Research on comprehensive treatment of water environment in wetland park based on purification and restoration of aquatic plants

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Abstract
The construction of landscape water bodies can improve the residential environment of the city to meet the residential requirements of residents. However, the cost of constructing landscape water bodies is too high and difficult to build. Most of them are static or immobile water systems. In many cities nowadays, the water landscape has been polluted, and the water body is overflowing with eutrophication. Reasonably optimizing the combination of multiple aquatic plants has a better purification function for the entire water body than a single plant, but it is easy to ignore the ecosystem chain of aquatic plants in the research process. With the improvement of people’s living standards, the requirements for landscapes are getting higher and higher, so ecological waterscape construction has emerged. The environment where the construction of ecological waterscape is best has ornamental value. After reasonable transformation, the purification effect was formed. Therefore, it has important value to strengthen the purification process of aquatic plants.

Keywords Aquatic plants · Wetland plants · Purification and restoration · Nutrition

Introduction
With the acceleration of urbanization, people more and more like the feeling brought by the natural environment, so people start to build landscape water bodies, such as artificial rivers, artificial lakes, artificial fountains, etc. The current water quality treatment methods of fountains are not optimistic, causing pollution in many urban water bodies, a large number of plankton deaths, and smelly water.

Definition of aquatic plants
Aquatic plants mean plants that can live in moist soil for a long time, generally referring to herbaceous plants. Ecologically speaking, aquatic plants are a group of organisms (Huan 2016). According to different types of aquatic plants, they can be divided into two categories: pond systems and constructed wetland systems. After the plant undergoes photosynthesis conversion, it changes from solar energy to ATP. Plants can also bring good environmental growth for animals, increase biodiversity, and reduce the absorption of pollution and degrade toxic substances. The pond system was formed under the development of the oxidation pond, so the oxidation pond system has also been applied to actual life (Bokuniewicz 1992). However, because the concentration of algae is too high, the SS and BOD in the water quality indicators are extremely high, resulting in substandard water quality.

The mechanism of aquatic plant purification technology
The principle of sewage purification by aquatic plants was established in 1977, and the root zone method was first proposed for treatment (Aguera et al. 2008). The meaning is: organisms that grow in the wetland system breathe through the leaves and stems growing on the ground and transmit them to the roots, forming an aerobic range through the roots. The same
role of aquatic plants and rhizomes includes plant absorption, assimilation, and metabolic decomposition. We divide the role of rhizomes into three parts: physical, chemical, and biological.

Advantages and problems of aquatic plant purification technology

The advantages of the purification effect of aquatic plants are the following:

1. There are a lot of heavy metal silts in the water body, and aquatic plants can dissolve these substances.
2. Blue-green algae and other algae organisms contain substances such as nitrogen and phosphorus, and their oxygen content is getting lower and lower, and aquatic plants can organize the decomposition of oxygen.
3. Decompose the nitrogen organic matter in the water body, so that the nitrogen content in the water body is reduced, and the survival rate of aquatic organisms is higher (Huang et al. 2018).
4. The water pollution produced by the chemical industry is prone to secondary pollution, and the purification effect of aquatic plants can prevent chemical pollution.
5. The energy consumption is reduced, and the engineering quantity is also reduced.
6. When aquatic plants purify water, they can form a complete natural landscape and form a low-cost water purification effect.

Problems with the purification effect of aquatic plants are the following:

1. In the comparison of physical and chemical effects, the purification effect of aquatic plants is longer. If not treated in time, it is likely to cause secondary pollution, so long-term maintenance is required.
2. Polluted water quality will affect the development of aquatic plants, and the growth of plants in sewage will hinder their development (Huang and Zhang 2013). Therefore, it is necessary to change the environment to adapt to growth.
3. There are few studies on wetland plants, and the purification function of a single aquatic plant is very limited, and the interaction between each plant is likely to cause pollution to water quality.

Materials and methods

Experimental materials

After consulting the data, according to the diversity of the water ecosystem, select plants suitable for the local environment, use screening to select water plants in a suitable eutrophic environment, and then artificially simulate the eutrophic water quality in different polluted environments, and then conduct testing to analyze the repair effect of water quality (Jo 2018). The selected plants are emergent plants such as lily bamboo, pocket coconut, dieffenbachia, spring feather, floating plants, Qingping, and Sophora japonicus and submerged plants such as green chrysanthemum, mini crown, and sophora.

Experimental method

Experimental design

Under the environment of sunlight and shelter from rain, the evaporation effect of tap water is used to ensure the change of water level. Wash the roots of aquatic plants with clean water and place them in tap water for cultivation (Aptoula et al. 2016). After propagation, the roots have a better growth and formed a plant type of equal size and shape, and moved it to a 15-l water sample. The test time was in the morning, and a 20-ml syringe was used to draw at 5 different water levels, and each time 5 ml sample was drawn, a total of 100 ml. Use the index of each index in the water tank to calculate the purification results of each aquatic organism, and finally calculate the plants with good purification effects.

