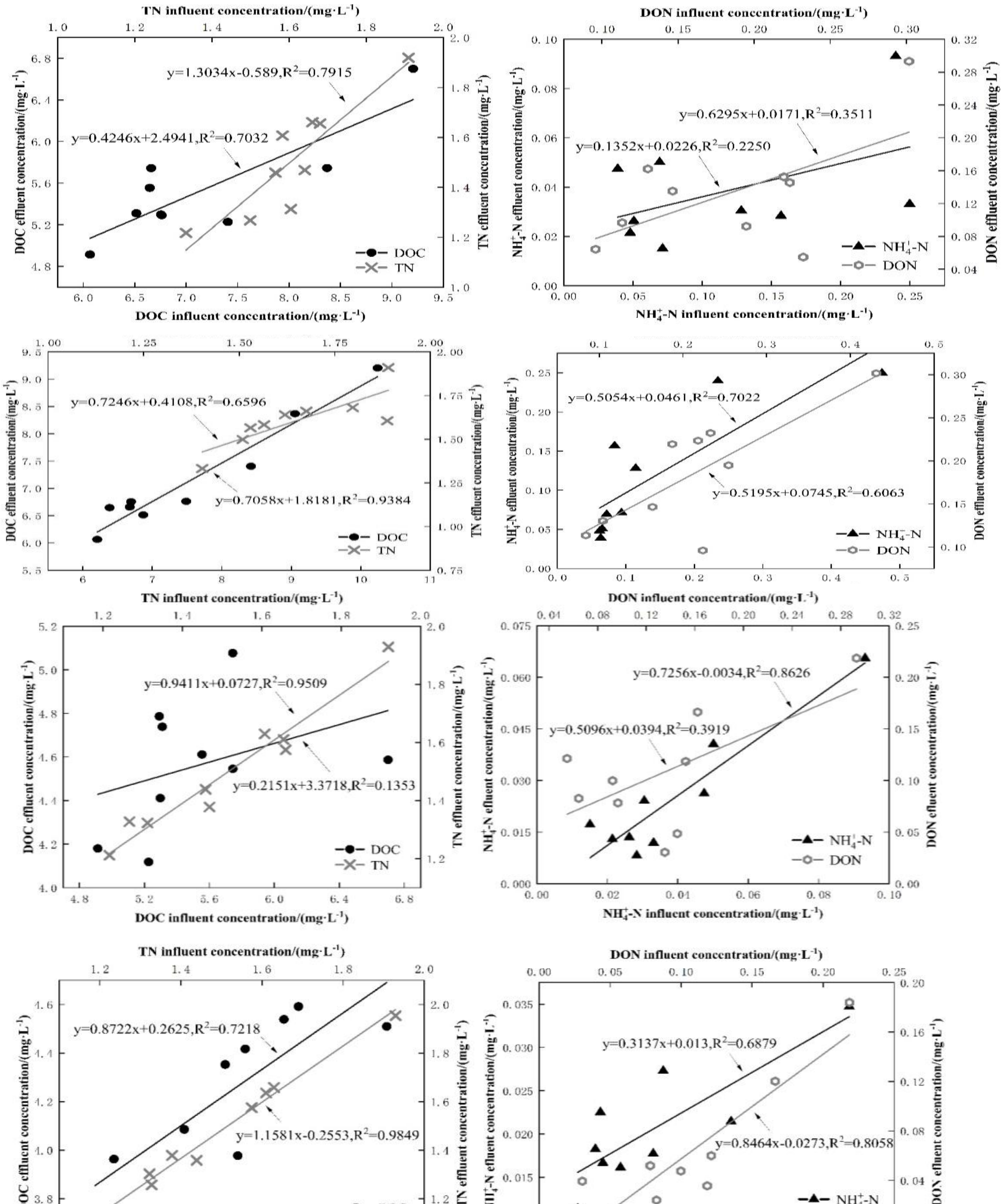

Figure 3 - The relationship between the influent concentration and the effluent concentration of pollutants in each structure:(I)Inclined tube sediment tank(a)relationship between DOC and TN influent concentration and effluent concentration;(b)relationship between NH_4^+−N and DON influent concentration and effluent concentration; (II)High-density clarifier (c)relationship between DOC and TN influent concentration and effluent concentration; (d)relationship between NH_4^+−N and DON influent concentration and effluent concentration;(III)V-type filter(e)relationship between DOC and TN influent concentration and effluent concentration;(f)relationship between NH_4^+−N and DON influent concentration and effluent concentration;(IV)Granular activated carbon filter(g) relationship between DOC and TN influent concentration and effluent concentration; (h)relationship between NH_4^+−N and DON influent concentration and effluent concentration.

