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Original Research Paper

Application of Internal Circulation (IC) and Two-Step Biochemical Process for Oil Wastewater Treatment

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ABSTRACT

In expectation to improve the properties of production wastewater with both complicated composition and high amount of organic compounds produced by oil and grease processing enterprise, pretreatment, IC anaerobic technology and the two stage biological contact oxidation technology were combined to process the oil wastewater. It was found that the removal rate of COD, oil and ammonia nitrogen could be enhanced to 99.71%, 99.8%, 85.8%, respectively when the concentration of influent COD, grease and ammonia nitrogen were 32500mg/L, 2800mg/L and 95 mg/L. Besides, the effluent quality could keep stable, coming up to the primary standard of the integrated wastewater discharge standard (GB8978-1996). Meanwhile, biogas, a kind of clean secondary energy, was also produced during the treatment process and could be applied in both power generation and steam production, exhibiting excellent technicality and economic.

INTRODUCTION

An oil processing enterprise, using waste vegetable oil recycling as raw materials, produces oleic acid, stearic acid, glycerol and other products. The oil wastewater comes mainly from various processes such as leaching, alkali refining, hydration, acidification, neutralization, degumming, deodorization, decolorization, filtration and washing process. Due to the intermittent discharge, the oil wastewater is of complex composition, unstable pH value, changeable water quality and quantity, and strongly harmful. The main pollution index of the oil wastewater and corresponding discharge standard are given in Table 1. The paper deals with the treatment of this wastewater by internal circulation (IC) and two-step biochemical process with generation of biogas. The economics of the process has also been discussed.

TREATMENT PROCESS

Technical Procedure

After considering the wastewater quality and related technical processes (Chen 2013, He 2001, Ouyang et al. 2013, Wang et al. 2006, Liu et al. 2011, Toru Matsui et al. 2005, Chavez et al. 2005, Zhang Z. H. 2006, Hu et al. 2004), IC and two-step biochemical process are adopted.

Wastewater is first treated by grid to remove large particles SS and then flows into the separation tank and regulation pool aiming at eliminating most of the oil slick and regulating water quality. The treated wastewater flows into the sump well and then is pumped to neutralization, coagulation and sedimentation pool where the wastewater reacts with lime, PAC and PAM. Next, the wastewater flows into the sedimentation pool where calcium sulphate precipitate, COD, chroma and grease are removed. Then the wastewater flows into the dissolved air flotation machine to remove the fine oil particles and suspended substances. The wastewater flows into the hydrolysis acidification pool where part of organic macro-molecules decomposed into small molecules, and simultaneously wastewater is heated especially in winter. The heated wastewater is pumped into the IC reactor for anaerobic reaction to decompose organic macromolecules into small molecules, which effectively reduces COD and enhances the ratio of B/C. If the process is stable, the reduced COD value is proportional to the produced biogas value. The IC reactor effluent flows successively into A/O biochemical pool, the secondary sedimentation tank, the contact oxidation tank and the third sedimentation tank. SS and biological membrane produced in the anaerobic or aerobic process are removed using the solid-liquid separation effect. The treated wastewater finally flows into the clean water tank, which can be used to wash the ground or discharged directly or made for outer-circulation for IC reactor according to the situation.

A lot of biogas generated by IC reactor is collected by methane collection apparatus. The biogas is delivered to the biogas tank before drying, desulphurization and booster. Finally, the biogas is engaged in the comprehensive utiliza-

Table 1: The main pollution index and the discharge standard of wastewater.

Item	pH	COD (mg/L)	NH_3-N (mg/L)	Oil (mg/L)	Chroma
Wastewater quality	1.5	32500	95	2800	500
Discharge standard	6~9	≤100	≤15	≤10	≤ 50

tion, such as producing hot water in biogas boiler, heating of wastewater in the hydrolysis acidification pool and generating electricity by excess biogas.

Air flotation scum and sludge in the neutralization coagulation sedimentation tank and the secondary sedimentation tank and the third sedimentation tank are pressed into sludge cake using the plate and frame filter press and carried away. Meanwhile, the supernatant flows inversely into the grille wells. Sludge cake can be processed together with the garbage.

Main Structures

Grille wells, oil separation tank and sump well: A reinforced concrete structure is designed with the size of 20.0m ×10.0m×3.0m, the inner of which is divided into four parts. The residence time, the effective volume and the total volume are respectively 24h, 500m^3 and 600m^3. The associated apparatus includes a coarse and a fine artificial grille, two anti-corrosion self suction pumps for alternative use with the model of 50KFX-28, flux of 25.0m^3/h, head of 24.0m, motor power of 4.0kW and suction height of 4.0m, two water level controllers with model of UQK, an electromagnetic flow meter with model of SKLD-50 and flow of 0.71-70.65m^3/h.