Nutrient solution configuration

Refer to the ratio of nutrient solution, and the test water is tap water. Tap water means residual chlorine and sulfide substances that are harmful to the roots (Khanal et al. 2012). Therefore, in the ratio of the nutrient solution, sodium ethylenediaminetetraacetate should be added to neutralize the substances in the water. According to the experiment, three nutrient solutions with different concentrations of light, medium, and high are obtained, as shown in Table 1.

Analysis of eutrophic water body evaluation model

Many scientists have explored the influencing factors of eutrophication factors in different waters and launched various methods to verify them. Through long-term search, the nutritional status index is the most basic way to be used in most water bodies (Li et al. 2018). The nutrient index method is relatively complicated to calculate, so it is rarely used.

Scoring method

Use the three levels of poor, medium, and high nutrition to evaluate the different levels. If the score is high, it means that the nutrition level is high. The calculation formula is as follows:
M = \frac{1}{2} \sum_{i=1}^{n} M_i \tag{1}

In the formula, \( M \) is the enrichment score; \( M_i \) is the score of the evaluation parameter; and \( n \) is the number of evaluation parameters.

It can be seen from the above formula that the scores of different nutritional levels are shown in Table 2.

**Nutrient index method**

The trophic index method is based on the analysis of levels and components to combine to form lake eutrophication to score. Its formula is as follows:

\[
TLI_C = \sum_{j=1}^{m} W_j \cdot TLI_j = \sum_{j=1}^{m} W_j (a_j + b_j \ln C_{jx}) \tag{2}
\]

\[
a_j = \frac{\ln C_{jx_{\min}}}{\ln C_{jx_{\max}} - \ln C_{jx_{\min}}} \times 100
\]

\[
b_j = \frac{1}{\ln C_{jx_{\max}} - \ln C_{jx_{\min}}} \times 100 \tag{4}
\]

In the formula, \( TLI_C \) is the nutritional level of the lake’s nutritional status; \( TLI_j \) is the degree of nutrition of the \( j \)-th variable; \( W_j \) is the comprehensive score of the \( j \)-th variable; \( C_{jx} \) is the monitoring value of the \( j \)-th variable; \( C_{jx_{\min}} \) is the concentration at which the nutrition level corresponding to the \( j \)-th variable is 0; and \( C_{jx_{\max}} \) is the concentration at which the nutrition degree corresponding to the \( j \)-th variable is 100.

**Table 1** Test nutrient solution water quality index

| Eutrophication | \( PH \) | \( TP \) (mg/L) | \( TN \) (mg/L) | \( NO_3^-N \) (mg/L) | \( NH_4^+-N \) (mg/L) |
|----------------|--------|----------------|----------------|---------------------|-------------------|
| Mild           | 6.0–6.8| 0.34–0.39      | 7.0–7.9        | 3.9–4.8             | 0.42–0.61         |
| Moderate       | 6.0–6.8| 0.96–1.03      | 12.9–14.8      | 8.8–9.7             | 0.86–0.99         |
| Height         | 6.0–6.8| 1.79–1.89      | 19.7–20.9      | 16.7–17.7           | 1.88–2.02         |

**Nutritional status index method**

The nutrient state index method is one of the methods of the lake eutrophication methods, including the Carlson nutrient state index method, the modified Carlson nutrient state index, and the comprehensive nutrient state index method (Li et al. 2014). The calculation formula is as follows:

\[
TSI(SD) = 10 \left( 5 \ln SD \right) \tag{5}
\]

\[
TSI(Chl-a) = 10 \left( 6 - \frac{2.04 - 0.68 \ln(Chl-a)}{\ln 2} \right) \tag{6}
\]

\[
TSI(TP) = 10 \left( 6 - \frac{\ln 48}{\ln TP} \right) \tag{7}
\]

In the formula, \( TSI \) is the Carlson nutritional status index; \( SD \) is the value of transparency (m); \( Chl-a \) is the chlorophyll content value (mg/m³); and \( TP \) is the concentration value of total phosphorus (mg/m³).

**Table 2** Nutritional level scoring standard

| Nutritional level | Score value | Parameter               | SD (m) | Chl-(mg/m³) | TP (mg/L) | TN (mg/L) | COD (mg/L) |
|-------------------|-------------|-------------------------|--------|-------------|-----------|-----------|------------|
| Poor nutrition    | 10          | 10.0        | 5.0    | 0.002       | 0.03      | 0.16      |
|                   | 20          | 5.0         | 1.0    | 0.005       | 0.06      | 0.5       |
|                   | 30          | 3.0         | 2.0    | 0.02        | 0.2       | 1.0       |
| Medium nutrition  | 40          | 1.6         | 4.0    | 0.026       | 0.4       | 2.0       |
|                   | 50          | 1.0         | 10.0   | 0.06        | 0.6       | 4.0       |
|                   | 60          | 0.6         | 26.0   | 0.2         | 1.0       | 8.0       |
|                   | 70          | 0.5         | 64.0   | 0.3         | 2.0       | 10.0      |
| Eutrophication    | 80          | 0.4         | 160.0  | 0.7         | 6.0       | 25.0      |
|                   | 90          | 0.3         | 400.0  | 0.9         | 9.0       | 40.0      |
|                   | 100         | 0.13        | 10000  | 1.4         | 16.0      | 60.0      |
Wetland plant diversity level and difference analysis

