Purification effect of two typical water source vegetation buffer zones on land-sourced pollutants

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Abstract. Two vegetation buffer zones (tree-shrub-grass pattern and tree-grass pattern) were selected as test objects around Siming reservoir in Yuyao City of China. The effect of the storm runoff intensity (low and high intensity) and the buffer zone width (1 m, 3 m, 5 m, 7 m, 9 m, 12 m, 16 m) on pollutants (suspended solids, ammonium nitrogen and total phosphorus) was studied by the artificial simulation runoff. The results showed that with the increase of the width of buffer zone, the pollutant concentration was decreased. The purification effect of the two buffer zones on suspended solids and total phosphorus was basically stable at 52-55% and 34-37%, respectively. But the purification effect on ammonium nitrogen was the tree-shrub-grass pattern (69.7%) significantly better than that of tree-grass pattern (52.1%). The purification rate at the low runoff intensity was 1.8-2.0 times that at the high runoff intensity. The relationship between the purification rate and buffer zone width can be expressed by the natural logarithm equation, and the model adjustment coefficient was greater than 0.92.

1. Introduction
The buffer zone of reservoir bank plays an important role in soil and water conservation, water purification, flood control [1,2]. A certain width vegetation buffer zone in reservoir bank can decrease pollutants of runoff, and reduce the degree of pollution through filtration, permeation, absorption, retention and deposition [3,4]. A large number of studies show that the type and structure of the buffer zone is an important factor to affect its ecological environment. For example, the Lee's study [5] found that in the natural rainfall condition, 7.1m wide grass strip can intercept more than 92% of the sediment in surface runoff. the same wide switchgrass hedgerow intercepted 95% of sediment, 80% of total nitrogen, 62% of nitro-nitrogen, 78% of total phosphorus and 58% of PO4-3-P. In 2005, Mariet [6] studied the purification effect of the forest and grass riparian buffer zone on the N element, respectively, in 6 countries of Europe. His study results showed that the forest riparian buffer zone can well absorb the N element. And the grass riparian buffer zone absorbed a small amount of the N elements but it played an important role in the whole riparian ecosystem cycle. In the same year, Syversen [7] carried out experiments on 4 different regions of the southern Norway. The results indicated that the purification rate of 10m wide riparian buffer zone was better than that of 5m wide riparian buffer zone. The purification rates of phosphorus and nitrogen were 60%-89% and 37%-81%, respectively.

2. Materials and Methods
2.1. study site
The Siming Lake was located in Yuyao city of China. The upstream catchment area is 103.1 km², the total storage capacity is 122.72 million m³ and the normal capacity is 79.46 million m³. And it was designated as the one-level drinking water source protection area. The average annual rainfall of
Liangnong hydrologic station, near the reservoir, is 1561.3 mm, and the mean annual runoff is 93.36 million m$^3$. The land and water ecotone zone is relatively flat, and the main vegetation is weeds. The upper buffer zone was mainly cultivated land and residential land.

2.2. Experimental design

The experiment designed three levels of pollutant concentrations and two levels of storm runoff intensity. According to the scheme selection, a total of 7 experiments were designed (in Table 1).

Table 1. Runoff intensity and pollutant concentration

| Group | SRI m$^{-1}$h$^{-1}$ | SSC mg·L$^{-1}$ | ANC mg·L$^{-1}$ | TPC mg·L$^{-1}$ |
|-------|---------------------|----------------|----------------|----------------|
| A     | 2.0                 | 200            | 2.0            | 0.4            |
|       | 2.0                 | 400            | 10.0           | 1.0            |
|       | 2.0                 | 700            | 20.0           | 1.5            |
|       | 3.9                 | 700            | 20.0           | 1.0            |
|       | 2.0                 | 200            | 2.0            | 0.4            |
|       | 2.0                 | 400            | 10.0           | 1.0            |
|       | 2.0                 | 700            | 20.0           | 1.5            |

Note: The SRI indicates storm runoff intensity. The SSC indicates suspended solids concentration. The ANC indicates ammonium nitrogen concentration. The TPC indicates total phosphorus concentration.

The sewage was mixed with chemical fertilizer and dried clay. Then adding the fertilizer and the clay in the bucket (0.5 m$^3$ plastic bucket), and keeping stirring to make it even. The bottom of plastic bucket was installed control valve. Regulating the control valve switch to control the water discharge, so as to realize the simulation of storm runoff. In order to realize the uniform distribution of the sewage in the test area, the sewage in the plastic bucket was first introduced to the overflow box. In this way, the distribution uniformity of the sewage can be controlled. The sewage sampling points were set at the distance of 1 m, 3 m, 5 m, 7 m, 9 m, 12 m, and 16 m. A small pit was dug in each sampling point and the sewage samples were collected from the small pit. This method is called pit sampling.

3. Results and Analysis

3.1. Effect of buffer zone on SSC

The change law that the different buffer zones reducing suspended solids concentration (SSC) was consistent, but the purification capabilities were different. With the width increased, the SSC decreased gradually (in Figure 2). Under high SSC (700 mg/L), the width increasing from 0 m to 9 m can significantly reduce the SSC. And the purification rate (SPR) increased from 16.7% to 46.5%. When the width was larger than 10 m, the increasing range of the SPR was not obvious. Under the condition of medium concentration (400 mg/L), the change law was similar with that of high concentration. From 0 m to 9 m, the buffer zone can significantly reduce the SSC, and the SPR increased from 5.25% to 34.25%. When the width was greater than 10 m, the SPR was stable between 48% - 50%. Under the condition of low concentration (200 mg/L), the width had a shorter turning point in 7 m. When the width was larger than 7 m, the SPR was stable between 60% - 63%.

