Engineering Advances, 2024, 4(1), 11-17
https://www.hillpublisher.com/journals/ea/
ISSN Online: 2768-7961

Study on the Effects of Ceramsite Particle Size Treating Low-polluted Water

Jiajia Yuan*, **Yuheng Liu**

School of Materials and Environmental Engineering, Shenzhen Polytechnic University, Shenzhen, Guangdong, China.

How to cite this paper: Jiajia Yuan, Yuheng Liu. (2024) Study on the Effects of Ceramsite Particle Size Treating Low-polluted Water. *Engineering Advances*, 4(1), 11-17.
DOI: 10.26855/ea.2024.02.002

Received: February 15, 2024
Accepted: March 12, 2024
Published: April 7, 2024

***Corresponding author:** Jiajia Yuan, School of Materials and Environmental Engineering, Shenzhen Polytechnic University, Shenzhen, Guangdong, China.

Abstract

In this study, the influence of ceramsite particle size was evaluated in treating low-pollution water obtained from the enclosed landscape water body. Ceramsites with varied particle sizes (2-4 mm, 4-8 mm and 8-16 mm) were valued for their pollutants removal performance. After the 6-day treatment of 2-4 mm and 4-8 mm ceramsites, the turbidity, surface color, and true color of the low-polluted water dropped to below 2 NTU, 7 degrees, and 4 degrees, respectively. The permanganate index of 4-8 mm and 2-4 mm treated water were 5.7 mg/L and 5.2 mg/L, respectively. 4-8 mm ceramsites also have an excellent removal effect on DOC, and their value dropped to 4.5 mg/L, with a corresponding removal rate reaching 62.1% after 6 days of operation. As with other indicators, the UV_{254}, UV_{280}, E_{250}/E_{365} and CDOM of the water treated with 2-4 mm and 4-8 mm ceramsites were also much better than those treated with 8-16 mm ceramsites. According to the three-dimensional fluorescence spectrum, 8-16 mm ceramsites also have a poor humic acid removal effect. Considering the clogging problem, it was recommended to choose 4-8 mm ceramsites using for low-pollution water treatment.

Keywords

Low-pollution water, Ceramsites, Substrates particle size, Pollutants removal

1. Introduction

Low-polluted water refers to water polluted by organic matter and the concentration of some water quality indicators exceeded the Class IV water quality standard limit of the Surface Water Environmental Quality Standard but was not higher than the secondary standard limit of the Pollutant Discharge Standard of Urban Sewage Treatment Plant [1].

Different types of low-polluted water in different watersheds differ significantly in terms of physical characteristics (e.g. suspended particulate matter etc.), chemical characteristics (e.g. pollutant composition etc.), and have significant differences in degradation, and therefore require different treatment technology systems, such as integrating ponds, forebay reservoirs, gravel beds, ecological filter bed constructed wetlands, and so on [2]. Substrate is one of the main parts of these systems, which plays the role of adsorption and interception of pollutants, and provides growth space for microorganisms [3].

The choice of substrate particle size is very critical, the size of the particle size directly affects the removal of pollutants. Usually, the smaller the particle size of the substrate, the larger its specific surface area, the more biofilm can be attached, and the removal of pollutants would be stronger. Cui et al. found that small-sized substrate particles have greater calcium phosphate, adsorbed phosphorus, and organic phosphorus adsorption capacities than large-sized substrate particles [4]. However, when the particle size of the substrate was too small, its hydraulic conductivity characteristics would be limited, and it was easy to produce the short flow of incoming water, forming a stagnant water zone, which in turn reduced its water purification capacity [5]. Therefore, the influence of substrate particle size on the pollutant removal effectiveness was not solely dependent on smaller particle size showing better removal performance. In the study of Yin et al., phosphorus removal of thermally-treated calcium -rich attapulgite was investigated, and removal rate and capacities decreased with the particle sizes increase [6].

In our study, ceramsites particle sizes of 2-4 mm, 4-8 mm, and 8-16 mm were investigated in terms of the low pollution characteristics using closed landscape water.