In terms of multiple indicators of plants, select species $R$, Simpson index $D$, Shannon Wiener index $H$, and Peru evenness index $J$. Among them, $R$ is the total number of species, the Simpson index calculates the probability of randomly selected species, the Shannon Wiener index expresses the uncertainty of random species, and the Peruvian uniformity index expresses the balance of various species and distributions (Li et al. 2015). The specific formula is as follows.

$$R = (S-1)/\ln N$$  \hspace{1cm} (8)

In the formula, $S$ represents species, and $N$ is the total number of individuals.

$$D = 1-\sum \left( \frac{n_i}{N} \right)^2$$  \hspace{1cm} (9)

$n_i$ in the formula represents the number of individuals of the $i$ species, $N$ is the total number of samples.

$$H = 1-\sum_{i=1}^{S} \left( \frac{n_i}{N} \right) \cdot \log_2 \left( \frac{n_i}{N} \right)$$  \hspace{1cm} (10)

The size table of the $H$ value in the formula is diversity, the greater the value, the greater the diversity.

$$J = H/H_{\text{max}}$$  \hspace{1cm} (11)

In the formula, $H$ is the species index actually observed, $H_{\text{max}}$ is the maximum value of the species index, and $H_{\text{max}} = \ln S$ ($S$ is the total number of species in the community), shown in Table 3 and Fig. 1.

**Results**

**Comprehensive screen for planting trees**

See Table 4 for the purification degree of various aquatic plants to pollution indicators (Fig. 2).

Among the emergent plant species, spring feathers are not adapted to the growth of eutrophic water bodies, so they are not considered. Pocket coconut has a better removal effect in TN and TP, and the removal effect is better. Evergreen has a better response to the values of $NH_{4}^{+}-N$ and $NO_{3}^{-}-N$. Among submerged plant species, green chrysanthemum has a better response to TN and has an improved effect on dissolved oxygen (Liu and Li 2019). Mini crown has a better response to $NH_{4}^{+}-N$ and $NO_{3}^{-}-N$. Among floating plant species, Qingping has a better response to the data of TP, TN, and $NO_{3}^{-}-N$.

**Purification effect of optimized aquatic plants on low-concentration eutrophic water**

The combination of many aquatic plants is more effective and stable than a single plant. It can also prevent ecological changes and reduce pests and diseases (Burnett et al. 2006). Therefore, three types of plants were selected for artificial combination. First, pay attention to the value of low-concentration eutrophication, and group them as follows:

1. Combination: 3 evergreen trees, 1 lily bamboo, 2 pocket coconuts, 2 mini crowns, 1 bitter grass, and 1/3 of the area
2. Combinations: 3 lily bamboos, 3 pocket coconuts, 2 green chrysanthemums, 1 bitter grass, and 1/3 area of Sophora japonica and Qingping
3. Combinations: 3 lily bamboos, 3 pocket coconuts, 2 mini crowns, 1 bitter grass, and 1/3 area of Sophora japonica and Qingping

**The purification effect of optimized aquatic plants on medium-concentration eutrophic water bodies**

1. Changes of DO in medium nutrient water

The influence of the combination of aquatic plants under different ratios on DO is that it has been cloudy and the sun is
not strong during the previous days, so the dissolved oxygen of each group is lower than the value of the CK group (Palchik 2003) (Fig. 3). The reasons analyzed are the same as the reasons for the low concentration.

2. Change of TN in nutrient water

The results showed that in the low concentration period of various aquatic plants, the removal rate in the first 5 days was weak, and the removal rate increased during 5–15 days. The number of aquatic plants in each group takes a long time and is different.

3. Changes of $NO_3^-$ in nutrient water

The change of purification parameter $NH_3^-$ is consistent with the change of TN concentration. The results show that the removal rate will increase in 10–15 days, perhaps due to environmental influences, plus sufficient influence, making the growth vigorous, and the purification rate is shown in Fig. 4.

4. Changes of $NH_4^+$ in nutrient water

The removal rate of $NH_4^+$ in each group is very high, which is different from the parameters of TN and $NO_3^-$. The analysis shows that the removal rate of CK group may be very high, indicating that there are more microorganisms in the water body, and the interaction between plants and plants makes the removal rate of $NH_4^+$ faster.

