Experimental Study on the Treatment of Flue Gas Desulfurization Wastewater by a Biological Fluidized Bed

Youchen LI*, **Jingfu FAN**, **Lina LI**

Luoyang R&D Center of Technology, Sinopec Engineering (Group) Co., Ltd., Luoyang 471003, China

Abstract For the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed process, the optimum temperature was 25 – 35 ℃, and the optimum hydraulic retention time was 10 h. When the influent quality was stable, the average concentration of COD, NH_4^+-N and TN in the inlet water was 210, 11 and 16.3 mg/L, respectively, and their average concentration in the effluent was 54, 0.32 and 4.09 mg/L, respectively. The treatment effect was good. When the incoming water quality of flue gas desulfurization wastewater fluctuated greatly, the effluent quality was still relatively stable after being treated by the biological fluidized bed, indicating that the biological fluidized bed process had a good ability to resist the impact of water quality in the treatment of high-salinity flue gas desulfurization wastewater. At the same time, the biological fluidized bed process provides a reference for high-salinity wastewater that is difficult to be biologically treated.

Key words Biological fluidized bed; Flue gas desulfurization wastewater; Average removal rate

DOI 10.19547/j.issn2152 – 3940.2025.02.011

Fluidized bed reactors can achieve mixed mass and heat transfer among gas, liquid and solid phases. A biological fluidized bed means that fine particles such as quartz sand, activated carbon and coke are filled in the bed as carriers, and a biofilm cover the surface of the carriers; under the action of a certain force, sewage flows from bottom to top to keep carrier particles in a fluidized state. The biofilm of a biological fluidized bed is attached to the carrier, and the concentration of its activated sludge is as high as 40 – 50 g/L, which is 10 – 20 times that of the traditional activated sludge method[1]. Moreover, the biofilm on the surface of the carrier fully contacts the wastewater and air in the bed, improving the utilization rate of oxygen molecules for mass transfer between gas and liquid phases, and thereby enhancing the effect of wastewater treatment by the biological fluidized bed[2].

Flue gas desulfurization wastewater is the wastewater produced during the desulfurization, denitrification and washing process of flue gas by catalytic cracking in the petrochemical industry. Flue gas desulfurization wastewater is characterized by high concentrations of suspended solids, high salt content, high nitrogen content and high COD, so it is relatively difficult to treat in petroleum refining and chemical enterprises[3].

The biological fluidized bed device developed by Luoyang Technology Research and Development Center has successively applied in side-line tests on the pretreatment of oil refining wastewater, ethylene glycol wastewater, PTA wastewater, and coal-to-ethylene glycol wastewater in petrochemical industry, with a good treatment effect. At the same time, industrial applications have also confirmed that a biological fluidized bed has the advantages of high sludge concentration, high volumetric loading, high reaction rate, short hydraulic retention time, strong resistance to load shock, high reaction efficiency, small land occupation area, and good treatment effect. Besides, it has a good effect on the treatment of petrochemical wastewater, and the treated effluent meets the requirements of enterprises[4–5].

In this paper, the mixed flue gas desulfurization wastewater with high salinity from a domestic petrochemical enterprise was treated by a biological fluidized bed process, and a side-line test was carried out. Meanwhile, in order to investigate the impact resistance capacity of the biological fluidized bed, the influent load was increased in the later stage of the test.

1 Test device and process

The process of the biological fluidized bed device is shown in Fig. 1. Flue gas desulfurization wastewater enters the anoxic tank through the regulating tank, and then overflows to the aerobic tank. The digestion liquid in the aerobic tank is recycled to the anoxic tank. The upper wastewater overflows to the sedimentation tank, with water discharged from the top of the sedimentation tank, and the sludge at the bottom flows to the anoxic tank. Both the anoxic tank and the aerobic tank adopt an internal circulation flow form with inner and outer cylinders. The anoxic tank is stirred with a stirrer, while the aerobic tank uses bottom aeration as the lifting power for uniform mixing. Meanwhile, biological carrier fillers are added to the aerobic bed.

2 Test materials and methods

2.1 Test water quality and source The test water was derived from the mixed water of flue gas desulfurization wastewater and domestic sewage in a petrochemical plant, with a mixing ratio of approximately 1 : 1.5. The quality of the wastewater is shown in

Received: March 12, 2025 Accepted: April 15, 2025

* Corresponding author.

Table 1.

