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The Tolerance of Anoxic-Oxic (A/O) Process for the Changing of Refractory Organics in Electroplating Wastewater: Performance, Optimization and Microbial Characteristics

Jingsi Gao ^{1,†}, Chongsen Duan ^{2,†}, Xiao Huang ^{2,*}, Jianghua Yu ², Zhen Cao ¹ and Jia Zhu ^{1,*}

- ¹ Department of Architecture and Environment, Shenzhen Polytechnic, Shenzhen 518055, China; gaojingsi@szpt.edu.cn (J.G.); 20181213044@nuist.edu.cn (Z.C.)
- ² Collaborative Innovation Center of Atmospheric Environment and Equipment Technology, Jiangsu Key Laboratory of Atmospheric Environment Monitoring and Pollution Control, School of Environmental Science and Engineering, Nanjing University of Information Science & Technology, Nanjing 210044, China; 20191213025@nuist.edu.cn (C.D.); 002399@nuist.edu.cn (J.Y.)
- * Correspondence: 003199@nuist.edu.cn (X.H.); zhujia@szpt.edu.cn (J.Z.)
- + These authors contributed equally to this work.



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Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). **Abstract:** In order to investigate the tolerance of an anoxic-oxic (A/O) process for the changing of refractory organics in electroplating wastewater, optimize the technological parameters, and reveal the microbial characteristics, a pilot-scale A/O process was carried out and the microbial community composition was analyzed by high-throughput sequencing. The results indicated that a better tolerance was achieved for sodium dodecyl benzene sulfonate, and the removal efficiencies of organic matter, ammonia nitrogen (NH₄⁺-N), and total nitrogen (TN) were 82.87%, 66.47%, and 53.28% with the optimum hydraulic retention time (HRT), internal circulation and dissolved oxygen (DO) was 12 h, 200% and 2–3 mg/L, respectively. Additionally, high-throughput sequencing results demonstrated that Proteobacteria and Bacteroidetes were the dominant bacteria phylum, and the diversity of the microbial community in the stable-state period was richer than that in the start-up period.

Keywords: electroplating wastewater; anoxic-oxic (A/O) process; microbial characteristics; operating parameters

1. Introduction

Electroplating wastewater produced by twenty-thousand electroplating factories, referring to the statistics of China forward industry research institute, contains high concentration nutrient and additives such as surfactant, ethylenediaminetetraacetic acid (EDTA) as well as citric acid [1], which harm human health and attracted extensive attention in recent years [2,3]. Matthew et al. found that additives, as emerging contaminant, had a negative impact on the environment and hindered the municipal wastewater treatment process [4]. Accordingly, it is of great necessity to treat electroplating wastewater [5].

Several methods, most notably including electrochemistry [6,7], adsorption [8], and Fenton oxidation [9,10], have been widely utilized before. Among them, metal colloid produced by electrochemistry can be applicable for organics removal [11,12], the functional groups of resin could improve their affinity for organic [12,13] and numerous free radicals generated by Fenton oxidation could degrade complex organics [14,15]. Meanwhile, these processes require high costs, restricting their application, and more importantly, are not effective for nitrogen treatment. Thus, the biological treatment process is equivalent to nitrogen and organic matter removal, and possesses huge economic and environmental advantages compared with other methods [16,17].

For reaching the discharge standard of electroplating wastewater, the anoxic-oxic (A/O) process is an effective treatment process, and the ammonia nitrogen (NH₄⁺-N) removal rate exceeded 80% and 95% with the influent concentration was about 40–90

and 13–20 mg/L, respectively by a two-stage anoxic-oxic (A/O) process [18,19]. However, refractory organic matter has great influence on biological systems (toxic to microorganisms and inhibits enzyme activity) [20]. Sodium dodecyl benzene sulfonate used as a common anionic surfactant in electroplating wastewater should be investigated to discuss the adoptive of A/O process for the changing of refractory organics pollutant concentrations.