5. Changes of TP in nutrient water

The concentration of TP will decrease with the concentration of TN and $NH_3^-$, the removal rate of each group within 10 days before the test will become lower, and the relative other factors will increase (Cao et al. 2009). In 10 to 15 days, the TP value will accelerate, and by the end of the experiment, the concentration removal rate will be significantly different from other data.

Throughout the experiment, the environment of each group will affect the rate of change, so at the end, some of the rate reached the maximum, which shows that the phosphorus

| Plant species | $NH_4^+$ (mg/L) | $NH_3^-$ (mg/L) | TN (mg/L) | TP (mg/L) |
|---------------|-----------------|-----------------|-----------|-----------|
| Lily bamboo   | 75              | 12              | 28        | 31        |
| Pocket coconut| 78              | 28              | 52        | 59        |
| Evergreen     | 82              | 66              | 54        | 32        |
| Haruha        | 15              | 48              | 7         | 25        |
| Green chrysanthemum | 39       | 9               | 43        | 27        |
| Mini crown    | 89              | 26              | 39        | 49        |
| Hay           | 85              | -1              | 35        | 7         |
| Sophora japonica | 91            | 22              | 38        | 71        |
| Qingping      | 58              | 85              | 79        | 53        |

Fig. 2 Purification effect of different aquatic plants
nutrition is saturated. In the 10 to 15 days of the experiment, when the sun is sufficient, aquatic plants will absorb the effect of photosynthesis, so the content of TP will be greatly increased. In a nutrient environment, remove the size ranking:

\[ T7(65\%) > T1, T3(59\%) > T5(51\%) > T4(41\%) > T6(39\%) > T2(38\%) \]

6. After selecting the combination of each plant under the medium concentration condition (Fig. 5), the removal rate of each pollution variable is obtained, as shown in Table 5.

Purification effect of optimized aquatic plants on high-concentration eutrophic water

Changes of DO in high nutrient water

Under the high-concentration test condition, the dissolved oxygen content and the values of low and medium concentrations in the CK group are different, and the DO values of each treatment group will show an upward and downward trend (Chen et al. 2018). The DO value of CK group will be higher; the reason is that the high concentration of water has higher nutrient content, reaching the value of heavy concentration. The algae growth under the test has turned cyan at the end, as shown in Fig. 6. The analysis showed that during the later period of the experiment, the sun was sufficient, and the aquatic plants received photosynthesis and produced a lot of gas, which made the dissolved oxygen content of the CK group higher.

The change of TN in high nutrient water

According to this experiment, under the middle and late treatment, the aquatic plants have adapted to the surrounding environment and the growth trend is also faster, so it has been found to be feasible, as shown in Fig. 7. It can be seen from the experiment that different aquatic plants have different growth speeds at different times, so the absorption capacity is also different (Piao et al. 2019). Such absorption capacity forms a complementary advantage, so the T1 combination of plants has high adaptability.

Changes of $NO_3^-\text{-}N$ in high nutrient water

The $NO_3^-\text{-}N$ concentration value of each group has a great downward trend, and the change trend will be the same, first becoming faster and then slower. The analysis showed that because the sun was sufficient in the later stage of the experiment, the temperature also increased, making the microorganisms more active, coupled with a large number of algae breeding, so the nitrate in the water body reached the maximum (Chen et al. 2014). Among the high concentration values, the removal rate of $NO_3^-\text{-}N$ is greater than that of the medium concentration. In addition to sufficient light, the degree of nutrition is also indispensable, as shown in Fig. 8.
that even if the microorganisms play an effect, they can quickly remove TP under the combination of aquatic plants, which shows that the repair ability of microorganisms is higher than that of aquatic plants.

Selection of planting combinations under high concentration

The combination of various aquatic plants under high concentration is sorted out by sewage variables (Fig. 9), and the ratio of removal rate is obtained, as shown in Table 6.

The purification effect of the best plant combination on the actual eutrophic water body

In order to test the repair ability between plant combinations, the screening of low, medium, and high nutrition was excluded, and the T1 comprehensive group, T5 group, and T7 group were selected, and the remaining nutrient solution was excluded. In order to show the growth environment of aquatic plants, during the whole experiment, the rainwater of the day was used for irrigation to supplement the evaporated water, and other conditions remained unchanged.

Changes of DO in eutrophic water

The aquatic plants can meet the water quality standards of the landscape, and the dissolved oxygen is relatively high. The whole experiment was carried out in a cloudy environment with insufficient light, so the weather is also a major cause of influencing factors. In addition, the value of DO content in each test group also changes with the overall change (Deng et al. 2018). All the values are lower than those of the CK group, which is also caused by weather. However, due to the weak light, the photosynthesis absorbed by aquatic plants is also called weak, and the water tank capacity is small, and the amount of dissolved oxygen is also small. All in the water environment, insufficient light can also be interfered by artificial means. The value of DO remains balanced.
The change of TN in eutrophic water

The samples in this experiment are from eutrophic landscape water bodies. The results of the experiment show that there are several major factors in the downward trend. One is because of sufficient sunlight, which makes the purification speed faster 5 days before the test; the second is because the weather is cloudy in the later period of the test; in order to show the real water environment, the evaporation of rainwater was estimated in the test. So the numerical content of TN will increase within 10 days (Schroeder et al. 2016). In 10 to 15 days, the purification effect of the plant itself will also reduce the content of TN.