Neutralization coagulation sedimentation pool: A reinforced concrete structure is designed with the size of 18.0m×3.0m×4.0m. The residence time, the effective volume and the total volume are respectively 8.2h, 172.8m^3 and 216m^3. The main associated apparatus includes a de-emulsifier dosing device with the volume of 1.5m^3 containing a dosing pump and a dosing flowmeter, a pH-regulated dosing device with the volume of 2.0m^3 containing a dosing pump and a dosing flowmeter, a flocculant dosing device with the volume of 3.0m^3 containing a dosing pump, a coagulant dosing device with the volume of 2.0m^3 containing a dosing pump, a mud and slag scraping machine with the span of 3m and the length of 15m, two anti-corrosion sludge pumps for use and spare with the model of 40FX-15, two sets of pH value controller and a waste oil tank.

Flotation machine: The basement scum pool is designed with the size of 4.0m×2.0m×5.0m. The flotation machine GF-30 has the processing capacity of 30.0m^3/h, which includes combined steel structural pool body, dissolved air system, chain plate foam scraper, releaser and release system. The main fitted apparatus includes two sludge pumps for use and spare with the model of 40FX-15.

Hydrolysis acidification pool: A reinforced concrete structure is designed with the size of 15.7m×4.0m×5.0m. The residence time, the effective volume and the total volume are respectively 13.4h, 282m^3 and 314m^3. The main associated apparatus includes two lift pumps with the model of 65KF-32 for alternative use, an electromagnetic flowmeter with model of SKLD-50, two sets of water level controller with the model of UQK and a set of perforated pipes.

IC reactor: A steel structure on the ground is designed with the size of Φ10×20m. It is treated by internal and external anti-corrosion process with the effective height of 19.5m, the residence time of 73h, the effective volume of 1530m^3 and the total volume of 1570m^3.

A/O biochemical pool: A reinforced concrete structure is designed with the size of 18.0m×4.5m×5.5m. The effective depth, the residence time, the effective volume and the total volume are respectively 5.2m, 20.0h, 421.2m^3 and 445m^3. The sizes of anoxic zone and oxic zone are 9.75m×4.5m×5.5m and 8.0m×4.5m×5.5m. The main associated apparatus includes 108 fine bubble aerators with the model of YMB-DN215mm, two roots blowers with the model of 3L42WC22KW-4 for use and spare which are shared with the contact oxidation pool, the elastic filler with the volume of 153m^3, size of ū 150×3500m, density of 3.2kg/m^3, film density of 69kg/m^2 and specific surface area of 310m^2/m^3, the soft filler with volume of 126m^3, size of Φ150×3500m, density of 3.4kg/m^3, film density of 65kg/m^2 and specific surface area of 296m^2/m^3, and a set of perforated pipes.

The secondary sedimentation tank: A reinforced concrete structure is designed with the size of 4.0m × 4.0m × 5.5m. The effective depth, the surface load, the effective volume and the total volume are respectively 3.0m, 1.30m^3/m^2·h, 595m^3 and 650m^3.

Contact oxidation pool: A reinforced concrete structure is designed with the size of 13.75m × 4.0m × 5.5m. The effective depth, the residence time, the effective volume and the total volume are respectively 5.0m, 28.0h, 421.2m^3 and 445m^3. The associated apparatus includes 360 fine bubble aerators with the model of YMB, the semi-soft filler with volume of 413m^3, size of Φ150 × 3500m, density of 3.4kg/m^3, film density of 65kg/m^2 and specific surface area of 296m^2/m^3, a roots blower shared with the contact oxidation pool and a filler bracket.

The third sedimentation tank: A reinforced concrete structure is designed with the size of 5.0m×5.0m×5.5m. The ef-

