Reclaimed water application to vegetation restoration in mining area: Determination of water quality standards and optimization of moderate treatment technology

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Abstract. Water shortage severely restricts vegetation restoration of mining area in the northwest China. Moderate treatment of reclaimed water is essential for improving the local ecological environment. In this study, relevant water quality standards issued by the states and research results were comprehensively considered to propose a reclaimed water quality standard suitable for vegetation restoration of mining area. The available domestic sewage and mine water was moderately treated by hybrid biological reactor system and nanofiltration membrane system, respectively. The effluent quality meet the requirement of reclaimed water quality standards in this study. This study provides theoretical support for vegetation restoration of mining area.

1 Introduction

The land desertification is serious in northwest China. Especially in mining area, ecological functions continue to deteriorate [1-2]. Using appropriate vegetation and soil amendments can effectively improve the ecological environment [3-5]. However, the water for vegetation restoration is in short supply in the northwest China [6-8]. To solve this problem, improving water use efficiency and seeking innovations in water resources management are feasible solutions [7].

The available reclaimed water sources in mining area include domestic sewage and mine water, which are particularly important for vegetation restoration. However, there is little study on water quality standard for vegetation restoration in mining areas. Furthermore, in consideration of the treatment effect, operation cost and species resistance, the moderate treatment of wastewater not only guarantees the removal of pollutants, which may destroy the vegetation, but also ensures that the appropriate amount of nitrogen and phosphorus are used as nutrients for vegetation [9]. However, the relevant research is limited.

Therefore, the purpose of this study is to propose a reclaimed water quality standard for

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vegetation restoration of mining areas. The domestic sewage and mine water were moderately treated through hybrid biological reactor system and nanofiltration membrane system to make effluent quality meet the requirement of vegetation restoration.

2 Materials and methods

2.1 Water quality survey in mining area in the northwest China

The domestic sewage quality was obtained from the water quality inspection report issued by the official website of Yinchuan City Ecological Environment Bureau. The mine water quality referred to the water quality results given by Geological Bureau of Ningxia Hui Autonomous Region, Yangchangwan Coal Mine Plant, and this research laboratory.

2.2 Determination of reclaimed water quality standards

The determination of reclaimed water quality standards in this study referred to relevant water quality standards issued by the states and research results.

2.3 Moderate treatment of domestic sewage

The moderate treatment of domestic sewage was carried out in a hybrid biological reactor. Filler ratio was set at 1/4, 1/3, and 1/2 under 7h of hydraulic retention time and 25 ℃ condition. The operating time of 7 h was set at a cycle.

2.4 Moderate treatment of mine water

2.4.1 Coagulation sedimentation pretreatment

Four coagulation solution with a mass fraction of 1% was prepared using polyaluminum sulfate (A), polyferric sulfate (B), polyaluminum chloride (C), and polyferric chloride (D). The coagulation solution of 10 mg/L, 20 mg/L, 40 mg/L, 60 mg/L, 80 mg/L, 100 mg/L, 120 mg/L, 140 mg/L, and 160 mg/L was added to mine water samples in a magnetic stirrer, respectively.

2.4.2 Membrane filtration experiment

NF90 nanofiltration membrane was selected in this study, installed in the membrane filtration experimental separator. To evaluate the optimum operating pressure, the separator was operated under 0.6 MPa, 0.8 MPa, 1 MPa, 1.2 MPa, 1.5 MPa, 2 MPa, 2.5 MPa, 3 MPa, and 3.5 MPa condition, respectively. To investigate the optimum operating temperature, the separator was operated under 5 ℃, 15 ℃, 25 ℃, 35 ℃, and 45 ℃ condition, respectively.

2.5 Analytical methods

For the moderate treatment of domestic sewage, the COD, NH_4^+-N and TP concentration were analyzed to evaluate treatment effect. For the moderate treatment of mine water, the turbidity, suspended solids, total hardness, total dissolved solids (TDS), and chloride were measured to evaluate treatment effect.

3 Results and discussion

3.1 Reclaimed water quality in mining area in the northwest China

The domestic sewage water quality referred to the official inspection report issued by Yinchuan City Ecological Environment Bureau. The main pollutant indicators tested in the report were COD, NH_4^+-N, and TP. The average value of the main pollutants of domestic sewage: COD (423.83 mg/L); NH_4^+-N (42.23 mg/L); TP (8.10 mg/L).

The mine water quality was obtained from Geological Bureau of Ningxia Hui Autonomous Region, the Yangchangwan Coal Mine Plant, and measured value in this research laboratory. The average value of the three inspection results was taken as the mine water quality in this study. The average value of the main pollutants of mine water: turbidity (503 NTU), suspended solids (406.18 mg/L), total hardness (1266 mg/L), TDS (5848.44 mg/L), chloride (2328.63 mg/L).