Changes of \(\text{NH}_4^+\) in eutrophic water

Using a single exponential variable method, the data is more than doubled, and the \(\text{NH}_4^+\) content in the water body is high. The change of \(\text{NH}_4^+\) value is consistent with the change of \(\text{NH}_4^+\) value in the changes of low nutrition, medium nutrition, and high nutrition in the previous period, and the value of \(\text{NH}_4^+\) purification content of each group also maintains consistency (Fauvel et al. 2013). In the first 5 days of the experiment, the \(\text{NH}_4^+\) concentration of each group dropped to the minimum standard, but there was an upward trend in the later stage of the experiment.

In the few days of this experiment, the content of \(\text{NH}_4^+\) increased from low to high, resulting in consistent changes in the concentration of TN. The reasons for this result are the same. There is no uniform standard for how to remove the \(\text{NH}_4^+\) content in water from aquatic plants. According to research, plants first reduce the nitrogen by \(\text{NH}_4^+\) and other substances in the water. When the content of \(\text{NH}_4^+\) becomes low, it will affect the change of \(\text{NH}_4^+\). Another argument is that nitrification is the dominant cause, which is transformed and utilized by plants.

Changes of TP in eutrophic water

The concentration of TP was calculated by manual sampling. According to the analysis of water quality standards, the value of TP was seriously exceeded. Except for no effect on the CK group, the TP treatment results of the other groups are very obvious. During the test, the changes in the purification effect of each group were similar to the values of TN and \(\text{NH}_4^+\). During the first 5 days of the test, the rate of decrease was relatively rapid. Due to the rain itself, the purification speed slowed down in the middle of the experiment, and the speed accelerated again in 10 to 15 days, and the TP value of each group reached the lowest point (Sene 2012). At the end of the test, the TP values in each test tank are relative, which means that the T1, T5, and T7 groups are fighting in an environment with insufficient nutrition. Except for the lower removal content of the T7 group, the T1 and T5 groups are more effective for TP. The removal rate is equal.

Changes of CODMn in eutrophic water

The removal rate of CODMn in each test group decreased in a short period of time, and the rate became slower for the
concentration value, while the concentration content of the CK group was almost unchanged. Studies have concluded that aquatic plants have a certain purification effect on the reduction in water bodies, but their removal rate is low. The CODMn value in the CK group is relatively high, which indicates that the water purification capacity is poor, and the area removal rate data.

Changes of Chl-a in eutrophic water

Chlorophyll is a plankton that is used to regulate photosynthetic pigments through photosynthesis, and then through the numerical value of Chl-a, the numerical value of algae organisms can be obtained, and the effect of its productivity can also be grasped (Filippi et al. 2009). The test results showed that the Chl-a content of each group exceeded the standard, and the main factor was that the phytoplankton and algae died in the water body because they did not adapt to the influence of the environment. By the end of the experiment, flocules floating on the surface of the water body of the CK group can be seen through observation, as shown in Fig. 10.

Comprehensive analysis

Analyze the removal rate of the eutrophic aquatic plants among the various pollution variables, and get the values in Table 7.

T5, T7, and T1 respectively represent the number of combinations of aquatic plants with the best purification effects of low nutrition, medium nutrition, and high nutrition. Using this eutrophication test and repair effect to count the books, except for the comparison of the removal rate of T5 combination and TN, there is no big difference in the removal rate of other parameters, which indicates that the plant combination selected under low nutrition, medium nutrition and high nutrition has a certain use value.

