Study on the Migration of Heavy Metals in Different Substrates of Wetland System

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Abstract. In order to study the solidification characteristics of heavy metals in different matrices, this paper intends to study the migration and distribution characteristics of heavy metals such as Cd, Cr, Pb, Zn, Cu in different matrix ratios of wetland systems. The vertical subsurface flow process (bean stone+gravel hollow brick) matrix, horizontal subsurface flow process (sand+slag+crushed hollow brick) matrix has better accumulation effect on Zn; vertical subsurface flow process (bean stone + gravel) matrix has more cumulative effect on Pb Good; the accumulation effect of Cu and Cr on different substrates is not obvious; the accumulation effect of horizontal subsurface flow treatment unit (sand + slag + gravel) on Cd is better than that of (sand + slag + gravel hollow brick) matrix. The content of Cd, Cr, Pb and Zn in the matrix of vertical subsurface flow (bean stone+gravel) is significantly correlated with the distance along the path. The content of Cd, Pb and Zn in the matrix of (bean stone+gravel hollow brick) is related to the distance along the path; the content of Cd, Cr, Zn in the horizontal subsurface flow process (sand+slag+gravel) matrix is significantly correlated with the distance along the path, (sand + slag + gravel hollow brick) matrix, (bean stone+slag) matrix Cr The content of Cu, Pb and Zn in sand (gravel + gravel) is significantly correlated with the distance along the path.

1. Introduction
The wetland system specifically refers to areas where the surface is too wet or often accumulates water, grows wetland organisms, and has multiple functions such as biodiversity conservation, regulation of runoff, improvement of water quality, regulation of microclimate, and even provision of production materials and tourism materials. As one of the three major ecosystems on the earth, the wetland plays a key role in regulating the global ecosystem and has the reputation of the kidney of the earth. In today's rapid economic development, non-renewable resources are constantly being exploited, the ecological...
environment is increasingly being destroyed, and the earth's load is gradually increasing. The wetland system improves the water quality of neighboring rivers, promotes regional ecological restoration, and solidifies refractory pollutants. Improving the ecological environment and adjusting the regional microclimate have a crucial role to play. Because of the diversity and high efficiency of wetland system functions, in addition to natural wetlands, in order to achieve the goal of ecological improvement, a large number of constructed wetland systems have been established according to different guiding needs. And the research on the improvement and restoration of the ecological environment by the constructed wetland system has gradually become a hot spot.

The wetland system is mainly composed of four key parts: matrix, water, plant and microorganism. The construction of the matrix is the basis of the whole system; the water body is the target body, purified in the system, and supplies the plant water and nutrients to meet the basic growth requirements of the crop; the plant provides the biological activity of the system, and with the development of the plant roots, the matrix. The root system of the plant can form a large root network, and the filtration retention effect of the system is more significant. At the same time, the population of microbial communities attached to the surface of the plant roots is continuously enriched, and the microbial degradation ability of the system is gradually enhanced.

After the water pollutants enter the wetland system, the pollutants are fixed under the combined action of physics, biology and chemistry. Some studies have shown that the matrix is the main body of the wetland system. At present, heavy metal pollution in water and soil has been paid more and more attention. The research on the solidification characteristics of heavy metals in water bodies and the migration and distribution of heavy metals in different matrix ratios in wetland systems are still few. This paper intends to study different wetland systems from different matrix ratios. Migration and distribution characteristics of heavy metals such as Cd, Cr, Pb, Zn and Cu in matrix ratio.