2.3 Concentration and removal rate of pollutant effluent along each structure of the water plant during high and low water levels

From Fig.4 (a) and (b), it can be seen that during the low water level survey period, except for TN, the effluent concentration of other pollutants in each structure showed a gradually decreasing trend, while the effluent concentration of TN was not much different from the influent concentration, and it remains basically unchanged throughout the process; during the high-water level investigation, the effluent concentration of each pollutant gradually decreased with the treatment of the water plant structure. Therefore, the water level change will not affect the overall trend of the pollutant removal effect of the water plant process. At high and low water levels, the pollutants can be better removed in each structure.

Among the treatment structures, the high-density clarifier has the best removal effect on DOC, with a removal rate between 13% and 31%, which caused the large range of removal rate variation main reason was that the inclined tube sediment tank has an unstable DOC treatment effect, which affected the influent water of the high-density clarifier to a certain extent, resulting in the continuous change of the DOC removal effect of the high-density clarifier. During the high water level investigation, the high-density clarifier has a significant removal effect on TN and NH_4^+−N, while during the low water level investigation, the V-type filter has a better removal effect on TN and NH_4^+−N than the high-density clarifier, which was because that organic matter in the bottom sludge enters the water plant with the water during the high water level, and the water beyond the river that enters the water plant will be directly sent to the high-density clarifier, which provided more carbon sources for denitrification. Therefore, when the source water was high, the removal effect of TN and NH_4^+−N by the high-density clarifier was better than that of the V-type filter. During the low water level survey, the V-type filter had the highest removal rate of DON, and during the high water level survey, the granular activated carbon filter had the highest removal rate of DON. The reason for the different structures under high and low water levels was that during the high water level, the removal effect of the V-type filter on TN and NH_4^+−N was improved, resulting in a decrease in the removal capacity of DON, but the subsequent granular activated carbon filter improved the treatment capacity of DON, so that the DON effluent concentration still met the EU drinking water effluent quality requirements.

When the influent load was high, compared with other treatment structures, the high-density clarifier had a better treatment effect on DOC, TN, and NH_4^+−N. Therefore, for source water with large changes in pollutant influent load, high-density clarifier technology can be used to achieve good removal of pollutants

When the influent load was high, compared with other treatment structures, the high-density clarifier had a better treatment effect on DOC, TN, and NH_4^+−N. Therefore, for source water with large changes in pollutant influent load, high-density clarifier technology can be used to achieve good removal of pollutants.