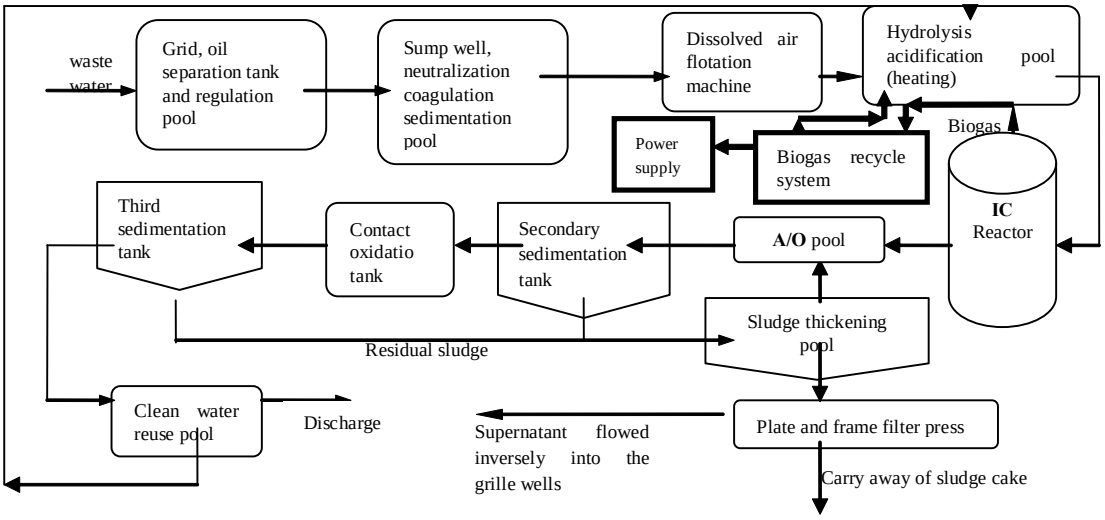

Fig. 1: Sketch of the wastewater process.

fective depth, the surface load, the residence time, the effective volume and the total volume are respectively 2.5m, 0.84m^3/m^2·h, 2.97h, 62.5m^3 and 80m^3. The associated apparatus includes a weir containing weir plate with the size of 0.3m × 0.2m × 20.0m, two sludge pumps with the model of 50F-15 for use and spare to recirculate and discharge, a set of draft tube with the size of φ 0.30 × 3.0m, a set of dosing device with the volume of 1.5m^3 for calcium hypochlorite containing a dosing pump and a dosing flow meter.

Clean water reuse pool: A reinforced concrete structure is designed with the size of 18.0m × 2.6m × 5.5m. The effective depth, the residence time, the effective volume and the total volume are respectively 4.5m, 10.0h, 210m^3 and 247m^3.

Sludge thickening tank: A reinforced concrete structure was designed with the size of 6.0m × 4.0m × 5.5m. The main associated apparatus includes two screw pumps with the model of G40-1 for use and spare, plate and frame filter press with the model of X^A_MYJ40/800-U^B_K and filtering area of 40.0m^2.

Comprehensive workshop: The workshop is a brick-concrete structure on the ground with the size of 15.0m × 4.0m × 2.8m. The roof is cast *in-situ*, internal scrapped with porcelain and outer coated with emulsion paint.

ENGINEERING OPERATION

Engineering Commissioning

Neutralization, coagulation, sedimentation pool: The method of adding lime for neutralization reaction is adopted in the process. Adjusting the pH value to 8-9 ensures the sulphate ion concentration below 2000mg/L. Only when the concentration of sulphate ion in wastewater is below 1500 mg/L, the run of IC reactor cannot be impacted on. To reduce the concentration of sulphate ion, the method of external back flow of the wastewater is used, i.e., wastewater in the clear water tank flows into the hydrolysis acidification tank.

Flotation tank: Part of dissolved air flotation takes place in the flotation tank with the processing capacity of 30t/h. The flotation tank aims to ensure the SS concentration below 50mg/L and the oil concentration below 10mg/L.

IC reactor: The IC reactor system consists of two parts, i.e., proposed hydrolysis acidification pool and the IC reaction tower. The heating device is arranged in hydrolysis acidification tank to maintain the water temperature at 35°C and to ensure the removal efficiency of COD in IC reaction tower. After the pretreatment of wastewater in the hydrolysis acidification pool, part of COD is degraded and part of sulphate ions is reduced into H_2S, which thus indirectly reduce the concentration of sulphate ion and ensure the follow-up IC reactor operation.

The operational parameters of IC reactor tower are as follows: pH value of influent is 7.5-9.5, sulphate ion concentration in influent is 1500mg/L, inlet oil concentration in influent is 10mg/L, water temperature is controlled at 35±2°C. In the initial debugging, only the bottom water distributor is enabled. The water distributor on the upper of reflection plate will be enabled until the stable operation. To improve the treatment effect of IC reactor and shorten the time of granular sludge production, at early stage of debugging the method of dosing diatomite is adopted. The digested sludge of city sewage treatment plant is inoculated in IC reactor, the amount of which is 200 tons containing about 80% water. As the influent remains unchanged, IC reactor