2. Materials and Methods

2.1 Experimental water and methods

Experimental water was acquired from the pond which only received rainwater and surface runoff without other pollution sources. The water quality was 9.5-17.5 NTU of turbidity; 17-41 degree of surface color; 7-17 degree of true color; 1.2-3.0 mg/L for TN; 0.04-0.15 mg/L for TP; 6.8-15.4 mg/L for permanganate index and 17.8-38.5 μg/L for Chlorophyll a. Three particle sizes of 2-4 mm, 4-8 mm and 8-16 mm ceramsites were set to compare the substrate particle size. The columns with a 0.14m diameter and 120cm height were used for the experiments, and the influent flow rate was 0.9m^3/d.

The experimental ceramsites were cleaned with tap water to remove floating ash and debris and then filled into columns. Under the same hydraulic load, a certain amount of water from a small landscape confined water body was recycled to compare the pollutant removal effect of different ceramsites particle sizes, so as to select the best particle size. The device was operated for 12 days, and samples were taken every day for analysis.

2.2 Analytical methods

2.2.1 Basic quality indexes

The total nitrogen (TN) and total phosphorus (TP) were measured according to the methodology described in the Standard Method [7].

2.2.2 Chromophore dissolved organic matter (CDOM)

CDOM is the part of dissolved organic matter that can be strongly absorbed in the ultraviolet and visible light spectrum [8]. Different types of dissolved organic matter appeared in different locations of the fluorescence peaks, hence the composition of substances in the water could be determined by the location of the fluorescence peaks. The positions of the fluorescence peaks of each type of dissolved organic matter in the water are shown in Figure 1.

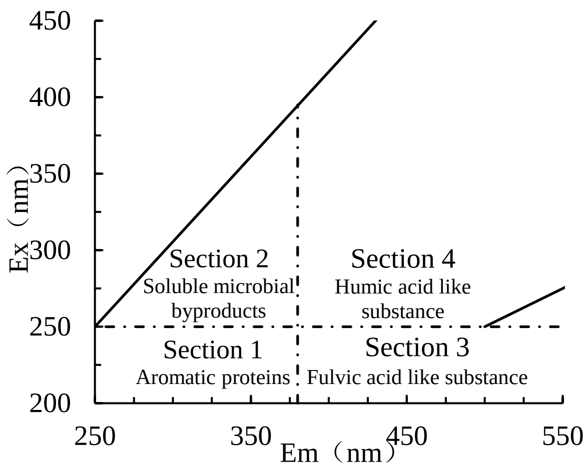


Figure 1. Common locations of three-dimensional fluorescence peaks of dissolved organic matter in aqueous environments.

The water samples were filtered by 0.45 μm filter membrane and scanned by Hitachi F-4500 three-dimensional fluorescence spectrometer. The slit width of the excitation spectrum was 10 nm, and the slit width of the emission spectrum was 5 nm. The scanning range was as follows: excitation wavelength of 220 nm-450 nm, emission wavelength of 250 nm -550 nm, and scanning spacing of 5 nm. The data were processed by Origin software, and the species of organic matter was determined according to the position of the fluorescence peaks, and the concentration of pollutants was compared according to the magnitude of the peaks.

The concentration of CDOM was characterized by absorption coefficient α(λ). After being pre-filtered by a 0.22 μm filter membrane, a water sample measured the absorbance D(λ) using 1 cm quartz cuvette in the wavelength of 355 nm by UV spectrophotometer (UV2600). Then, CODM was calculated by Eq. (1).

$$\alpha(\lambda)= 2.303\cdot D(\lambda)/r - \alpha'(700)\cdot \lambda/700 \quad \text{Eq. (1)}$$

α(λ) — corrected absorption coefficient at wavelength λ (m^{-1});

α'(λ) — uncorrected absorption coefficient at wavelength λ (m^{-1});
D(λ) — absorbance at wavelength λ;
r — optical path (m) ;
λ — wavelength (nm).