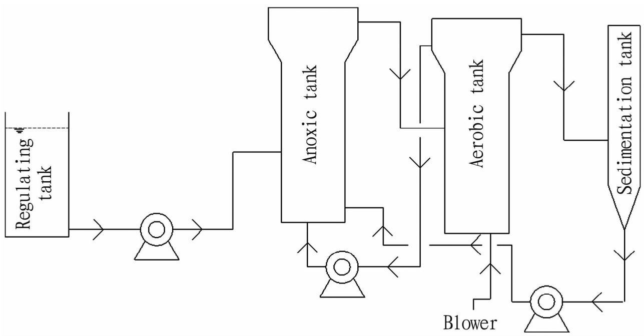

Fig. 1 Process diagram of the biological fluidized bed

Table 1 Quality of the flue gas desulfurization wastewater

Item	Value
COD // mg/L	180 – 300
NH_4^+ -N // mg/L	9 – 15
TN // mg/L	9 – 20
BOD // mg/L	60 – 100
Conductivity // μS/cm	8 000 – 10 000
B/C	0.3 – 0.35
pH	7 – 8.5

The experimental sludge was collected from the residual sludge from the biochemical treatment tank of this petrochemical plant.

2.2 Analysis items and methods The indicators of water quality in this test mainly include COD, NH_4^+-N, TN, pH and conductivity. Sampling and analysis were carried out in a timely manner at the side-line test site.

The process of this side-line test is divided into the sludge acclimation and cultivation stage and the continuous influent test stage. The sludge acclimation and cultivation stage and the carrier biofilm formation stage adopted intermittent influent, and the carrier biofilm formation spent approximately 20 d. The carrier biofilm formation was completed when a uniform film was attached to the surface of most carriers. Through microscopic examination of samples, it is seen that there were many types and quantities of microorganisms on the biofilm, mainly including vorticella, epistylis, paramecium, *etc.*

The biological carrier packing used in the test has a special geometric structure, so the specific surface area of the carrier packing is large. Meanwhile, the aerobic fluidized bed has a special gas distribution mode and biofilm removal structure, which is conducive to the biofilm removal of the carrier. In the fluidized bed, the carrier could move in different directions through the turbulent fluidization of gas, liquid and solid, so that the aged biofilm on the carrier would be shed, renewed and regenerated in time.

3 Results and analysis

3.1 Effects of temperature on the operation effect of A/O biological fluidized bed The effects of temperature on the treatment effect of the biological fluidized bed on the mixed flue gas desulfurization wastewater with high salinity were studied under certain test conditions (the concentration of dissolved oxygen was less than 0.5 mg/L in the anoxic bed and 2.0 – 4.5 mg/L in the aerobic bed; the influent pH ranged from 7.0 to 8.5, and temperature was between 20 and 35 ℃). The variation of pollutant removal with temperature is shown in Fig. 2. As temperature ranged from 20 to 35 ℃, the effects of COD, NH_4^+-N, and total nitrogen (TN) removal were all relatively good. At 20 ℃, the removal rate of COD, NH_4^+-N, and total nitrogen was the lowest, and effluent COD concentration was relatively high (around 60 mg/L). According to the conventional nitrification and denitrification temperature, the optimal operation temperature of the biological fluidized bed was 25 – 35 ℃.