2. Overview of the study area
This study selected Xi'an Zaohe constructed wetland water purification demonstration project as the research area. The demonstration project is located 300m downstream of Zaohe Bridge along Yanjiang Avenue in Xi'an and 250m away from Yanjiang Avenue. Covers an area of 1.33ha. There are 5 series in the wetland system, which are series 1~5. Each series is a composite wetland system consisting of different wetland units. In order to study the distribution characteristics of heavy metals in different matrix-matched wetland systems, this study selected series 1 and series 3 with the same process and different matrix ratios for wetland systems. Analysis, series 1 and series 3 information is shown in Table 1.

| Table 1. Size and matrix of constructed wetlands |
| Series | Combination Process | Matrix | Pool Size (length×width) |
|--------|---------------------|--------|-------------------------|
| Series 1(A) | Primary vertical subsurface flow | 200mm bean stone, 400mm gravel | 20m×20m |
| | Secondary horizontal undercurrent | 100mm sand, 100mm slag, 400mm gravel | 20m×20m |
| Series 3(B) | Primary vertical subsurface flow | 200mm bean stone, 400mm gravel hollow brick | 20m×20m |
| | Secondary horizontal undercurrent | 200mm sand, 200mm slag, 200mm gravel hollow brick | 20m×20m |
| | Tertiary surface flow | 150mm planting soil, 200mm sand | 50m×20m |

Note: The matrix order in the table is top-down filling
3. Experimental schemes and methods

3.1. Sample selection

(1) Series 1 (A system) The first stage vertical submersible flow processing unit has 5 sampling points of AS1~AS5, the sampling points are 4m apart, and the second level horizontal submersible processing unit has 5 sampling points of AS6~AS10. The sampling point interval is 4m;

(2) Series 3 (C system) the first-stage vertical submersible processing unit has five sampling points CS1~CS5, and the second-level surface stream processing unit has five sampling points CS6~CS10, sampling interval 4m;

3.2. Sample collection method

Use a sediment sampler to take about 0.5-1 kg of sediment sample at 0-20 cm under water. Due to the heterogeneity of the matrix, three matrix samples were selected and mixed into a clean polyethylene plastic bag when the matrix sample was collected. The package is shipped back to the laboratory for pre-treatment. The collection of the matrix sample is to remove the leaves and dead branches of the plant. The tool materials used in the sampling process are non-metallic products such as polyethylene and wood, and human interference and pollution have been avoided. After the sample was taken back to the laboratory, it was air-dried and ground, and the content of heavy metals was detected by ICP-MS by microwave digestion.

4. Experimental results and analysis

Distribution characteristics of heavy metals in different matrices of 3.1 series 1 (A system) and series 3 (C system)

The series 1 vertical submerged flow + horizontal submerged two-stage composite artificial wetland system and the series 3 vertical submerged flow + horizontal submerged flow + surface flow three-stage composite artificial wetland system have the same two-stage processing unit. The content of heavy metals in the two wetland matrices is shown in Figure 1.

![Figure 1. Distribution of heavy metals in the series 1 (A system) and series 3 (C system) matrix](image-url)
According to Figure 1, the heavy metal content at the sampling point 1 of the series 3 first-stage processing unit (bean stone + crushed hollow brick) is higher than the series 1 first-stage processing unit (bean stone + gravel) matrix except Pb. It can be seen that under the condition of close concentration of heavy metal (the bean stone + gravel hollow brick), the matrix has a better accumulation effect on heavy metals than the (bean stone + gravel) matrix. However, with the change of the distance along the path, the change of heavy metal content in the matrix and the accumulation effect of heavy metals are shown in the differential analysis of heavy metal content given below and the correlation analysis with the distance along the path.

(1) Analysis of the difference in heavy metal content in different substrates of series 1 and series 3. The difference analysis of heavy metal content in different matrices of series 1 and series 3 is shown in Table 2.

Table 2. Difference analysis of heavy metals content in different substrates of Series 1 (A system) and Series 3 (C system)

| Sampling point pairing | Cd   | Cr   | Cu   | Pb   | Zn   |
|------------------------|------|------|------|------|------|
| Series 1A-5—Series 3C-5| 0.080| 0.400| 0.776| 0.027*| 0.018*|
| Series 1A-10—Series 3C-10| 0.038*| 0.499| 0.639| 0.263| 0.029*|
| Series 1A-15—Series 3C-15| 0.106| 0.954| 0.801| 0.970| 0.021*|

Note: * There is a significant difference when the confidence is 0.05.