Meanwhile, microbial action is the core for the A/O process to treat electroplating wastewater. Previous studies found that microorganisms mainly involve Proteobacteria, Bacteroidetes, Acidobacteria, Chlorobi, Ignavibacteriae, and Nitrospirae [19,21]. Nevertheless, because a variety of toxic substances of electroplating wastewater could result in the huge change of types and characteristics of sludge, few studies have focused on the changes of microorganisms in A/O process with the changes of refractory organics pollutant concentrations [22,23]. Hence, discussing the changes in microorganisms before and after adding refractory organic pollutant concentrations is necessary for revealing the degradation mechanism of pollutants in electroplating wastewater.

Therefore, the possibility of treating chemical oxygen demand (COD) and nitrogen in electroplating wastewater using the A/O process was discussed, and the effects of hydraulic retention time (HRT), internal circulation, and dissolved oxygen (DO) concentration on the whole system were optimized. The microbial community composition in two compartments during start-up and steady state periods was analyzed by using highthroughput technology. This study provided a high cost-effective treatment method and theoretical support for electroplating wastewater treatment.

2. Materials and Methods

2.1. Experimental Devices of A/O Process

As shown in Figure 1, a pilot-scale A/O system was constructed, and a 20 L pretreated water tank was designed before the anoxic unit to stabilize the operation of the system. The wastewater flowed from pretreated water tank to A/O process for treatment. The A/O process was made of plexiglass, and the overall size was $L \times W \times H = 800 \times 200 \times 375$ mm, and the effective volume was 60 L. To be specific, the effective volume of the anoxic unit was 15 L and a mixer was set up inside it, and the effective volume of the oxic unit was 45 L, and four aerators were placed symmetrically at the bottom of this unit.



Figure 1. Structure diagram of the A/O system.

The experimental operation period includes the start-up (the first 60 d) and the stablestate periods (60–90 d). Mixed liquor suspended solids concentration (MLSS) of the system was controlled at about 3200 mg/L, the sludge reflux was 100%, and the stirrer speed in the anoxic unit was 150 r min⁻¹.

2.2. Characteristics of Seed Sludge and Electroplating Wastewater

The seed sludge used in this experiment was collected from the secondary sedimentation tank of an electroplating wastewater treatment plant (Shenzhen, China). It was settled until the sludge concentration was 7500–8000 mg/L. The supernatant was removed and then fresh sludge was sent to the laboratory in cold storage. In order to restore the nitrification activity of the sludge, the aeration process was carried out for 2 h and then domestic sewage was regularly supplied.

According to the water quality of electroplating wastewater selected from the abovementioned plant, the main characteristics of simulated electroplating wastewater are shown in Table 1.

Table 1. Main characteristics of raw wastewater.

Parameter	Range	Average
COD/(mg/L)	300~340	305
$NH_4^+-N/(mg/L)$	14.23~16.65	15.24
Total phosphorus (TP)/mg/L)	3~4	3.5
Suspend Soils (SS)/(mg/L)	8~10	9
pH	7~8	7.5

2.3. The Process of Start-Up and Optimiastion

The start-up process was as follows. With the purpose of avoiding a whole system crash and obtaining the best treatment effect on simulated water, the method of gradually improving the concentration of sodium dodecyl benzene sulfonate in pretreated water was employed. To be specific, the volume ratios of prepared water and simulated water were 50:1, 25:1, 12.5:1, 8:1, 6.12:1, and 5:1 under the conditions that the total COD of pretreated water was retained at 300 mg/L. Meanwhile, the system was kept in operation for 10 d at each concentration gradient, and the variation of effluent quality in pretreated water was observed under different concentration gradients to use for further analysis. Furthermore, five parameters were set during start-up operation: the HRT was controlled to 12 h, the internal circulation ratio was adjusted to 200%, the sludge return ratio was maintained at 100%, the DO concentration in the oxic unit was retained at 2–3 mg L⁻¹, and the rate of influent flow was 0.12 m³/d.