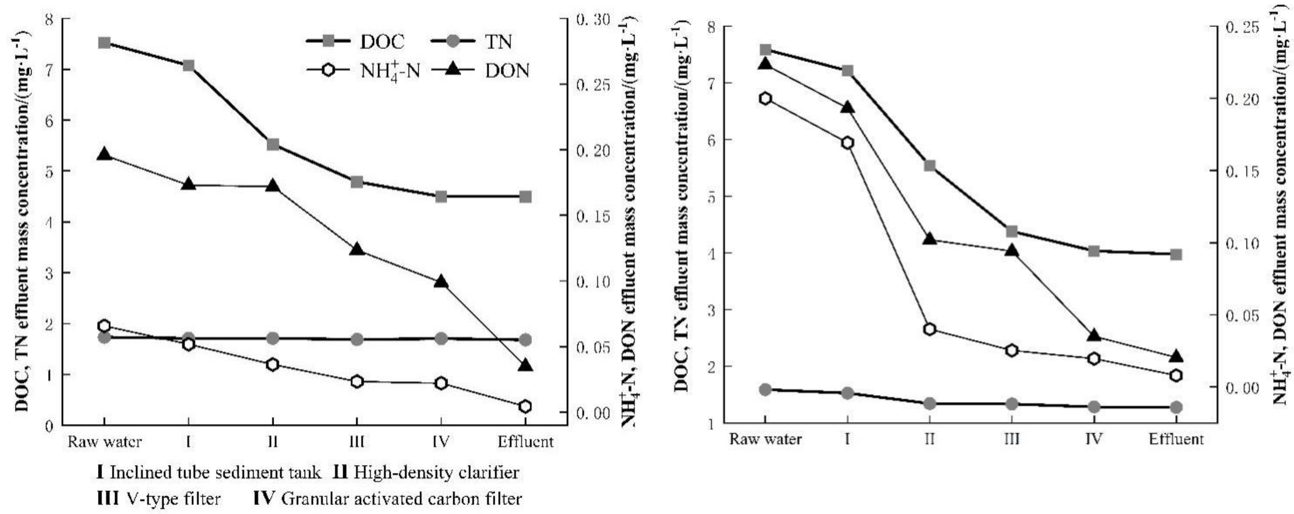

Figure 4 - Concentration of pollutant effluent along the water plant structures during high and low water levels:(a) low water period;(b) high water period.

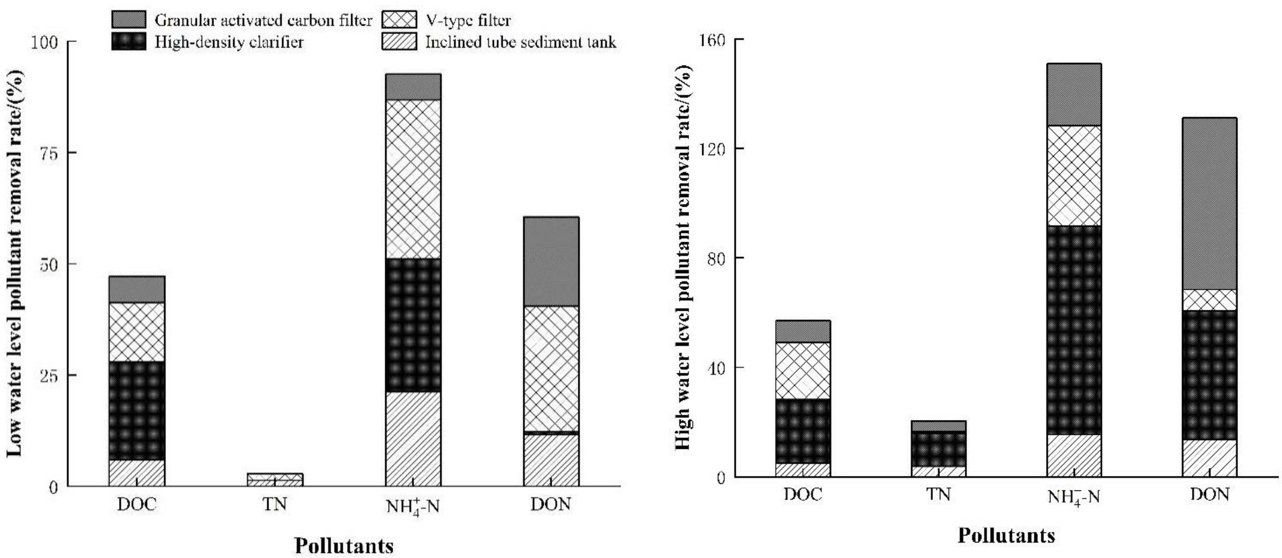

Figure 5 - Pollutant removal rates along the water plant structures during high and low water levels: (a) low water period;(b) high water period.

3 Conclusion

(1) Under different water levels, the water plant process had a good removal effect on various pollutants. The DOC, TN, NH_4^+−N and DON concentrations of the factory water met the effluent water quality requirements. The structures of the water plant can adapt to changes in water quality

and quantity and have strong resistance to impact loads.

(2) According to the obtained linear correlation between the pollutant influent concentration and the effluent concentration, the water quality can be estimated through the influent water quality to ensure that the effluent water quality meets the "Sanitary Standards for Drinking Water" (GB5749-2006).

(3) Under high and low water levels, DOC, TN, NH_4^+−N and DON all show a gradual decrease trend in each structure, and the change of water level will not affect the overall change trend of the pollutant removal effect of the water plant process. The high-density clarifier shown a good removal effect on pollutants, in actual projects, for source water with large changes in pollutant influent load, the high-density clarifier process can be used to achieve good removal of pollutants.

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