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Purification effects of five landscape plants on river landscape water

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Abstract. Five species of landscape plants which are *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* were used as experimental materials to study their removal effects on nitrogen, phosphorus, chemical oxygen demand (COD_{Mn}) and suspended solids (SS) in urban river water. The results show that the 5 landscape plants have good adaptability and vitality in water body, among them, *water hyacinth* had the best life signs than the other 4 plants, and its plant height and root length increased significantly. They have certain removal effects on the nitrogen, phosphorus, COD_{Mn} (Chemical Oxygen Demand) and SS (Suspended Substance) in the landscape water of Dalong Lake, Xuzhou. *Scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* on the removal rate of total nitrogen were 76.69%, 78.57%, 71.42%, 69.64%, 67.86%; the ammonia nitrogen removal rate were 71.06%, 74.28%, 67.85%, 63.02%, 59.81%;the total phosphorus removal rate were 78.70%, 81.48%, 73.15%, 72.22%, 68.52%;the orthophosphate removal rates were 78.37%, 80.77%, 75.96%, 75.96%, 71.15%;the removal rate of COD_{Mn} was 52.5%, 55.35%, 46.02%, 45.42%, 44.19%; the removal rate of SS was 81.4%, 86%, 79.1%, 76.7%, 74.42%.The purification effect of 5 kinds of landscape plants of Dalong Lake in Xuzhou City: *water hyacinth*> *scindapsus aureus*>*cockscomb*>*calendula officinalis*>*salvia splendens*.

1. Introduction

Eutrophication of water bodies is a kind of water pollution caused by excessive nitrogen and phosphorus nutrients in water. Many methods for the removal of nitrogen and phosphorus, but the effect is not ideal, according to a large number of studies show that: emerged plants, floating plants and submerged plants have a certain effect on the removal of nitrogen and phosphorus [1]. Different aquatic plants have different effects on water body restoration, but the removal methods of nitrogen and phosphorus by aquatic plants are not single, in natural conditions, nitrogen is mainly removed by volatilization of ammonia, while phosphorus is removed only by absorption of microorganisms and by sedimentation of particles. The purification effect of different plants on various pollutants in water and absorptive capacity are different, therefore, in choosing the plant, we should spend more effort on it, not only to understand the physiological characteristics of plants, but also to understand the mechanism of purification. The combination of various methods makes the water function repaired. With the combination of various methods, the functions of the water body are repaired, and the ecological benefits are improved, the economic benefits are promoted, and the social benefits are highlighted. [2,3,4]

There are many kinds of aquatic landscape plants, and plants, as an indispensable part of the water ecosystem, cannot be replaced by other plants in the restoration of water environment and the beauty of the environment. The purification of polluted water by plants not only for the destruction of the original ecological environment is small, but also to increase the diversity of the species in the region, and has a certain aesthetic effect. With the continuous improvement of treatment technology, phytoremediation of aquatic plants has become more and more popular, and its use is also more and more extensive [5,6]. The application of this technology will help to increase the proportion of water resources reuse, slow down the pollution status of water bodies, improve the pollution proportion of water bodies in China, and promote the restoration of aquatic ecosystems at the same time.

2. Mmaterials and Methods

2.1. Landscape plants

Considering the pollution characteristics of landscape water body and previous related experimental research, considering the temperature and equipment constraints, we used plantlets as experimental material, therefore, the selected *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* 5 kinds of landscape plants as the experimental materials[7,8] .

2.2. Experimental design

The experiment was carried out in the Environmental Engineering Laboratory of Xuzhou University of Technology. The experimental vessel is a round plastic bucket with a height of 30 cm, and the upper and lower diameters are 30 cm and 20 cm, respectively. In the self-made 25cm×10cm×3cm at the bottom of the rectangular plastic foam board with holes, according to the distance between 3 cm, 4 mm aperture, drilling, playing two rows of five holes. The test specimens which are *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* are inserted in the center of the plastic foam plate in sequence, a row of 2 strains, another row of 3 strains, 5 strains of a barrel, Plastic foam plate is placed in the durm and fixed. Test set 5 groups of experimental group, 1 groups of blank control group, a total of 6 groups, 5 plants were cultivated in 5 different drums,in the blank control group, no plants were Once every 3 days tested water samples in each plastic drum dissolved oxygen content, temperature and pH value; The total phosphorus, orthophosphate, total nitrogen, ammonia nitrogen, chemical oxygen demand and suspended matter content of each sample were measured every 7 days, a total of 5 measurements were performed. The experimental data were recorded, and the value of each index to be measured was repeated 3 times, and the average value was determined.