The process of optimization was as follows. So as to study the effect of the A/O system on organic matter and nitrogen removal under different conditions, HRT, internal circulation ratio, and DO of the oxic unit were optimized after stable-state periods. The HRT was 8, 10, 12, and 15 h, the internal circulation proportion was 100%, 200%, and 300%, the DO concentration was 1–2, 2–3, and 3–4 mg/L.

In the whole operation phase, the others parameters were as follows in Table 2.

Table 2. Main operation characteristics of the A/O process.

Parameter	Anoxic Unit	Oxic Unit
рН	7.43	7.12
Oxidation-reduction potential (ORP)/mV	-114	45

2.4. Chemical Analytical Methods

Samples were collected from the effluent of pretreated water and secondary sedimentation tanks at a frequency of 2 d, and the detection methods for MLSS, COD, NH_4^+ -N, and TN, suspend soils (SS), pH, and oxidation-reduction potential (ORP) were determined from standard protocol of State Environmental Protection Administration of China (SEPA, 2002). Three repetitions were carried out for each measurement test, and the average value was taken to analyze the conclusion.

2.5. Microbiological Analytical Methods

Four sludge samples were gathered from the central area of the anoxic and oxic units before adding sodium dodecyl benzene sulfonate and the end of stable-state operation periods. All samples were placed in a refrigerated laboratory before DNA extraction. A polymerase chain reaction (PCR) instrument (9700, GeneAmp[®]ABI, New York, NY, USA) was used for the polymerase chain reaction (PCR) program [16], using primers 338F and 806R for amplification.

The amplified PCR products were sequenced using the double-ended sequencing (paired end) method and the small fragment library was constructed on *Illumina MiSeq PlantForm* from Majorbio (Shanghai, China). Amplified PCR products were sequenced using the double-end method and a small fragment library was constructed with Illumina MiSeq PlantForm from Majorbio (Shanghai, China). Using CASAVA base recognition analysis can transform the original sequence in the original image data file to keep it in the FASTQ file, and obtain the richness and diversity of the microbial community such as Chao 1 index and Simpson index through correction by Mothur. After the steps above were completed, the sequence is divided into operational taxonomic units (OUTs) with a similarity level of 97%.

2.6. Statistical Analysis

The above indicators were to be sampled in three groups, the average values were calculated and displayed in diagram. The Origin 2018 software was introduced for drawing figures.

3. Results and Discussion

3.1. Setup of A/O Process

3.1.1. COD Removal Performance

The COD removal performance in the entire experimental period (90 d) is demonstrated in Figure 2 and the start-up process expended 60 d to reach a steady state. During the entirety of the operation phase, the average concentration of influent COD (the effluent of pretreated water) was maintained at 300 mg/L while the effluent COD concentration (mean value was 36 mg/L) in the start-up and steady-up periods was far lower than the standard limit (80 mg/L) of electroplating pollutant discharge standard of China (GB21900-2008), with the removal rate ranging from 85% to 90%. In addition, continuously improving the concentration of refractory organic pollutants in influent resulted in the effluent COD concentration gradually increased, and then stabilized at around 55 mg/L between the 52–60th day. Especially after the 25:1 operating mode, the sharp increase of effluent COD indicated that the whole A/O system has a certain tolerance limit for the refractory organic pollutants. This phenomenon was caused by the increasing toxic effect of sodium dodecyl benzene sulfonate on bacteria [24]. Accordingly, the operation mode of 25:1 was chosen in the stable-state operation period, and the effluent water quality was always better in the long run operation period.

3.1.2. Nitrogen Removal Performance

With respect to the removal performance of NH_4^+ -N and TN in the A/O system during the entire setup period are manifested in Figures 3 and 4. Because NH_4^+ -N is the main component of TN (about 97–98%) [25], the curve of TN removal efficiency was similar to that of NH_4^+ -N. It showed that NH_4^+ -N and TN removal efficiency displayed a decreasing trend in the initial start-up period and reached stability until the 50th day. However, the removal efficiency has been increasing during the stable-state period, reaching up to 80% in 90 d, the average effluent concentration of NH_4^+ -N and TN was 5 mg/L, lower than the discharge standard of 15 and 20 mg/L, respectively. Higher concentration of refractory organic matter resulted in higher toxic effect on nitrifying bacteria, which contributed to descent in the degradation rate of nitrogen removal efficiency during the start-up period [26]. In addition, a high concentration of poisonous organic matter resulted in the inhabitation of nitrifying bacteria, which also limited the nitrification and resulted in the accumulation of NH_4^+ -N. Therefore, the removal efficiency of NH_4^+ -N and TN began to show an upward trend.