Discussion

Analysis of research results of aquatic plant purification

1) Using the diversity characteristics of the ecosystem and the ornamental characteristics of aquatic plants, emergent plants, submerged plants, and floating plants were
selected as research targets. Emergent plants include lily bamboo, miniature coconut, ornithogalum, and Chunyu; submerged plants include green chrysanthemum, mini crown, and sorrel; floating plants include two kinds of sophora japonica and chrysoprase. Comparing the ratio of the nutrient solution, the nutrient solution was manually proportioned, and the ecological environment characteristics were simulated (Gao et al. 2012). The first step is to select aquatic plants that are both ornamental and purifying. The spring feathers that emergent plants cannot live in such an environment are discharged, and the compact coconuts (N 54%, TP 59%) and evergreen (NH$_4^+$-N 82%, NO3-N 66%) with excellent purifying effects are selected, and Lily bamboo with less reaction to dissolved oxygen. Green chrysanthemum (TN 43%), bitter grass (TP 93%) and mini crown (NO3-N 39%, NH$_4^+$-N 89%) with excellent purification ability were selected from submerged plants; the net ability of floating plants is relatively good. (TN 79, NO3-N 85%, TP93%), the ice-cleaning landscape effect on the removal rate of NH$_4^+$-N up to 90%, Sophora japonica, etc.; this combination is a combination form with excellent purification effect and high removal rate. It is the best combination with high removal rate in high nutrition. The removal rate is TN 60%, NH$_4^+$-N 89%, NH$_3$-N 56%, and TP 65%; the high-concentration nutrient-rich combination is the T1 combination, which contains 3 lily bamboo trees, 3 evergreen trees, 1 lily bamboo, 2 mini coconut trees, 1 mini crowns, 1 bitter grass, 1/3 area of the area Sophora japonica and Qingping, etc.; the combination is a combination form with excellent purification effect and high removal rate. It is the best combination with high removal rate in high nutrition. The removal rate is TN 60%, NH$_4^+$-N 89%, NH$_3$-N 56%, and TP 75%; in the eutrophic water test, the repair ability of the combination of T1, T5, and T7 has been selected, and the removal rate is TN (T1 64%, T5 78%, T7 67%), NH$_3$-N (T1 67%, T5 63%, T7 66%), TP (T1 90%, T5 90%, T7 89%), COD (T1 33%, T5 19%, T7 27%), Chl-a (T1 84%, T5 91%, T7 83%), etc.

### Improvement strategies for wetland parks based on aquatic plant purification and landscape design

According to local conditions, renew the plant landscape of the tree layer

The arbor layer refers to the factors that can see the size and scope of the space in the waterfront plants, so in the plant viewing of the waterfront area, the construction of the arbor

**Table 7.** Purification effect of each treatment group in eutrophic water

| Combination index | NH$_4^+$-N (mg/L) | TN (mg/L) | TP (mg/L) | COD$_{\text{Mn}}$ (mg/L) | Chl-a (mg/m$^3$) |
|-------------------|-------------------|-----------|-----------|--------------------------|-----------------|
| T1                | 67                | 64        | 91        | 33                       | 84              |
| T2                | 63                | 78        | 91        | 19                       | 91              |
| T3                | 66                | 67        | 89        | 27                       | 83              |

**Fig. 10.** Eutrophic water quality in the blank control group
layer also adds an atmosphere effect (Han et al. 2015). Our country has more than 30,000 plant species, among which ornamental plants account for about 20,000, and woody plants have 7000. After the continuous improvement and development of the garden landscape, more and more plants are applied to the garden landscape, so according to the local characteristics, a unique landscape has been formed.

**People-oriented, increase open waterfront plant landscape belt**

Being close to water resources is an instinctive need of human beings. People can have close contact with water resources in the waterfront area. Therefore, the landscape design of the waterfront area can meet people’s requirements for water. Let visitors not only see the water but also play in the water in the waterfront landscape, which reflects the harmonious relationship between people and water, and establishes a natural landscape in which people and nature live in harmony, which is conducive to the establishment of the landscape and the harmonious development of the landscape (Singh et al. 2010). While designing the entire landscape, in addition to satisfying customers’ appreciation of the beautiful scenery, safety issues must also be fully considered, such as setting up fences in the waterfront and setting up gentle slopes at the platforms, etc. These are all human-oriented design concepts.

**Highlight features and enrich the landscape of aquatic plants**

The current wetland park landscape is divided into five forms: emergent plant landscape, floating-leaf plant landscape, floating plant landscape, and submerged plant landscape.

Emergent plant landscapes are plant types that are planted in emergent water, such as barradas, sagittaria, and other organisms. There are various types of emergent plants, which are important types of plant landscapes. The floating-leaf plant landscape is where the aboveground stems and floating-leaf plants are soft, and can only float on the water surface, adding effects to the water landscape (Han et al. 2016). The roots of the floating plant landscape are not in the soil, but above the water surface, to ensure the stability of the landscape. Submerged plant landscape is a submerged plant that is used in small landscape water bodies to create a sense of plant landscape. The plant floating island landscape is a kind of artificial raft landscape, in which various aquatic plants are planted on artificial appendages.

**Strengthen plant landscape construction**

In the city’s waterfront landscape belt, there is a very rich history and culture. When designing the landscape, it is necessary to understand the ecological environment around the site and the history and culture of the site and conduct an in-depth investigation to facilitate the subsequent planting of plants with local characteristics (Zhang and Dang 2014). With the continuous development of urbanization, people have higher and higher requirements for plant landscapes. Therefore, under the premise of a unified style, people should combine the local characteristics and the feeling of the plant landscape to form a complete landscape effect with various trees.