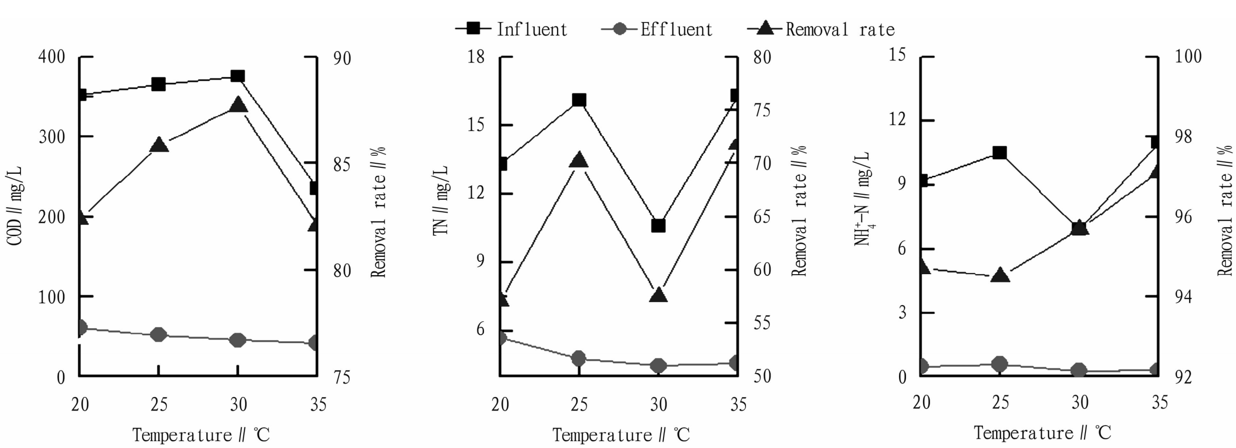

Fig. 2 Effects of temperature on the operation of the biological fluidized bed

3.2 Effects of hydraulic retention time on the operation effect of the biological fluidized bed The effects of hydraulic retention time (HRT) on the treatment effect of the biological fluidized bed on the mixed flue gas desulfurization wastewater with high salinity were analyzed under certain test conditions (the concentration of dissolved oxygen was less than 0.5 mg/L in the anoxic bed and 2.0 – 4.5 mg/L in the aerobic bed; the influent pH varied from 7.0 to 8.5, and temperature was 30 ℃). Fig. 3 presents the change of pollutant removal with HRT. When the retention time ranged from 10 to 20 h, effluent COD concentration, NH_4^+-N and total nitrogen was all relatively low, so the removal effect was good. However, as the retention time was 7 – 8 h, effluent COD concentration was relatively high, and the removal rate of total nitrogen was relatively low. In view of the operation cost, the optimal HRT of the biological fluidized bed was about 10 h.

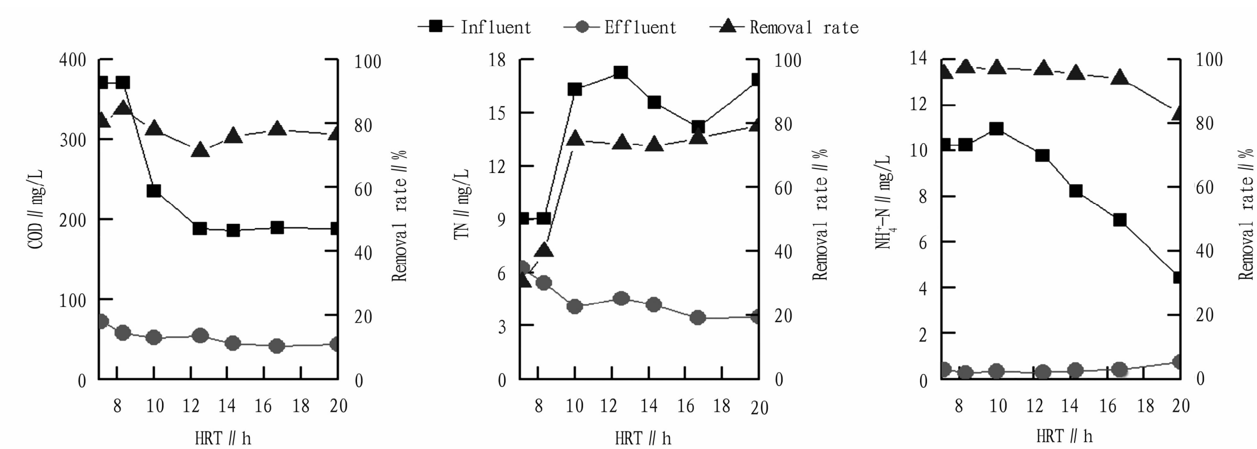

Fig. 3 Effects of HRT on the operation of the biological fluidized bed

3.3 Continuous operation of the biological fluidized bed

3.3.1 Effect of COD removal. As shown in Fig. 4, influent COD concentration fluctuated between 180 and 260 mg /L during the continuous operation of the biological fluidized bed (1 – 26 d), averaging 210 mg /L during this period. After treatment by the A/O biological fluidized bed, effluent COD concentration was all less than 60 mg/L, with an average of 54 mg/L, and the average removal rate of COD was greater than 75%. From 27 to 40 d, influent COD concentration was impacted and fluctuated significantly, with the maximum of 710 mg/L. However, the effluent quality remained relatively stable, and the effluent concentration was below 80 mg/L. The average removal rate of COD exceeded 85%. The results show that the biological fluidized bed had a better effect on the removal of COD from the mixed flue gas desulfurization wastewater with high salinity, as well as a better ability to resist COD impact.