2.3. Determination method

Total nitrogen: peroxide potassium sulfate-ultraviolet spectrophotometry; Total phosphorus: ammonium molybdate spectrophotometric; Orthophosphate: molybdate spectrophotometric; Chemical oxygen demand (CODMn): potassium permanganate method; suspended solid (SS): gravimetric analysis.

3. Rresults and Analysis

3.1. Plant growth analysis

During the experiment, from the plant growth, *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* can maintain their vitality and survive normally in polluted water bodies, this shows that these 5 landscape plants have stronger adaptability to the Dalong Lake landscape water body. *scindapsus aureus* and *water hyacinth* growth situation is good, fast breeding, leaves full and lustrous, while the growth of *cockscomb*, *calendula officinalis*, a string of red, the plants were not found in the phenomenon of death. After six weeks of growth, plant height and root length increased, but the growth rate was small. The analysis shows that the cause of this situation may be due to the low water temperature, little accumulation of biomass in the plant and slow metabolism.

3.2. Nitrogen removal by plants

3.2.1. Removal of total nitrogen, the removal of total nitrogen (TN) from water by the 5 landscape plants was more obvious. At the beginning of the experiment, the total nitrogen content decreased rapidly, and decreased slowly in the late experiment. At the end of the experiment, the total nitrogen content of the water body reached the minimum.

Analysis believe that At the beginning of the experiment, the sedimentation of water is stronger, total nitrogen in water can be absorbed and intercepted through plant roots; over time the settlement effect gradually weakened, while the plant roots reached the adsorption saturated adsorption has little effect, so the removal efficiency of total nitrogen poor late plants. As time goes on, the settlement action of silt is gradually weakening, and when the plant roots reach the saturated state of adsorption, the adsorption effect is also small, so the removal of total nitrogen by late plants is not good, and when the plant roots reach the saturated state of adsorption, the adsorption effect is also small, so the removal of total nitrogen by late plants is not good. Therefore, the later period of the experiment mainly depended on the absorption of plants, the degradation of microorganisms and the adsorption to remove nitrogen. The content of total nitrogen in *water hyacinth* decreased from 1.12mg/L to 1.01mg/L, the removal rate was 78.57%,*scindapsus aureus*, *cockscomb*, *calendula officinalis* and *salvia splendens*, removal of total nitrogen in water were 76.69%, 71.42%, 69.64%, 67.86%. The total nitrogen removal rate of the control group was only 8.93%, which was significantly lower than that of the five groups($p < 0.05$). Therefore, *water hyacinth* and *scindapsus aureus* in Xuzhou City of Dalonghu water total nitrogen removal (Figure 1).