2.2.3 UV_{254}, UV_{280}, and E_{250}/E_{365}

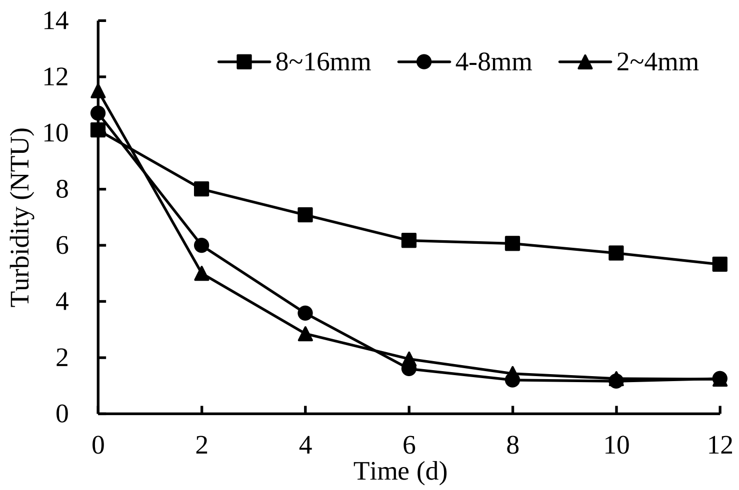
The water samples were filtered with 0.45 μm membrane and then the absorbance at 250 nm, 254 nm, 280 nm, and 365 nm was measured by ultraviolet spectrophotometer (UV2600). E_{250}/E_{365} was the absorbance ratio at 250 nm and 365 nm, and the large value showed the small molecular mass and the degree of aromaticity.

3. Results and Discussion

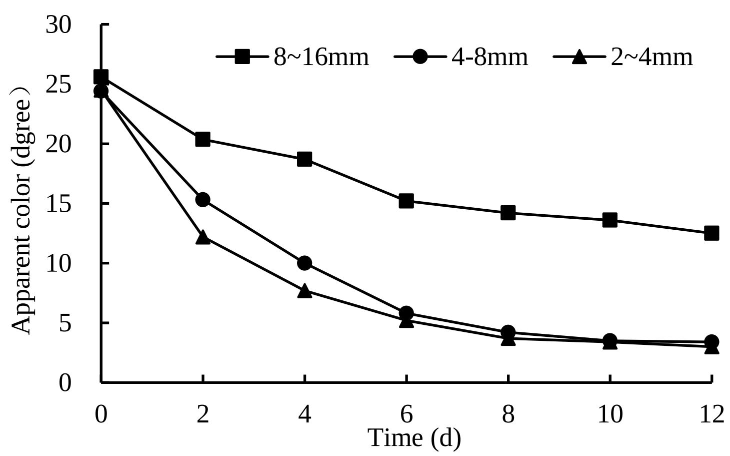
3.1 Ceramsite particle size comparison

3.1.1 Turbidity and chromaticity removal

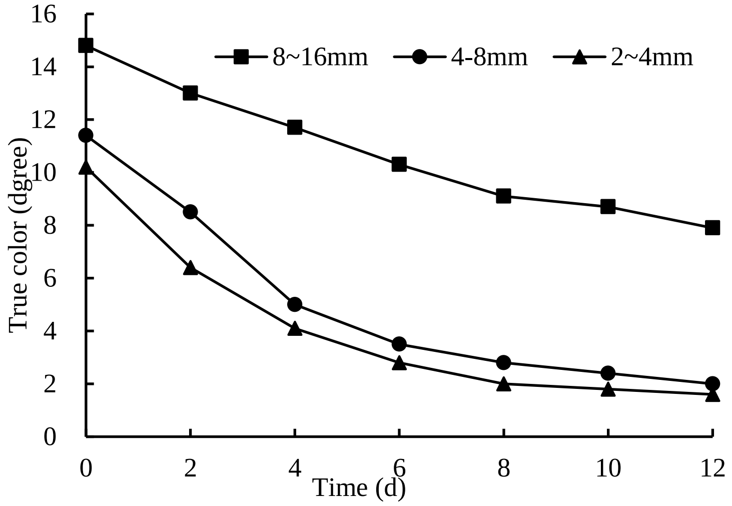
The removal effect of the substrates on pollutants has a great relationship with the particle size [9]. On the one hand, as the particle size decreases, its specific surface area increases, as a result, the growth of microorganisms, the biofilm hanging space, and the system's dirt-holding capacity would increase, which was conducive to the precipitation, adsorption, and filtration of pollutants. On the other hand, as the particle size of the substrate increased, the system's void increased and the oxygenation capacity improved, and at the same time, the clogging of the substrate could slow down [10]. Three kinds of ceramsites with 2-4 mm, 4-8 mm, and 8-16 mm particle sizes were selected for particle size comparison, and the removal effects on each pollutant were compared to determine the optimal ceramsites particle size.