3.2. Effect of buffer zone on ANC

Figure 2 also showed the effect of different buffer zones on the ammonium nitrogen concentration (ANC), there were differences in the effects of width on the ANC. the tree-shrub-grass pattern (TSG pattern) better than the tree-grass pattern (TG pattern). The former APR was significantly higher than the latter. When the former width was 16 m, the APR can reach 75%, but the latter was only about 45%. Under medium concentration (10.0 mg/L) condition, the two patterns had good effect on the purification of ANC. With the increase of the width, the ANC decreased. The width less than 9 m, the TSG pattern was better than the TG pattern. When more than 9 m, the purification effect was basically no difference.
The width equal to 16 m, the former APR was 60.2% and the latter was 51.5%. At high concentration (20.0 mg/L), the two patterns showed significant differences in the APR. Especially in 5-7 m, the purification capacity of the TSG pattern was higher (5.07 mg/L) than that of the TG pattern. The APR of TSG pattern reached 55.6% at width equal to 5 m, which was equivalent to APR of TG pattern at width 12 m.

![Figure 2. Variation of pollutant concentration and purification rate with width of buffer zone](image)

![Figure 3. Purification effect under different runoff intensities](image)

| Group | SSC/SRI | Parameters | Adj.R² | Width /m 50% | Width /m 60% | Width /m 70% |
|-------|---------|------------|--------|-------------|-------------|-------------|
| A     | 200/2.0 | 12.37 -0.70 29.49 | 0.978  | 5.3         | 11.8        | 27.2        |
|       | 400/2.0 | 36.47 4.76 -59.32 | 0.967  | 15.3        | 21.6        | 30.0        |
|       | 700/2.0 | 16.05 0.72 7.50  | 0.973  | 13.4        | 25.7        | 48.4        |
|       | 700/3.9 | 27.82 5.54 -46.11 | 0.927  | 26.3        | 39.9        | 59.5        |
| B     | 200/2.0 | 42.46 4.40 64.84  | 0.951  | 10.6        | 14.6        | 19.6        |
|       | 400/2.0 | 30.59 3.03 -35.58 | 0.927  | 13.4        | 19.7        | 28.5        |
|       | 700/2.0 | 18.24 1.10 -5.34  | 0.963  | 19.7        | 34.9        | 61.1        |

3.3. Effect of buffer zone on TPC
According to the effect of the two patterns on total phosphorus concentration (TPC), the purification effects of buffer zone on the low and medium concentration (1.0 mg/L and 0.4 mg/L) were consistent, but it was different on high concentration (1.5 mg/L). Under the conditions of low and medium concentration, the width increased from 0 m to 16 m, the TPC can be reduced by 0.43 mg/L (PPR was 42%) and 0.15 mg/L (PPR was 36%), respectively. In high concentration, especially in 5-7 m, the purification effect of TSG pattern was obvious higher (0.17 mg/L) than that of TG pattern. The PPR was not as good as SPR and APR. When the width was 16 m, the PPR of the two patterns were only 34%
and 27%, respectively. The width less than 8 m, the difference of PPR between the two patterns was not obvious.

3.4. effect of storm runoff intensity on pollutants

Figure 3 reflected the purification effect of TSG pattern on pollutants under different storm runoff conditions. Under high intensity (3.9 m³/h) and low intensity (2.0 m³/h) of storm runoff conditions, TSG pattern can purify pollutants at a certain extent. And with the increase of the width, the purification rate was also increasing. Width increased from 0 m to 16 m, under low runoff intensity, the SSC, ANC and TPC were decreased by 350 mg/L, 14.88 mg/L and 0.44 mg/L, respectively. Under high runoff intensity, the SSC, ANC and TPC were decreased by 262 mg/L, 7.01 mg/L and 0.22 mg/L, respectively. In the 16 m of width, the SPR were 50% (2.0 m³/h) and 37.43% (3.9 m³/h), respectively. And the APR were 74.4% and 35.05%, respectively. And the PPR were 44% and 22%, respectively.

3.5. relationship between purification effect and width

Table 2 showed the statistical relationship between the purification rate (SPR) and the width (L). the SPR and the L were in accordance with the SPR = a ln(L + b) + c statistical model. The adjustment coefficient (adj. R²) of all the model was more than 0.92.

4. Conclusions

Buffer zone on the different pollutant concentrations in runoff had certain purification benefits, and with the increase of the buffer zone width, the purification efficiency increased. But when the buffer zone width was greater than 10m, the increase range of the purification rate was smaller. The purification rate on suspended solids was basically stable at 52-55%, the purification rate on total phosphorus was stabilized at 34-37%. The purification effect of the two patterns on ammonium nitrogen was different. the tree-shrub-grass pattern was better than the tree-grass pattern. Under the condition of low storm runoff intensity, the concentration of pollutant had no obvious influence on the purification rate of the buffer zone. However, under the condition of high concentration of pollutants, the storm runoff intensity had a significant impact on the purification efficiency of buffer zone. The purification rate of buffer zone at low storm runoff intensity was 1.8-2.0 times that of buffer zone at the high storm intensity. With the width of buffer zone change, the purification effect of buffer zone on the suspended solids had obvious law, which can be expressed by the natural logarithm equation, and the adjustment coefficient of the equation is greater than 0.92. Through the calculation of the model, if the purification effect of buffer zone on suspended solid reached more than 50%, the width of buffer zone was about 15 m.

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