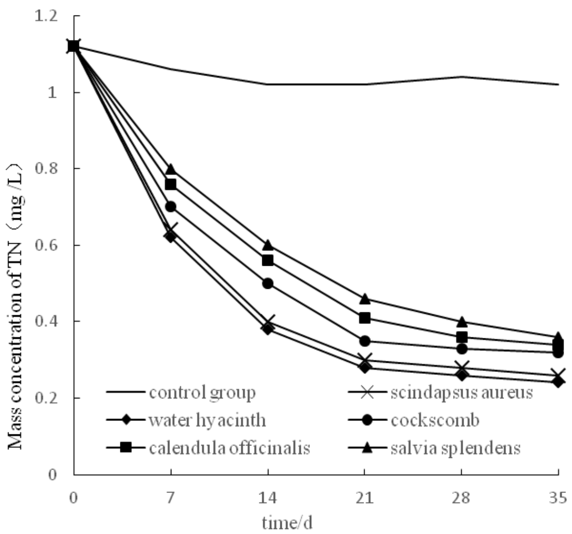

Figure 1. Effect of plant removal on TN

3.2.2. Removal effect of ammonia nitrogen, five groups of landscape plants also had significant effect on removal of ammonia nitrogen (Figure 2). The concentration of ammonia nitrogen in the experiment within 21 days of the scindapsus aureus, water hyacinth, cockscomb, calendula officinalis and salvia splendens in water body is reduced from 0.622mg/L to 0.23mg/L, 0.20mg/L, 0.26mg/L, 0.30mg/L and 0.32mg/L respectively, the removal rates were 63.02%, 67.85%, 58.20%, 51.77% and 48.55%, respectively, the removal rate of ammonia nitrogen was 3.5% in the control group; To the end of the experiment when the ammonia scindapsus aureus, water hyacinth, cockscomb, calendula officinalis and salvia splendens removal rate were 71.06%, 74.28%, 67.85%, 63.02%, 59.81%, 6.8%. It can be seen that the 5 groups of experimental groups compared to the control group, ammonia nitrogen removal effect is more significant ($p < 0.05$).