(a) Turbidity



(b) Apparent color



(c) True color

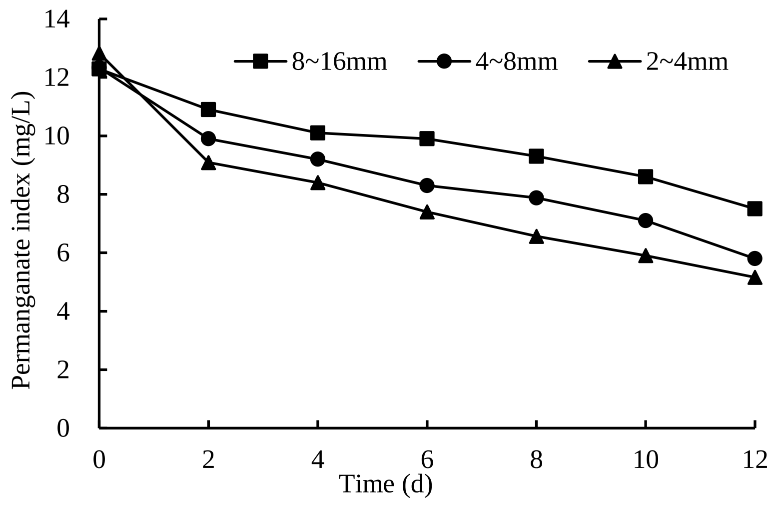
Figure 2. Removal effect of turbidity and chromaticity under different ceramsite particle size.

The removal effects of different sizes of ceramsite on turbidity, surface color, and true color were shown in Figs. 2(a), (b), and (c), respectively. The turbidity and chromaticity of the water treated with 2-4 mm and 4-8 mm ceramsites were similar and significantly lower than 8-16 mm ceramsites. At the 6th d of operation, the effluent turbidity, apparent color, and true color decreased to about less than 2 NTU, 7 degrees, and 4 degrees for the 2-4 mm and 4-8 mm ceramsites, respectively, while the turbidity, apparent color and true color of 8-16 mm ceramsites treated water merely decreased to 7 NTU, 16 degrees and 11 degrees. Therefore, ceramsites with particle sizes of 2-4 mm and 4-8 mm have better treatment effects on turbidity and color than 8-16 mm.

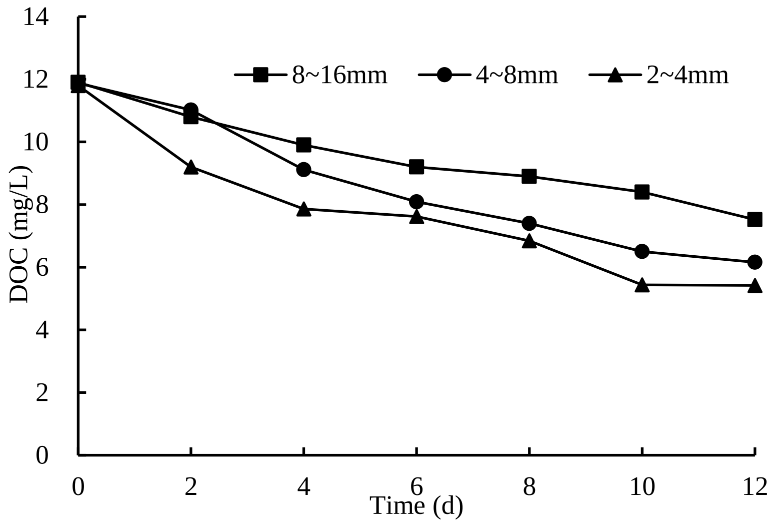
3.1.2 Organic matter removal

It could be seen from Fig. 3(a) that the smaller the particle size of the ceramsites has the better the permanganate index removal rate. After 12 days, the effluent permanganate index of 8-16 mm, 4-8 mm, and 2-4 mm was 7.5 mg/L, 5.7 mg/L and 5.2 mg/L, respectively. As the removal of organic matter in constructed wetlands, which was the conventional low-polluted water treatment method, is mainly through precipitation, biodegradation, and absorption, small particle size ceramics have a larger specific surface area and stronger interception effect. Therefore, the smaller particle size received a better removal effect of the permanganate index.