According to Table 2, the content of five heavy metals in the series 1 vertical submerged flow + horizontal subsurface two-stage composite constructed wetland system and series 3 vertical submerged flow + horizontal submerged flow + surface flow tertiary composite wetland system is not significant except Zn. The content of Zn in the matrix of the series 1 vertical subsurface + horizontal subsurface two-stage composite constructed wetland system is significantly smaller than that of the series 3 vertical subsurface flow + horizontal subsurface flow + surface flow three-stage composite type constructed wetland system.

There is no significant difference in the content of Cd, Cr and Cu in the matrix of the first-stage processing unit (bean stone + gravel) of series 1 and the content of Cd, Cr and Cu in the matrix of the first-stage processing unit (bean stone + gravel hollow brick) of series 3. There is a significant difference in the content of Pb and Zn in the two matrices. It can be seen that the accumulation of Cd, Cr and Cu is similar to that of the (bean stone + gravel) matrix, and the accumulation of Pb is better than that of the (bean stone + gravel) matrix. Stone hollow brick, (bean stone + gravel hollow brick) matrix has better cumulative effect on Zn than (bean stone + gravel). There is no significant difference in the contents of Cr, Cu and Pb between the series 1 second-stage treatment unit (sand + slag + gravel) matrix and the series 3 second-stage treatment unit (sand + slag + gravel hollow brick) matrix, but in the two matrices There is a significant difference in the content of Cd and Zn. Series 1 second stage processing unit (sand + slag + gravel) matrix has better cumulative effect on Cd than series 3 second stage processing unit (sand + slag + gravel hollow brick) matrix, series 3 second stage processing unit (sand + The slag + crushed hollow brick) matrix has better accumulation effect on Zn than the series 1 second stage treatment unit (sand + slag + gravel) matrix.

Wang Xu et al. (2001) [7] studied the migration of Cu in matrix by coke matrix constructed wetland system and gravel matrix constructed wetland system. The results show that the fixation of Cu by coke system is better than that of gravel system.

(2) Correlation analysis of heavy metal content and range distance in series 1 and series 3 matrix. The correlation analysis between the content of heavy metals in the series 1 and series 3 matrix and the distance along the path is shown in Tables 3 and 4. According to Table 3 and Table 4, the correlation between the content of Cd, Cr, Pb and Zn in the matrix of the first-stage treatment unit (bean stone + gravel) of Series 1 is significantly correlated with the distance along the path, and the matrix pair of
The cumulative amount of Cu did not change much along the path; the content of Cd, Cr, Zn in the matrix of the second-stage treatment unit (sand + slag + gravel) of Series 1 was significantly correlated with the distance along the path, (sand + slag + gravel) matrix. The cumulative amount of Cu and Pb did not change much along the path. The correlation between the content of Cd, Pb and Zn in the matrix of the first stage processing unit (bean stone + gravel hollow brick) and the distance along the path is significant. The cumulative amount of Cr and Cu in the matrix of the bean stone + gravel hollow brick. The variation of the process is not significant; the correlation between the content of Cr, Cu, Pb, Zn and the distance along the path of the series 3 second-stage treatment unit (sand + slag + crushed hollow brick) is significant (sand + slag + gravel hollow brick) and the cumulative amount of matrix to Cd did not change much along the path.

**Table 3.** Pearson correlation analysis of heavy metal content and distance in series 1 (A system) matrix

| Matrix                          | Bean stone + gravel |                |                | Pb   | Zn   |
|---------------------------------|---------------------|----------------|----------------|------|------|
| Indicator distance              | Cd                  | Cr             | Cu             | Pb   | Zn   |
| -0.954*                         | -0.980**            | -0.223         | -0.945*        | -0.945* |
| Matrix                          | Sand + slag + gravel|                |                |      |      |
| Indicator distance              | Cd                  | Cr             | Cu             | Pb   | Zn   |
| -0.980**                        | -0.972**            | -0.708         | -0.871         | -0.973** |