3.2 Analysis of reclaimed water quality standard

The standards of reclaimed water quality (forestry, SL368-2006) is the most suitable for vegetation restoration. Considering that plants have little difference in water quality requirements, this study also selected water quality standard for non-potable urban use (GB/T18920-2002), water quality standard for green space irrigation (GB/T25499-2010), and standards for irrigation water quality (GB5084-2005) as the reference standard. Related reclaimed water quality standards were listed in Table 1.

Table 1. Related reclaimed water quality standard selected by this study.

Parameters	SL368-2006	GB/T18920-2002	GB/T25499-2010	GB5084-2005
Turbidity (NTU)	10	10	10	/
NH_4^+-N	/	20	20	/
Total hardness (mg/L)	450	/	/	/
Suspended solids (mg/L)	30	/	/	100
COD (mg/L)	90	/	/	200
TDS (mg/L)	1000	1000	1000	2000
Chloride (mg/L)	/	/	250	350

3.2.1 Determination of domestic sewage quality standards

The limiting value of NH_4^+-N in water standards of GB/T18920-2002 and GB/T25499-2010 both are 20 mg/L. The COD limiting value of 90 mg/L was found in water standards of SL368-2006. However, related research found that average COD more than 65 mg/L and TP more than 4 mg/L were harmful to growth of herbaceous plant [10].

Therefore, the recommended values of domestic sewage quality for vegetation restoration in this study were follows: COD (65 mg/L), NH_4^+-N (20 mg/L), TP (4 mg/L).

3.2.2 Determination of mine water quality standards

The turbidity of 10 NTU and the TDS of 1000 mg/L were selected as water quality standard according to water standards of SL368-2006, GB/T18920-2002 and GB/T25499-2010. The

suspended solids of 30 mg/L and the total hardness of 450 mg/L were set as limiting value according to water standards of SL368-2006. The limiting value of chloride in water standards of GB/T25499-2010 is 250 mg/L. Considering that perennial herbs with strong tolerance were planted in the northwest China, the chloride limiting value of 350 mg/L from water standards of GB5084-2005 was selected as water quality standard in this study.

Therefore, the recommended values of mine water quality for vegetation restoration in this study were follows: turbidity (10 NTU), total hardness (450 mg/L), suspended solids (30 mg/L), TDS (1000 mg/L), chloride (350 mg/L).

3.3 Moderate treatment performance of domestic sewage

The traditional activated sludge and the microorganisms attached to the filler added form a biofilm system which can improve wastewater treatment performance in hybrid biological reactor [11-13]. The suitable fillers ratio is beneficial to improve the effluent quality. Fig. 1 shows the change of effluent quality under different fillers ratio. When filler ratio increased from 1/4 to 1/3 . the average effluent COD concentration decreased from 61.35 mg/L to 45 mg/L. When filler ratio further increased, the average effluent COD concentration was more than water quality standard of 65 mg/L. The best removal rate of NH_4^+-N and TP were achieved at filler ratio of 1/3. Taking into account the principle of meeting the water quality standard while reducing unnecessary costs, the filler ratio of 1/4 was considered the optimal.

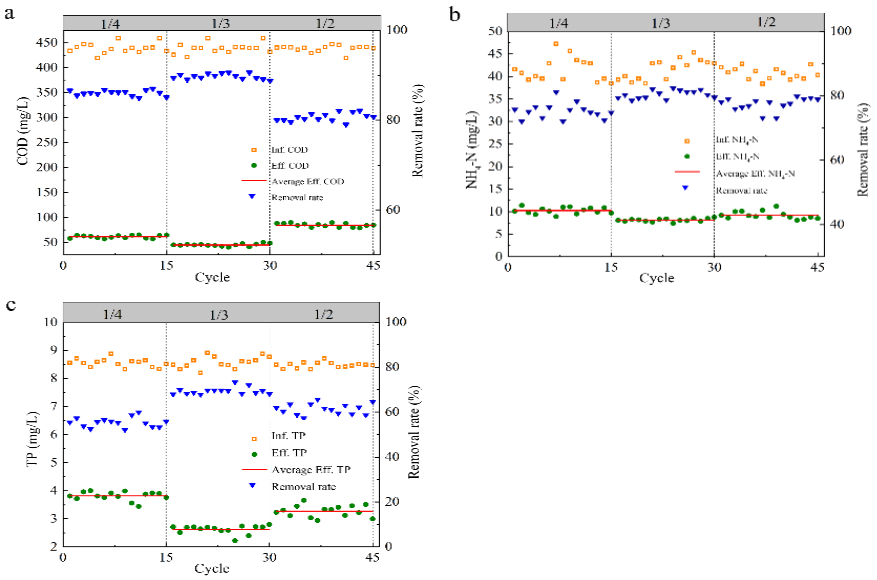

Fig. 1. Change of (a) COD, (b) NH_4^+-N and (c) TP under different fillers ratio (first 15 cycles: 1/4, middle 15 cycles: 1/3, last 15 cycles: 1/2).