Figure 2. COD removal performance of the A/O system.



Figure 3. NH₄⁺-N removal performance of the A/O system.



Figure 4. TN removal performance of the A/O system.

3.2. Optimization of Operation Parameters of A/O Process

3.2.1. HRT

As shown in Table 3, three HRT of 15, 12, and 8 h were selected to study the removal efficiency of pollutants in this study, and the internal recycle ratio and DO of different HRT were 200% and 2–3 mg/L. With the extension of HRT, the removal efficiency of COD gradually increased, but the increasing trend slowed down. Likewise, the change trends of NH4⁺-N and TN removal rate were similar to the COD under different HRT. This can be explained by the longer HRT, the greater exposure of the microorganisms to the organics in the electroplating wastewater, and it becoming easier to metabolize the organic matter in the wastewater [27]. However, long HRT will cause the increase of process cost (such as excessive land area and energy consumption). When HRT was 12 h, the concentration of COD in the effluent was 44 mg/L, which not only owned a high pollutant removal efficiency, but also met the relevant pollutant discharge standards. Besides, as HRT were from 8 to 15 h, the removal rates of NH4⁺-N and TN were from 39.46% and 27.17% to 76.71% to 76.26%, respectively, and the concentrations of NH4⁺-N and TN in effluent met the discharge standards. Considering the combined effect of cost and benefit, the HRT was selected as 12 h.

Table 3. The removal performance of COD, NH_4^+ -N, and TN in the A/O process at different operation parameters and discharge limits in China.

		COD			NH4 ⁺ -N			TN		
Parameter/Discharge Limit		Influent (mg/L)	Effluent (mg/L)	Removal Efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency (%)	Influent (mg/L)	Effluent (mg/L)	Removal Efficiency (%)
	15	308	28	90.91	15.67	3.65	76.71	15.67	3.72	76.26
LIDT (b)	12	314	44	85.99	15.23	4.87	68.02	15.23	5.18	65.99
FIKI (II)	10	310	79	74.52	14.96	6.42	57.09	14.96	7.05	52.87
	8	315	115	63.49	15.46	9.36	39.46	15.46	11.26	27.17
Internal recycle ratio (%)	100	318	68	78.62	14.02	7.62	45.65	14.02	8.74	37.66
,	200	324	49	84.88	13.88	4.83	65.20	13.88	5.21	62.46
	300	306	46	84.97	13.73	4.76	65.33	13.73	5.04	63.29
DO (mg/L)	1–2	302	78	74.17	14.32	7.64	46.65	14.32	9.23	35.54
	2–3	321	55	82.87	13.87	4.65	66.47	13.87	6.48	53.28
	3–4	317	54	82.96	14.05	4.34	69.11	14.05	6.64	52.74
GB21900-2008 of China			80			15			20	

3.2.2. Internal Recycle Ratio

The internal circulation ratio is also an important factor affecting pollutant removal [28]. The higher the internal circulation ratio, the better the removal effect of pollutants and the higher the operating cost [29]. Besides, the other parameters in this section were as follows: HRT were retained at 12 h and DO were maintained 2–3 mg/L. As the internal circulation ratio was 200%, the effluent concentrations of COD, NH₄+-N, and TN (49, 4.83, 5.21 mg/L) reached the discharge standard with the removal efficiencies of 84.88%, 65.20%, and 62.46%, respectively. The effluent concentrations of COD and TN were far within the discharge standard level, while the value of NH₄⁺-N discharge was close to the limit in the discharge standard of electroplating wastewater in the conditions of 100% internal circulation ratio. Meanwhile, the proportion of internal circulation was too high to keep the environment of the anoxic unit in an anoxic environment at the internal recycling rate of 300%, which resulted in the reduction of the nitrogen removal rate and it is consistent with the study by Peng et al. [30]. In summary, the optimal operating process was selected with an internal circulation ratio of 200%.