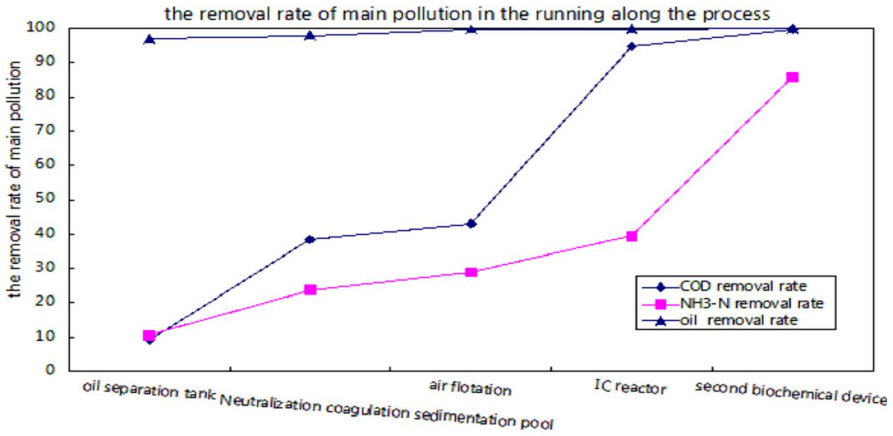

Fig. 2: The removal rate of main pollution in the running along the process.

proceeds strictly according to the given water load increments. In other words, if the load is 2000mg/L in the beginning and the load increases by 500mg/L every 10 days, 10 months later the effective load will achieve 15,000-20,000 mg/L (Gu et al. 2013). The removal rate of COD can be maintained about 90%, the effluent VFA stabilized at 260-300 mg/L and pH value kept at 7-8.

A/O contact oxidation: The two-step biochemical treatment is adopted. The first biochemical treatment is the activated sludge process with plug flows. The high concentration of MLVSS is used to treat IC tower outlet. The sludge concentration reaches about 5000mg/L. After the first biochemical treatment, the COD removal rate reaches 70%. Before the second biochemical treatment, the COD concentration is below 600mg/L. The contact oxidation method is used in the second biochemical process for the organic matter degradation by bio-membrane. The COD concentration in the treated wastewater maintains below 100mg/L. In the first biochemical treatment, the concentration of ammonia-nitrogen is only 20-30mg/L, and total phosphorus is 1-1.5mg/L. The ratio of COD:N:P is lower than that (100:5:1) of the nutrient sludge. So urea and mono-sodium phosphate are added in the process to improve the concentration of N and P, which ensures the growth and reproduction of sludge and the removal of organic matter.

Operation Effects

The average water quality data in the period from May of 2013 to December of 2013 is listed in Table 2, which shows that all indexes can meet the First Grade Standard of GB8978-1996.

Fig. 2 shows the removal rate of COD, NH_3-N and oil in

Table 2: Average water quality of the actual running along the process (2013.05-2013.12).

Item	Oil separation tank		Neutralization coagulation	Air flotation	IC reactor	Second biochemical
	Influent	Effluent	sedimentation pool effluent	pool effluent	effluent	device effluent
COD (mg/L)	32500	29500	20000	18500	1750	95
NH_3-N (mg/L)	95	85	72.5	67.5	57.5	13.5
Oil (mg/L)	2800	90	60	10	6.5	5.5
pH	1.5	4.5	8	7.5	7.5	7.5
Chroma	500	500	350	300	30	15

Table 3: Economic benefits analysis of wastewater treatment project.

Item		Fees(RMB/d)	Fees(RMB/a)	Note
Running costs	Electricity bills	369	787,150	Assuming that the project runs 350 days annually. Biogas boiler of 1 ton capacity produces about 10m^3/d steam of pressure 0.8Mpa, a cubic meters of steam is about 260 RMB. 45kW generating units are used.
	Agent fees	1,480		
	Labour costs	400		
Biogas profits	Steam power	2600	1, 212,400	
		864		
Total profits			424,250	Biogas profits minus running costs

the running along the process including oil separation tank, neutralization coagulation tank, flotation tank, IC reactor and second biochemical device. The removal rate of COD and NH_3-N is enhanced due to the function of IC reactor and the second biochemical treatment. The oil is removed remarkably in the oil separation tank.

BENEFIT ANALYSIS

The running costs of wastewater treatment project include electricity bills, agent fees and labour costs. The annual benefit of 424, 250 RMB comes from the use of biogas generating steam and power. Specific analysis is given in Table 3.

CONCLUSIONS

The oil wastewater treatment technology using IC and two-step biochemical process achieves the stable effluent and convenient operation or management. The removal rate of COD, ammonia-nitrogen and oil was respectively 99.7%, 85.8% and 99.8%. The water quality can reach GB8978-1996 level standard. Meantime the clean secondary energy biogas can be produced in the process for the power generation and the boiler to generate steam, which generates 424, 250 RMB economic profits annually in the minus sewage treatment station running costs. Therefore, the process is of good technicality and economy.

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