3.4 Moderate treatment performance of mine water

3.4.1 Comparison of pretreatment effect of four coagulants

Fig. 2 shows the change of effluent suspended solids and turbidity at different dosage of coagulant. When the dosage of coagulant solution was 80 mg/L and 100 mg/L respectively,

the concentration of suspended solids and turbidity in the effluent were relatively low, reaching the requirements of mine water quality standard proposed in this study. In view of principle of moderate treatment, the coagulant solution of 80 mg/L was selected in this study. Furthermore, it can be found that treatment effect of polyaluminum chloride was best among the four coagulant solution when coagulant solution was 80 mg/L.

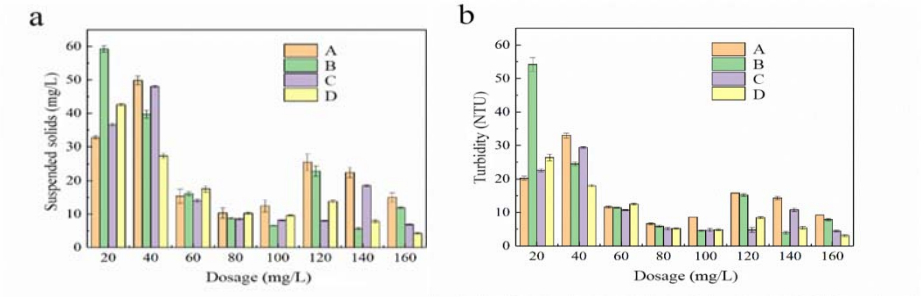

Fig. 2. Change of effluent (a) suspended solids and (b) turbidity at different dosage of coagulant.

3.4.2 Optimization of operating temperature and pressure

Fig. 3 shows the filtration effect of NF90 membrane at different operating temperature and pressure. When the operating temperature was 25 ℃, the TDS, total hardness and chloride concentration of the effluent were the lowest and satisfied requirements of effluent water quality standard proposed in this study. Generally, the pore size of membrane increases with the increase of operating pressure, leading to an increase in membrane flux. Exorbitant operating pressure is not conducive to pollutants removal. It can be found that TDS concentration exceed the limiting value of 1000 mg/L when the operating pressure increased to 1 MPa. Therefore, the optimum operating temperature and the optimum operating pressure of NF90 nanofiltration membrane was 25 ℃ and 0.8 MPa respectively.

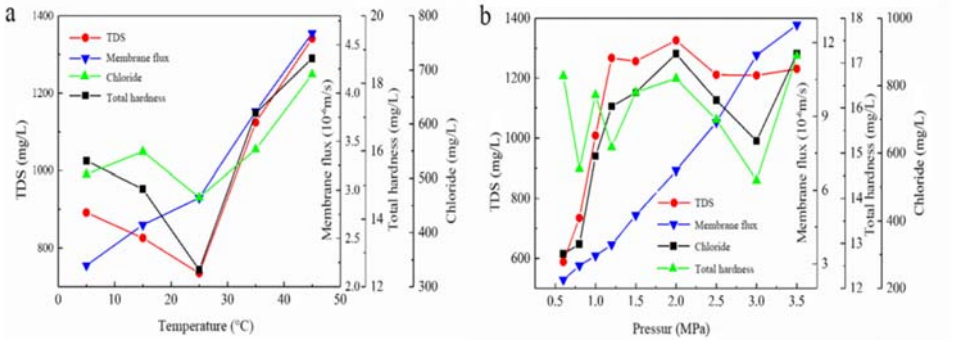

Fig. 3. Filtration effect of NF90 membrane at different operating (a) temperature and (b) pressure.

4. Conclusions

This study proposed a reclaimed water quality standard suitable for vegetation restoration in mining areas. For domestic sewage, the recommended values in this study were follows: COD (65 mg/L), NH_4^+-N (20 mg/L), TP (4 mg/L). For mine water, the recommended values were follows: turbidity (10 NTU), total hardness (450 mg/L), suspended solids (30 mg/L), TDS (1000 mg/L), chloride (350 mg/L). The filler ratio of 1/3 made the effluent pollutants meet the water quality requirements under the principle of moderate treatment. For moderate treatment of mine water, the treatment effect of polyaluminum chloride of 80

mg/L was best. The optimal operating temperature and the optimal operating pressure of NF90 nanofiltration membrane was 25 ℃ and 0.8 MPa respectively.

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