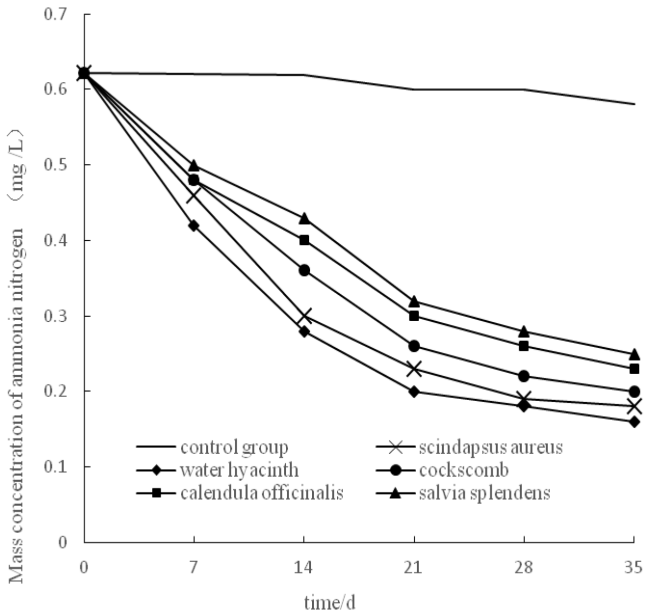

Figure 2. Effect of plant removal on ammonia nitrogen

Total nitrogen is composed of inorganic nitrogen and organic nitrogen. Inorganic nitrogen mainly includes nitrate nitrogen, nitrite nitrogen and ammonia nitrogen. Generally speaking, the nitrite nitrogen in the normal water body is easily oxidized to nitrate nitrogen, and the content is very little. Therefore, the study on the removal of nitrogen mainly begins with ammonia nitrogen and nitrate nitrogen. For water bodies that exist in aquatic plants, there are two main steps to complete the removal of nitrogen: One is the conversion of some ammonia nitrogen into nitrate nitrogen and nitrite nitrogen by nitrification and denitrification, there is a small part of the ammonia nitrogen, nitrate nitrogen and nitrite nitrogen directly by aquatic plants absorb their life activities required for synthesis of organic compounds, there is also a small fraction of ammonia nitrogen, nitrate nitrogen and nitrite nitrogen, which can be absorbed directly by aquatic plants to synthesize organic nitrogen compounds required for their own life activities; The other is to remove partial nitrate nitrogen by denitrification. It has been found that the removal route of ammonia in experimental water has a great influence on the characteristics of ammonia nitrogen concentration [9,10] , ammonia is mainly removed in three ways in water: Ammonia volatilization: ①The value of pH in water body has a certain influence on ammonia volatilization. When pH is 8.0 to 9.3, ammonia volatilization is most significant; When pH is 7.5 to 8, ammonia volatilization is not particularly obvious; However, when the pH of water is less than 7.5, ammonia volatilization can be neglected directly. The pH value of water in this experiment is between 6.5 and 8, so the effect of ammonia volatilization can be neglected. Therefore, this experiment mainly through nitrification and absorption of aquatic plants to remove ammonia nitrogen. ②Nitration: nitrification is the process of oxidation of ammonia to nitric acid under the action of nitrifying bacteria. Nitrifying bacteria are aerobic bacteria, so the concentration of dissolved oxygen in water has a certain influence on nitrification. Meanwhile, temperature and pH are also important factors of nitrification. The optimum pH of nitrification is between 7 and 8.6, the concentration of DO (dissolved oxygen) is generally higher than 2mg/L, and the nitrification inhibition is obvious when the temperature is lower than 15℃. The concentration of dissolved oxygen in water was higher than that of 2mg/L, at a temperature of 14.5℃ to 20.3℃, pH ranged from 6.5 to 8, the experimental data show that the experimental water environment suitable for the growth of nitrifying bacteria, so ammonia nitrogen removal is in direct contact with the nitration reaction. ③Plant uptake: plants absorb nitrogen from the free nitrate nitrogen and ammonia nitrogen in the water to remove the nitrogen. Nitrogen is a necessary nutrient for the growth of different plants. The accumulation of nitrogen in plants has a strong correlation with its physiological characteristics, in eneral, the plant will be absorbed to produce its own biological nitrogen can according to their own physiological activities, so the growth trend of the plant itself can be more intuitive to reflect absorb the nutrients in water from plants. The study found that, at the end of the experiment of 5 kinds of plant height and root length increased, it can be seen that they have certain absorption effect on nitrogen in water, the *scindapsus aureus* and *water hyacinth* biomass and growth rate is larger, so for the adsorption of nitrogen is stronger, the removal rate is greater. 5 kinds of plants have obvious effect on the removal of total nitrogen in the water, but the removal effect has certain differences, this is due to the different physiological mechanism, there are some differences, so there are some differences on the removal mechanism of nitrogen [11].

3.3. removal of phosphorus by plants

3.3.1. Removal efficiency of total phosphorus, As can be seen from Figure 3, the removal of TP in Dalong Lake landscape water in 5 landscape plants is obvious, tamong which the total phosphorus content decreased and the fastest was the water body of the water hyacinth, the fastest decline in TP content is the body of water of water hyacinth, but cockscomb, calendula officinalis and salvia splendens, for water in the total phosphorus removal rate is not particularly large. At the end of the experiment, water hyacinth, scindapsus aureus, cockscomb, calendula officinalis, salvia splendens and the mass concentration of TP in the water of the control group decreased from 0.108mg/L to0.020mg/L, 0.023mg/L, 0.029mg/L, 0.030mg/L, 0.034mg/L, 0.100mg/L respectively, the removal rates were 81.48%, 78.70%, 73.15%, 72.22%, 68.52%, 7.4% respectively, the removal rate of TP in the experimental group was much higher than that of the control group ($p < 0.05$).

Some phosphorus in water body can be absorbed by aquatic plants directly. After assimilation, the synthetic plants form the components of their own structure, the storage method can make the phosphorus firmly stored in the plant, and the phosphorus fixed in the plant is artificially harvested, and the phosphorus can be easily carried out of the water body to achieve phosphorus removal effect, which is economical and efficient. At the same time, plant roots have a certain amount of phosphorus accumulating bacteria, which can reduce phosphorus content by absorbing phosphorus, however, in the control group without plant cultivation, the total phosphorus content in the barrel also showed a downward trend, which indicated that the water had a certain removal effect on phosphorus through sedimentation. Therefore, in addition to the absorption and assimilation of plants by the total phosphorus, the decomposition of microbial roots and the gravitational sedimentation is one of the important ways to reduce phosphorus.