Note: *: means P<0.05 (2-tailed), ** means P<0.01 (2-tailed)

**Table 4.** Pearson correlation analysis of heavy metal content and distance in series 3 (C system) matrix

| Matrix                          | Bean stone + gravel hollow brick |                |                | Pb   | Zn   |
|---------------------------------|----------------------------------|----------------|----------------|------|------|
| Indicator distance              | Cd                  | Cr             | Cu             | Pb   | Zn   |
| -0.942*                         | -0.860               | -0.560         | -0.887*        | -0.965* |
| Matrix                          | Sand + slag + gravel hollow brick|                |                |      |      |
| Indicator distance              | Cd                  | Cr             | Cu             | Pb   | Zn   |
| -0.708                          | -0.927*              | -0.879*        | -0.886*        | -0.918* |

Note: *: means P<0.05 (2-tailed), ** means P<0.01 (2-tailed)

5. Conclusion

5.1. Analysis of cumulative effect of Zn on different constructed wetland systems
In the vertical submerged flow + horizontal submerged composite constructed wetland system, in the vertical submerged flow treatment unit, the accumulation of Zn in the (bean stone + gravel hollow brick) matrix is better than the (bean stone + gravel) matrix; in the horizontal subsurface flow processing unit (sand + slag + crushed hollow brick) matrix has better accumulation effect on Zn than sand (slag + gravel) matrix.

5.2. Analysis of cumulative effect of different constructed wetland systems on Pb
In the vertical submerged flow + horizontal submerged composite constructed wetland system, the vertical submerged flow treatment unit (bean stone + gravel) matrix has better cumulative effect on Pb than (bean stone + gravel hollow brick); horizontal submerged flow treatment unit, (sand + slag) + Crushed hollow brick) The matrix and (sand + slag + gravel) matrix have no significant difference in the cumulative effect of Pb.

5.3. Analysis of cumulative effect of different constructed wetland systems on Cu
In the vertical subsurface flow + horizontal submerged composite constructed wetland system, there is no significant difference in Cu accumulation between the vertical subsurface flow treatment unit (bean stone + gravel hollow brick) matrix and the (bean stone + gravel) matrix; horizontal submerged flow
treatment unit (sand + slag + gravel) matrix and (sand + slag + crushed hollow brick) matrix have no significant difference in Cu accumulation.

5.4. Analysis of cumulative effect of Cr on different constructed wetland systems
In the vertical submerged flow + horizontal submerged composite constructed wetland system, the vertical submerged flow treatment unit (bean stone + gravel) matrix and (bean stone + gravel hollow brick) matrix have no significant difference in the cumulative effect of Cr; horizontal submerged flow treatment unit (sand + slag + gravel substrate and (sand + slag + crushed hollow brick) matrix have no significant difference in the cumulative effect of Cr.

5.5. Analysis of cumulative effect of different constructed wetland systems on Cd
In the vertical subsurface flow + horizontal subsurface complex type constructed wetland system, the vertical submerged flow treatment unit (bean stone + gravel) matrix and (bean stone + gravel hollow brick) matrix have no significant difference in the cumulative effect of Cd; horizontal subsurface flow processing unit (sand + The slag + gravel matrix has a better cumulative effect on Cd than the sand (slag + slag + crushed hollow brick) matrix.

5.6. Correlation analysis of content and distance of heavy metals in different constructed wetland systems
The content of Cd, Cr, Pb and Zn in the matrix of vertical subsurface flow (bean stone + gravel) is significantly correlated with the distance along the path. The content of Cd, Pb and Zn in the matrix of (bean stone + gravel hollow brick) is related to the distance along the path. Significantly; the content of Cd, Cr, Zn in the horizontal subsurface flow process (sand + slag + gravel) matrix is significantly correlated with the distance along the path, (sand + slag + gravel hollow brick) matrix, (bean stone + slag) matrix Cr The correlation between the content of Cu, Pb and Zn and the distance along the path is significant. The correlation between the content of Pb and Zn in the matrix (sand + gravel) and the distance along the path is significant.

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