**Multi-directional development of wetland science and tourism projects**

With the rapid development of urban economies, while bringing huge economic benefits to people, it also greatly reduces the physical area in towns, which greatly prevents the development of cities. After launching the wetland research project, people have a deeper understanding of the juniors, and the development of wetland and tourism status have also been further developed. For on-site tourism, development should be carried out around the following points:

In the wetland culture, the actual culture is diverse and has its unique characteristics, which are mainly manifested in its historical culture, folk culture, food culture, architectural culture, and other aspects (Zhang and Li 2011). These cultures have their unique attractions.

In the wetland landscape, the wetland landscape is a kind of matrix landscape, and it has greater research value. The landscape itself has peculiar characteristics, which makes its tourism value great. It can not only enhance the quality of the wetland park but also inject the soul into the wetland park.

In holiday activities, it is also a special tourism resource to enhance the overall tourism image. The wetland holding holiday activities is also a seasonal feature. The wetland will organize activities with different themes according to the characteristics, allowing the audience to experience the wetland activities and understand the wetland culture.

**Establish a long-term sustainable protection mechanism**

**Sustainable development and utilization** Maintain the natural conditions of the urban wetland system under the natural conditions of the urban wetland system, carry out reasonable resource allocation, adhere to the principle of protection, make rational use on the basis of protection, and protect the wetland within the scope of the wetland ecology. The combination of planning and multiple planning forms a sustainable development goal.

**Strengthen the monitoring of the wetland environment** So far, the protection of wetlands in my country is relatively weak, and the lack of research on wetlands itself has also limited the construction and development of wetlands to a
certain extent (Hu et al. 2012). Therefore, we regularly monitor the wetland in the city and provide monitoring data to provide a basis for the planning and protection of the city’s wetland park.

**Vigorously rectify environmental pollution** In recent years, the pollution of the ecological environment has become more and more serious. In densely populated areas, a large amount of sewage has been discharged into the river, and the wetland environment has been destroyed. Therefore, we strictly control the pollution of wetlands, and effectively control the use of pesticides, and know farmers’ scientific planting and maintenance to prevent secondary pollution of the wetland environment.

**Conclusion**

Regarding the types of plants, observations were made in the landscape architecture of a wetland park in a certain city, and the following conclusions were drawn:

1. **The sense of landscape construction of the waterfront.** It covers the site selection of plants, the selection of plants, the way of planting proportions, the shape of the landscape, and the sense of artistic design brought by the landscape, showing the diversity of plants and creating a sense of landscape construction of the waterfront.

2. **Understand the use of waterfront landscape plants from the perspective of plant diversity.** The waterfront area is composed of many species, which greatly increases the diversity and heredity of the ecosystem. Use multilayered greening to create a sense of ecological environment and plant types, and avoid tall and dense forms.

3. **Analyze the wetland park.** Analyze the understanding of plant diversity, through the design sense of waterfront landscape plants, and waterfront landscape elements, summarize the plant landscape problems existing in the wetland park, and give the corresponding countermeasures: redesign the plant landscape for the environment; human-oriented design, open waterfront plant landscape based on lighting landscape features and enriching waterfront landscape; meticulously dividing the sense of coordination between plants and landscape; emphasizing the waterfront landscape construction sense of plants, full-scale field development and tourism; and establish a long-term effective protection mechanism.

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**Declarations**

Conflict of interest The authors declare that they have no competing interests.