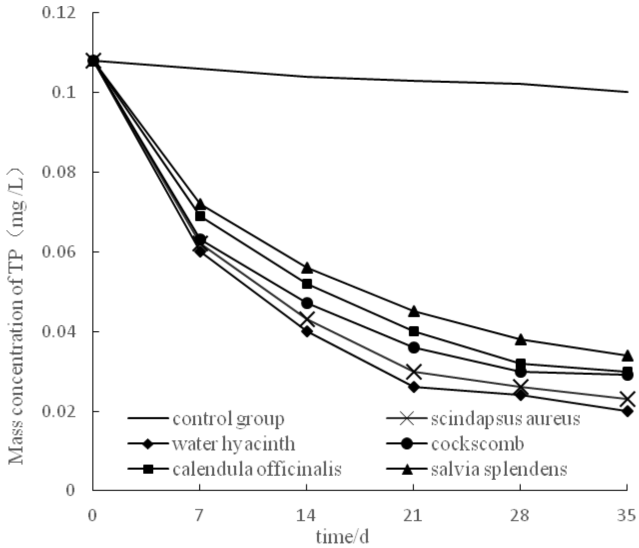

Figure 3. Effect of plant removal on TP

3.3.2. Removal of orthophosphate, As can be seen from Figure 4, the 5 landscape plants have a certain removal effect on orthophosphate in the landscape water of Dalong Lake. For the cultivation of water hyacinth, scindapsus aureus, cockscomb, calendula officinalis, salvia splendens and control group in water for phosphate removal rate were 80.77%, 78.37%, 75.96%, 75.96%, 71.15%, 15.8%. Combination of Figure 3 shows that the removal efficiency of orthophosphate in 5 water bodies is almost the same as that of total phosphorus, but the removal rate is slightly lower than that of total phosphorus. The reason for this result is that total phosphorus in water is not only a form of orthophosphate, but also contains acid hydrolysis phosphate, soluble organic phosphate and phosphorus. Studies on orthophosphate have shown that orthophosphate is the dominant form of phosphorus in the experimental water. Different forms of phosphorus removal, assimilation and transformation are different in different plants and microorganisms. The transformation of organic phosphorus cannot be separated from the synergistic effects of plants and microorganisms, first of all, through the transformation of microorganisms, the organic phosphorus is converted to inorganic phosphorus, and then through the absorption and assimilation of plants into a component of the plant itself. The removal of phosphorus is much simpler, and the plant can be removed directly through the adsorption and filtration of the root system. The removal mechanism of orthophosphate is basically the same as that of total phosphorus removal, that is to say, plant roots have a certain retention and adsorption effect on phosphorus, accompanied by microbial degradation [5,12]