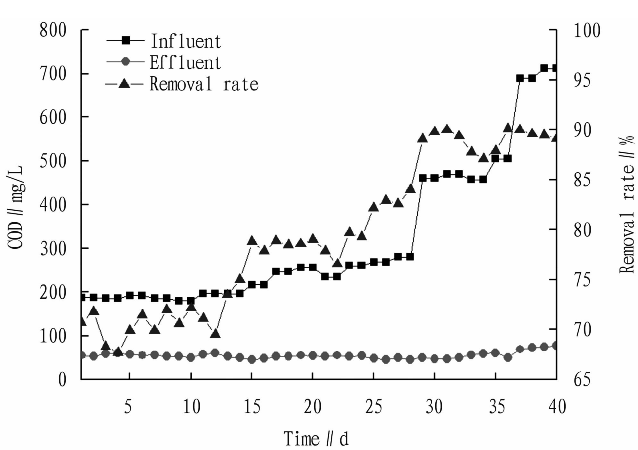

Fig. 4 Effect of COD removal during the continuous operation of the biological fluidized bed

3.3.2 Effect of NH_4^+-N removal. It can be seen from Fig. 5 that during the continuous operation of the biological fluidized bed, influent NH_4^+-N concentration fluctuated between 9 and 15 mg/L, averaging 11 mg/L. After treatment by the biological fluidized bed, effluent NH_4^+-N concentration was less than 1 mg/L, with an average of 0.32 mg/L, and the average removal rate of NH_4^+-N was above 97%. Tests show that the biological fluidized bed had a better effect on the removal of NH_4^+-N from the mixed flue gas desulfurization wastewater with high salinity.

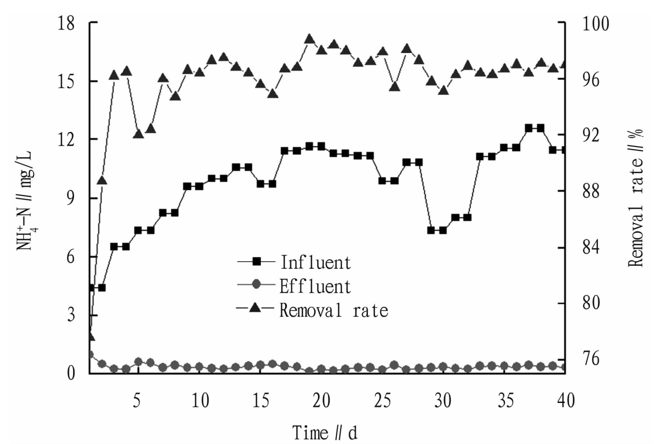

Fig. 5 Effect of NH_4^+-N removal during the continuous operation of the A/O biological fluidized bed

3.3.3 Effect of TN removal. It can be known from Fig. 6 that influent TN concentration varied from 9 and 18 mg/L during the continuous operation of the biological fluidized bed (1 – 26 d), averaging 16.32 mg/L during this period. After treatment by the A/O biological fluidized bed, effluent TN concentration was less than 5 mg/L, with an average of 4.09 mg/L, and the average removal rate of TN was higher than 72%. From 27 to 40 d, influent TN concentration was impacted and fluctuated obviously, and the maximum was up to 47 mg/L. However, the effluent quality was relatively stable, and the effluent concentration was below 8 mg/L. The removal rate of TN was higher than 75%. The results show that the biological fluidized bed had a better effect on the removal of TN from the mixed flue gas desulfurization wastewater with high salinity, as well as a better ability to resist TN impact.

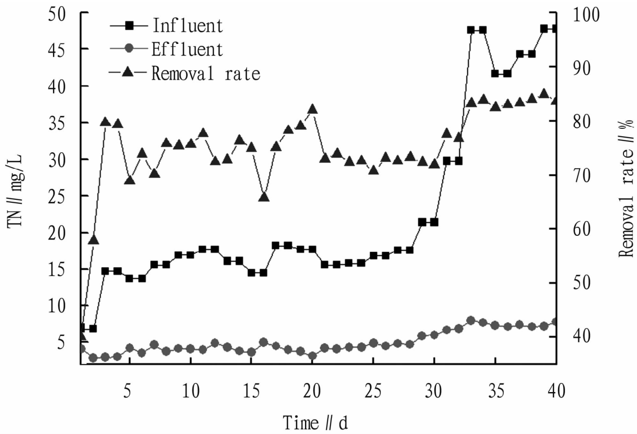

Fig. 6 Effect of TN removal during the continuous operation of the biological fluidized bed

4 Conclusions

(1) For the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed process, the most suitable temperature was 25 – 35 ℃, and the optimal hydraulic retention time was about 10 h.

(2) After the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed process, effluent COD concentration was lower than 60 mg/L, and the average removal rate reached 75%; NH_4^+-N concentration was lower than 1 mg/L, and the average removal rate was up to 97%; TN concentration was lower than 5 mg/L, the average removal rate was 72%. It is indicated that the biological fluidized bed process had a good effect on the treatment of flue gas desulfurization wastewater with high salinity.