**References**

- Aguera F, Aguilar EJ, Aguilar MA (2008) Using texture analysis to improve per-pixel classification of very high resolution images for mapping plastic build-ups. ISPRS J Photogramm Remote Sens 63:63–64
- Aptoula E, Ozdemir MC, Yanikoglu B (2016) Deep learning with attribute profiles for hyperspectral image classification. IEEE Geosci Remote Sens Lett 13:1970–1974
- Bolin JH (1992) Analytical descriptions of subaqueous groundwater seepage. Estuaries 15(4):458–464
- Burnett WC, Aggarwal PK, Aureli A, Bokuniewicz H, Cable JE, Charette MA, Kontar E, Krupa E, Kulkami KM, Loveless A, Moore WS, Oberdorfer JA, Oliveira J, Ozuyurt N, Povinec P, Privitera AMG, Rajar R, Ramessur RT, Scholten J, Stiegitz T, Taniguchi M, Turner JN (2006) Quantifying submarine groundwater discharge in the coastal zone via multiple methods. Sci Total Environ 367:498–543
- Cao X, Chen J, Imura H, Higashi O (2009) A SVM-based method to extract urban areas from DMSP-OLS and SPOT VGT data. Remote Sens Environ 113:2205–2209
- Chen Y, Lin Z, Zhao X, Wang G, Gu Y (2014) Deep learning-based classification of hyperspectral data. IEEE J Sel Top Appl Earth Observ Remote Sens 7:2094–2107
- Chen C, Jiang F, Yang C, Rho S, Shen W, Liu S, Liu Z (2018) Hyperspectral classification based on spectral–spatial convolutional neural networks. Eng Appl Artif Intell 68:165–171
- Deng Z, Sun H, Zhou S, Zhao J, Lei L, Zou H (2018) Multi-scale object detection in remote sensing imagery with convolutional neural networks. ISPRS J Photogramm Remote Sens 145:3–22
- Fauvel M, Tarabalka Y, Bendiksson JA, Chanussot J, Tilton J (2013) Advances in spectral-spatial classification of hyperspectral images. Proceedings of the IEEE, Institute of Electrical and Electronics Engineers 101:652–675
- Filippa AM, Archibald R, Bhaduri BL, Bright EA (2009) Hyperspectral agricultural mapping using support vector machine- based endmember extraction (SVM-BEE). Opt Express 17:23823–23842
- Gao YF, Huang WP, Liu GL, Zhang SF, Zhu QM, Deng ZY (2012) The relationship between permeable fractured zone and rock stratum tensile deformation. J Min Saf Eng 29(3):301–306
- Han B, Zdравкович L, Stavroula K (2015) The stability investigation of the generalised - α time integration method for dynamic coupled consolidation analysis. Comput Geotech 64:83–95
Han B, Zdravković L, Stavroula K, Taborda DMG (2016) Numerical investigation of the response of the Yele rockfill dam during the 2008 Wenchuan Earthquake. Soil Dyn Earthq Eng 88:124–142
Hu XJ, Li WP, Cao DT, Liu MC (2012) Index of multiple factors and expected height of fully mechanized water flowing fractured zone. J China Coal Soc 37(4):613–620
Huan H (2016) Applying partial least squares regression to calculate the height of water flowing fractured zone. International Conference on Mechanical Manufacturing and Energy Engineering (ICMMEE), Changsha, China
Huang X, Zhang L (2013) An SVM ensemble approach combining spectral, structural, and semantic features for the classification of high-resolution remotely sensed imagery. IEEE Trans Geosci Remote Sens 51:257–272
Huang B, Zhao B, Song Y (2018) Urban land-use mapping using a deep convolutional neural network with high spatial resolution multispectral remote sensing imagery. Remote Sens 214:73–86
Jo I (2018) World energy issues: an inquiry-based lesson using ArcGIS online. Geogr Teach 15(1):43–46
Khanal M, Adhikary D, Balusu R (2012) Numerical analysis and geotechnical assessment of mine scale model. Int J Min Sci Technol 22:693–698
Li P, Wu J, Qian H, Lyu X, Liu H (2014) Origin and assessment of groundwater pollution and associated health risk: a case study in an industrial park, northwest China. Environ Geochem Health 36(4):693–712
Li ZH, Xu YC, Li LF (2015) Forecast of the height of water flowing fractured zone based on BP neural networks. J Min Saf Eng 32(6):905–910
Li HJ, Chen QT, Shu ZY, Li L, Zhang YC (2018) On prevention and mechanism of bed separation water inrush for thick coal seams: a case study in China. Environ Earth Sci 77:759–770
Liu SL, Li WP (2019) Zoning and management for phreatic water resources conservation impacted by underground coal mining: a case study in the arid and semiarid area. J Clean Prod 224:677–685
Palchik V (2003) Formation of fractured zones in overburden due to longwall mining. Environ Geol 44:28–38
Piao CD, Wang D, Kang H, He H, Zhao C, Liu W (2019) Model test study on overburden settlement law in coal seam backfill mining based on fiber Bragg grating technology. Arab J Geosci 12(13):401–409
Rezaei M, Hossaini MF, Majdi A (2015) Development of a time-dependent energy model to calculate the mining-induced stress over gates and pillars. J Rock Mech Geotech Eng 7:306–318
Schroeder AJ, Gourley JJ, Hardy J, Henderson JJ, Parhi P, Rajaram V, Reed KA, Schumacher RS, Smith BK, Tappero MJ (2010) The development of a flash flood severity index. J Hydrol 541:523–532
Sene K (2012) Flash floods: forecasting and warning. Springer Science & Business Media
Sharif HO, Al-Juaidi FH, Al-Othman A, Al-Dousari I, Fadda E, Jamal-Uddeen S, Elhassan A (2016) Flood hazards in an urbanizing watershed in Riyadh, Saudi Arabia. Environ Nat Haz Risk 7(2):702–720
Singh PK, Gaur ML, Misra SK, Rawat SS (2010) An updated hydrological review on recent advancements in soil conservation service-curve number technique. J Water Clim Chang 1(2):118–134
Zhang MS, Dang XY (2014) Water resources and environmental problems in arid and semi-arid regions-analysis of Yulin energy and chemical base in northern Shaanxi. Science Press, Beijing
Zhang YJ, Qian H (2011) Monitoring analysis of fissure development evolution and height of overburden failure of high tension fully-mechanized caving mining. Chin J Rock Mech Eng 30(S1):2995–3001