From Fig. 3(b), 4-8 mm ceramsites displayed the best effect on DOC removal, and the value of DOC decreased to 4.5 mg/L after 6 days, with a removal rate of 62.1%. 2-4 mm and 8-16 mm ceramsites were slightly less effective, and the 12 days of DOC decreased to 5.4 and 6.2 mg/L, respectively. In general, the small ceramsites size was more favourable to the DOC removal.



(a) permanganate index



(b) DOC

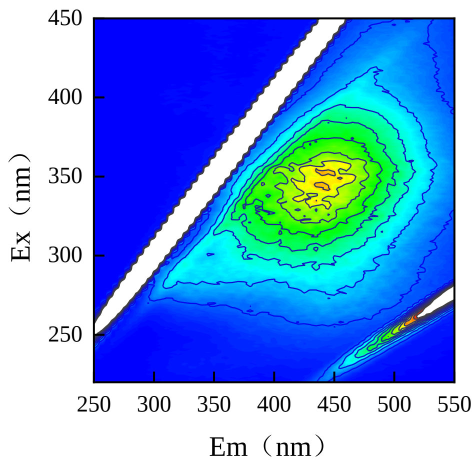
Figure 3. Removal effect of permanganate index and DOC under different ceramsites particle size.

The values of UV_{254}, UV_{280}, E_{250}/E_{365}, and CDOM before and after treatment of low polluted water are shown in Table 1. The CDOM values treated with 2-4 mm and 4-8 mm ceramsites were 1.9 and 1.6, respectively, which were significantly lower than 8-16 mm ceramsites treated water 5.7 and influent of 9.4. It could be seen that the 2-4 mm and 4-8 mm ceramsites particles could effectively remove coloured dissolved organic matter, and reduce the degree of water aromatization and organic matter structuring, the size of molecular mass, and the extent of polymerization, so as to achieve the purpose of reducing water colour.

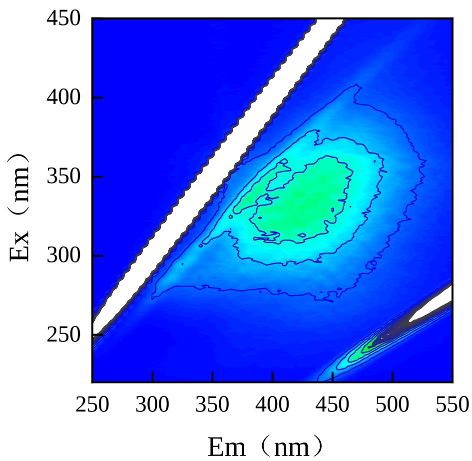
The three-dimensional fluorescence spectra before and after the treatment of water with different particle sizes are shown in Fig. 4. The position of the fluorescence peak corresponds to humic acid, and the three-dimensional fluorescence peak of water after 4-8 mm and 2-4 mm ceramsites treatment has significantly decrease. From the results, it could be concluded that the humic acid removal effect of these two particle sizes was significantly better than 8-16 mm.

Table 1. Removal effect of organic matter-related indicators under different ceramsites particle size