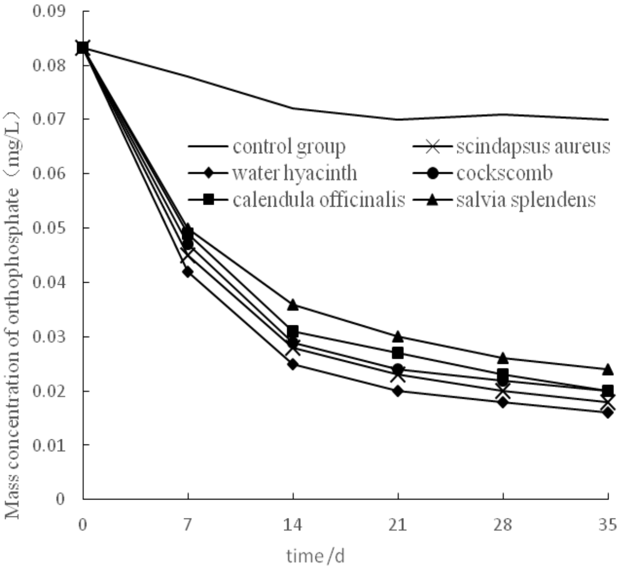

Figure 4. Effect of plant removal on orthophosphate

3.4. The removal efficiency of chemical oxygen demand (CODMn) by plants

As can be seen from Figure 5, the 5 groups of landscape plants have significant effects on the removal of COD_{Mn} in water. Among them, *water hyacinth* had the most significant removal effect on COD_{Mn}, which decreased from initial 32.25mg/L to 14.4mg/L; The second is the cultivation of *scindapsus aureus*, COD_{Mn} in water decreased to 15.32mg/L; The difference of final removal rate of COD_{Mn} in water between three other plants is not obvious. At the end of the experiment, *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* for the chemical oxygen demand in water in the final removal rate is 52.5%, 55.35%, 46.02%, 45.42%, 44.19%. The concentration of CODMn in the control group also decreased to some extent, and the removal rate was 12.25%, which was significantly different from that of the 5 groups($P < 0.05$).

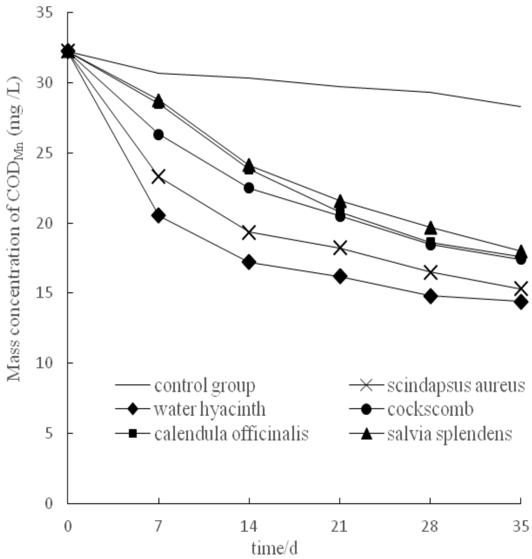

Figure 5. Effect of plant removal on COD_{Mn}

The degradation of chemical oxygen demand in water is mainly limited by several factors, one is temperature; The other is dissolved oxygen concentration; The third is the species and quantity of microorganisms attached to plant roots in water. Generally speaking, the concentration of dissolved oxygen in water is usually the controlling factor. When the concentration of dissolved oxygen is less than0.20mg/L, anaerobic degradation occurs. When the concentration of dissolved oxygen is between 0.20mg/L and 1.0mg/L, the anoxic degradation reaction occurs. When the concentration of dissolved oxygen is greater than 1.0mg/L, the aerobic degradation reaction occurs [13]. The concentration of dissolved oxygen in the 5 experimental groups was consistently greater than 1.0mg/L, therefore, COD_{Mn} is degraded mainly by aerobic degradation process. *Water hyacinth* on the highest removal rate of CODMn, mainly due to its roots, growth and reproduction provides good places for microorganisms, promote the adsorption and absorption of CODMn interception and filtering effect, of course, microbial degradation cannot be ignored [14].

3.5. Removal of suspended solids (SS) by plants

Suspended particles in water are particles with diameters ranging from 10nm to 0.1μm, visible to the naked eye, most of them are composed of sediment, bacteria, viruses, protozoa, algae and high molecular organic matter. They usually exist in water in suspended state. These particles are unstable and tend to vary with season, temperature, and region. For the water environment, suspended solids are also an important parameter, but from the literature data of water environment research over the past few years, it is found that there is little research on the suspended solid.

As illustrated in Figure 6, the 5 landscape plants have a certain removal effect on suspended matter in water. At the end of the experiment, each experimental group for the removal rate of SS: the *water hyacinth* is 86%, *scindapsus aureus* is 81.4%, *calendula officinalis* is 76.7%, *cockscomb* is 79.1%, *salvia splendens* is 74.42%. Although the removal rate was higher than that of the control group whose removal rate was 44.2%, the removal efficiency was not ideal. The removal effects of suspended substances in water are different due to the different species of aquatic plants. The removal of suspended solids in *water hyacinth* and *scindapsus aureus* is significant, *calendula officinalis*, *salvia splendens*, *cockscomb* to suspended solid in water removal take second place. Because the experiment was performed in a fixed volume of the drum, there is a big gap compared to the rivers and lakes in the aquatic environment, so the test has some limitations. Composition of suspended solids in the drum is mainly sediment, algae, bacteria and so on are few and can be negligible. Therefore, in this experiment, the suspended substances in water body are mainly removed by natural sedimentation, and some suspended substances which cannot be removed by sedimentation are removed by the adsorption and retention of plant roots.