(3) During the treatment of the mixed flue gas desulfurization wastewater with high salinity by the biological fluidized bed, when influent quality was impacted, the maximum of COD and TN concentration reached 710 and 47 mg/L, respectively. However, the effluent quality was relatively stable, and effluent COD and TN concentration were below 80 and 8 mg/L, respectively. The removal rate of COD and TN exceeded 85% and 75%, respectively. The results show that the biological fluidized bed process had a better ability to resist water quality impact during the treatment of the mixed flue gas desulfurization wastewater with high salinity.

(4) Meanwhile, the biological fluidized bed process provides a reference for the treatment of high-salinity wastewater that is difficult to be biologically treated.

References

[1] LIU XL, ZHANG JC, WANG FH, *et al.* Three-phase biological fluidized bed reactor for sewage treatment: Beijing, CN2791027[P]. 2006-06-28.

[2] FAN JF, HE QS, LIU JL. Pilot study on coal to EG wastewater treatment-by new biological fluidized bed A/O process[J]. Petroleum Refinery Engineering, 2019, 49(1): 17-22.

[3] HUANG DC. Discussion on treatment of FCC flue gas desulfurization wastewater by denitrification technology[J]. Sino-Global Energy, 2021, 26(5): 83-87.

[4] HE QS, FAN JF, ZHANG JC, *et al.* Application effect of biological fluidized bed in treating petrochemical wastewater[J]. Sino-Global Energy, 2020, 25(2): 81-84.

[5] HE QS, LIU XL, ZHANG JC, *et al.* Experimental study of pretreatment of PTA wastewater by aerobic biological fluidized bed[J]. Petroleum Processing and Petrochemicals, 2019, 50(11): 102-105.

(From page 48)

and collapse, and suspend the construction. Outdoor pedestrians should immediately take shelter in a safe place, and the vehicles and other outdoor objects or equipment that are vulnerable to hail attack should be properly protected.

References

[1] LI Q, ZHOU SY. Preliminary analysis for the examination and review of climatic feasibility[J]. Journal of Guangxi Meteorology, 2005(2): 29-31.

[2] SONG LL. The effect and practice of China's climate feasibility demonstration[J]. Yuejiang Academic Journal, 2013, 5(3): 31-34.

[3] Weather Teaching and Research Office, Meteorological College of Chinese People's Liberation Army. Synoptic meteorology[M]. Beijing: People's Education Press, 1960.

[4] ZHAO HJ, WANG XR, GUO JH. Summary of climate feasibility demonstration practice and future suggestions in China[J]. Public Communication of Science & Technology, 2022, 14(13): 1-7.

[5] CHEN SD, XU WM, GUI BY, *et al.* Problems and countermeasures of climate feasibility argument in Jiangxi[J]. Meteorology and Disaster Reduction Research, 2019, 42(2): 140-145.

[6] China Meteorological Administration. Code for surface meteorological observation[M]. Beijing: Meteorological Publishing House, 2003.

[7] HU YF. Principle and measurement method of automatic weather station[M]. Beijing: Meteorological Publishing House, 2004.

[8] WANG Y, LIU XN. Comparative analysis of AWS- and man-observed temperatures[J]. Journal of Applied Meteorological Science, 2002(6): 741-748.

[9] LIU XN, REN ZH, WANG Y. Differences between automatic-observed and manual-observed surface temperature[J]. Journal of Applied Meteorological Science, 2008(5): 554-563.

[10] TU QP. Meteorological application probability statistics[M]. Beijing: Meteorological Publishing House, 1984.

[11] LIU XN. The homogeneity test on mean annual wind speed over China[J]. Journal of Applied Meteorological Science, 2000(1): 27-34.

[12] LI QX, JIANG ZH, HUANG Q, *et al.* The experimental detecting and adjusting of the precipitation data homogeneity in the Yangtze Delta[J]. Journal of Applied Meteorological Science, 2008(2): 219-226.

[13] ZHANG Z, LIN L, LIANG P, *et al.* The study of homogeneity test on the annual mean temperature in Ningxia[J]. Meteorological Monthly, 2009, 35(10): 79-83.

[14] YIN WY, ZHU QL. Adjusting methods of monthly mean temperature series in Dalian[J]. Meteorological Science and Technology, 2008, 36(6): 740-744.

[15] ZHANG CH, WANG GQ, LI TJ. Prevention countermeasures and suggestions for urban rainstorm disasters under changing environment[J]. Bulletin of Chinese Academy of Sciences, 2022, 37(8): 1126-1131.