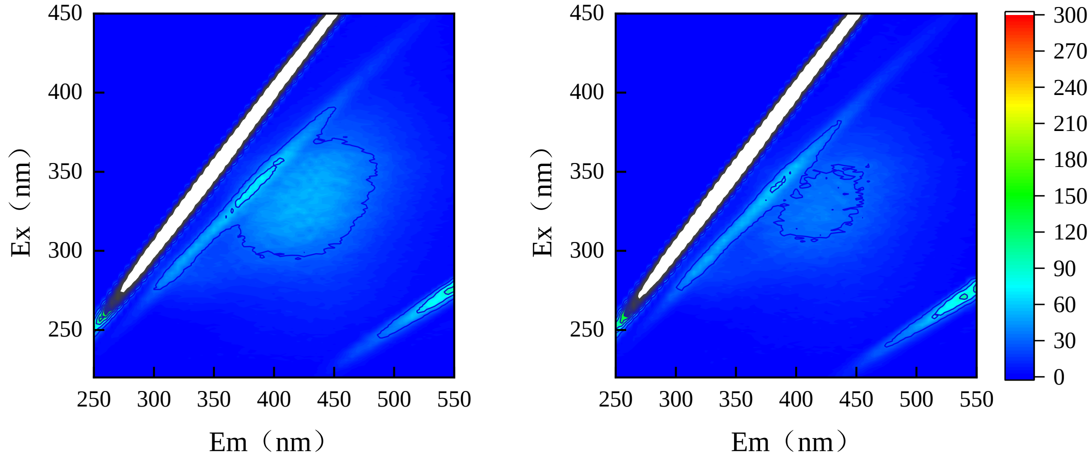
	True color (degree)	UV_{254}	UV_{280}	E_{250}/E_{365}	CDOM
Influent	13.6	0.157	0.122	4.1	9.4
8-16 mm Ceramsites	7.9	0.114	0.087	6.9	5.7
4-8 mm Ceramsites	2.0	0.039	0.026	18.2	1.9
2-4 mm Ceramsites	1.6	0.030	0.020	21.8	1.6



(a) raw water



(b) 8-16 mm ceramsites

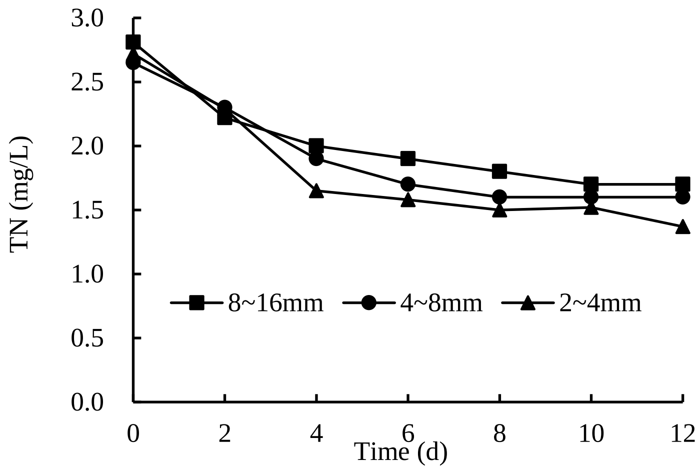


(c) 4-8 mm ceramsites (d) 2-4 mm ceramsites

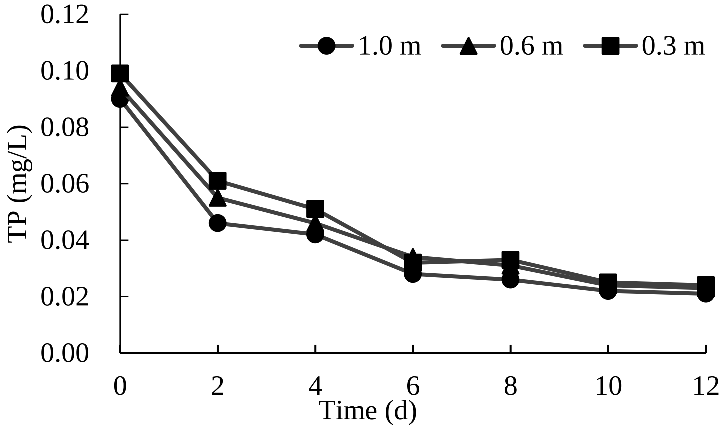
Figure 4. Three-dimensional fluorescence spectrum of raw water and treated water using different ceramsites particle size.

3.1.3 TN and TP removal

From Fig. 5(a) and Fig. 5(b), it was found that 2-4 mm ceramsites have the best effect on TN removal, followed by 4-8 mm and 8-16 mm, respectively. The removal rate of TP by ceramic particles was little difference between 2-4 mm and 4-8 m, and which was significantly better than 8-16 mm ceramasite.