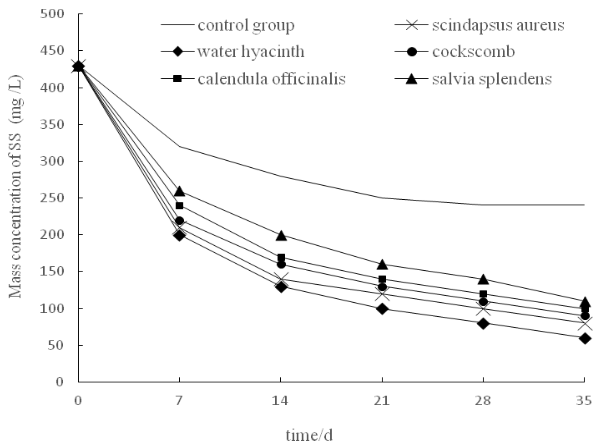

Figure 6. Effect of plant removal on SS

Cui Xiang's [13] research shows that the method of removal of suspended solids in waste water, the majority of using the traditional method of removal, the best known is the method of adding medicament in water, adding various coagulants to fine suspended matter in water and colloidal substances into the sediment, removed by sedimentation. The removal of suspended solids in water can be removed by other methods, such as: centrifugal separation, air flotation, filtration, reverse osmosis, membrane separation, evaporation concentration. These methods are not only efficient in removal, but also economical and fast compared to the present experiment. Therefore, for the removal of suspended solids, it is not suitable for the removal of suspended matter in water using a single plant. Although there are some ecological advantages in the removal of suspended solids by plants, there are many disadvantages such as long time consuming, low treatment intensity and high cost compared with traditional treatment methods. Although higher aquatic plant communities have good effects on the removal of suspended solids in water bodies, they have high requirements for plant species collocation, planting density and range, and are difficult to implement. At the same time, the research shows that the removal effects of suspended matter are related to different kinds of plant combinations, and should be acted according to actual circumstances of the specific conditions of water quality.

4. Conclusion

(1) Five kinds of landscape plants which are *scindapsus aureus*, *water hyacinth*, *cockscomb*, *calendula officinalis* and *salvia splendens* grows well in the laboratory hydroponics conditions, plant height and roots all increased to a certain degree,the roots and its height is increased to a certain extent.

(2) The final removal rate of *water hyacinth*, *scindapsus aureus*, *cockscomb*, *calendula officinalis*, *salvia splendens* in the laboratory after 35 days of plant growth in the city of Xuzhou in Dalong Lake the total nitrogen in the water were 78.57%, 76.69%, 71.42%, 69.64%, 67.86% respectively; The final removal rates of ammonia nitrogen were 74.28%, 71.06%, 67.85%, 63.02%, 59.81% respectively; The removal rate of total phosphorus were 81.48%, 78.70%, 73.15%, 72.22%, 68.52% respectively; The removal rates of orthophosphate were 80.77%, 78.37%, 75.96%, 75.96%, 71.15% respectively; The final removal rate of chemical oxygen demand were52.5%, 55.35%, 46.02%, 45.42%, 44.19%, the removal of SS is not particularly satisfactory. The removal of total nitrogen adsorption mainly depends on the absorption and assimilation of plants, microbial degradation and the adsorption and retention of plant roots, the removal of ammonia nitrogen mainly through absorption and assimilation, ammonia removal in the control group mainly rely on physical effects, that is ammonia volatilization.

(3) Different landscape plants on the water purification capacity there is a certain difference, *water hyacinth*, *scindapsus aureus* for the Dalong Lake landscape water in Xuzhou in nitrogen, phosphorus and chemical oxygen demand removal efficiency significantly.

Acknowledgements

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