(a) TN



(b) TP

Figure 5. Removal effect of TN and TP under different ceramsites particle size.

By comparing the removal effects of different ceramsites particle sizes treating various water pollutants, it was found that the removal effect of 2-4 mm ceramic particles was slightly better than that of 4-8 mm ceramic particles, but the overall difference was not significant, while was much better than 8-16 mm ceramic particles. The ceramasite layer showed a good ability to remove conventional pollutants has also revealed in the reach of Sun et. al, with the average removal efficiency of TN and TP being 46.33 and 96.81%, respectively, which particle size used 4-10 mm [11]. Though the concentration of suspended solids and other pollutants in the low polluted water, such as landscape water, was not high, three kinds of particle size ceramic particles in the operation of the period have been monitored to the obvious clogging phenomenon. Therefore, the clogging problem cannot be ignored when determining the ceramasite particle size. According to previous research, the smaller the particle size was usually more prone to clogging [12]. Through combination considerations, a 4-8 mm ceramasite particle size was suggested for use in low-pollution water treatment.

4. Conclusion

The research led to the conclusion the removal effect of 2-4 mm ceramsites was slightly better than 4-8 mm ceramsites, but not much difference overall, while it was obviously better than 8-16 mm ceramic grains in terms of particle size. In general, the most suitable substrate for low-polluted water was 4-8 mm ceramsites in our study.

Funding

This research was supported by grants 6022310026K from Shenzhen Polytechnic Colonel-level Science and Technology Youth Innovation Project and grants 6022312024K of Shenzhen Polytechnic University Research Project.

References

[1] Shandong Bureau of Quality and Technical Supervision. Technical guide of constructed wetland water purification system: DB 37/T 3394—2018 [S]. 2018.

[2] Huang T, Liu W, Zhang Y, et al. A stable simultaneous anammox, denitrifying anaerobic methane oxidation and denitrification process in integrated vertical constructed wetlands for slightly polluted wastewater [J]. Environmental Pollution, 2020, 262: 114363.

[3] Ji Z H, Tang W Z, Pei Y S. Constructed wetland substrates: A review on development, function mechanisms, and application in contaminants removal [J]. Chemosphere, 2021, 286:131564.

[4] Cui L, Li W, Zhou J, et al. Influence of substrate depth and particle size on phosphorus removal in a surface flow constructed wetland [J]. Water Science and Technology, 2017, 75(10):2291-2298.

[5] Hanxi W, Lianxi S, Jianling X. Clogging mechanisms of constructed wetlands: A critical review [J]. Journal of Cleaner Production, 2021, 295:126455.

[6] Yin H, Yan X, Gu X. Evaluation of thermally-modified calcium-rich attapulgite as a low-cost substrate for rapid phosphorus removal in constructed wetlands [J]. Water Research, 2017, 115:329-338.

[7] APHA. Standard methods for the examination of water and wastewater, twentieth ed. American Public Health Association, Washington, DC, USA. 1988.

[8] Logozzo, L., Tzortziou, M., Neale, P., et al. Photochemical and Microbial Degradation of Chromophoric Dissolved Organic Matter Exported from Tidal Marshes [J]. Journal of Geophysical Research: Biogeosciences, 2021, 126(4):1-24.

[9] Gholami, M, O'Sullivan, AD, Mackey, HR, et al. Nutrient treatment of greywater in green wall systems: A critical review of removal mechanisms, performance efficiencies and system design parameters [J]. Journal of Environmental Management, 2021, 345:118917.

[10] Wang, H X, Sheng, L X, Xu, J L. Clogging mechanisms of constructed wetlands: A critical review [J]. Journal of Cleaner Production, 2021, 295:126455.

[11] Sun, WJ, Zheng, Z. Research on removal of fluoroquinolones in rural domestic wastewater by vertical flow constructed wetlands under different hydraulic loads [J]. Chemosphere, 2022, 303:1335100.

[12] Xu, Q, Wang, L, Wang, P. Clogging in Vertical Flow Constructed Wetlands: Causes for Clogging and Influence of Decontamination [J]. Ecological Chemistry and Engineering S-Chemia I Inzynieria Ekologiczna S, 2022, 29:65-75.