3.2.3. DO

The optimization results of DO (HRT and internal circulation ratio were the best conditions) are also compiled in Table 3. Under the above optimal conditions, the corresponding COD removal rates for DO concentrations of 1–2, 2–3, and 3–4 mg/L were 74.17%, 82.87% and 82.96%, respectively. It is evident that the removal rate of COD increased with the raise of DO concentration, and the subsequent removal efficiency increased more slowly. Due to the excess DO potentially raising the operation cost of this process, so the DO concentration was controlled at 2–3 mg/L. Under these conditions, the corresponding NH_4^+ -N and TN effluent concentrations were 4.65 and 6.48 mg/L respectively, which had reached the discharge standard. When the DO concentration was 3–4 mg/L, the excessive DO in the oxic unit was transported to the anoxic unit which damaged the growth and reproduction environment of denitrifying bacteria and thus affected the operating results of the system [31].

3.3. *Characteristics of Microbial Community during Process Startup and Operation* 3.3.1. Richness and Diversity

The richness and diversity of the microbial community are demonstrated in Table 4. A total of 158,197 effective sequence reads (45,236, 42,323, 35,847, and 34,791 for A1, O1, A2, and O2, respectively, in Table 3) were obtained from activated sludge samples in the whole periods by using Illumina MiSeq plantform.

Table 4. Bacterial richness and diversity of four samples. (A1: anoxic unit before refractory organics addition; A2: anoxic unit after refractory organics addition; O1: oxic unit before refractory organics addition; O2: oxic unit after refractory organics addition).

Sample	Reads	OTU	Chao1	Simpson
A1	45236	45236	429.7	0.0848
O1	42323	42323	434.8	0.0808
A2	35847	35847	413.1	0.0768
O2	34791	34791	437.8	0.0691

Chao1 (Table 4) is an essential indicator of the richness of the microbial community; to be specific, they are positively correlated [25]. Microorganism in four samples showed a similar richness from 410 to 440, and the oxic unit (O1, O2) appeared to be the highest, i.e., 434.8 and 437.8 for Chao1 index, respectively. This conclusion is consistent with Kim et al. [32]. It is interesting that the biological diversity of microbial populations at the end of the stable-state period was lower than that of pre-cultured populations. This may be because the increasing number of refractory organic pollutants in the influent has a certain degree of inhibition on microbial reproduction and growth, as well as the slow growth of microorganisms adapted to the electroplating wastewater.

The Simpson index (Table 4) could be used to estimate the microbial community biodiversity. The higher the Simpson index, the higher the diversity of the microbial community biodiversity. It was obvious that this conclusion was basically in accordance with Chao 1 (Table 4).

3.3.2. Community Composition

Figure 5A shows the relative abundance of phylum in different compartments before and after acclimation. Obviously, Proteobacteria is the main phyla with the relative abundance of 72.63% (A1), 67.77% (O1), 54.14% (A2), and 52.72% (O2). A similar conclusion was reached by Gao et al. [32] and Wang et al. [33], whose research found that Proteobacteria was the most abundant in sludge. Bacteroidetes (20.31%–37.93%) and Chloroflexi (2.17%–5.47%) were the most dominant phylum behind Proteobacteria where this study was similar to the other researches [34]. The phylum like Actinobacteria, Patescibacteria, Spirochaetes, Firmicutes, Gemmatimonadetes, Chloroflexi, and Nitrospirae were minor communities, accounting for less than 5% in all units.





The relative abundance of microorganisms in the anoxic unit changed before and after domestication was depicted in Figure 5A. The result showed that the microbial diversity of A2 was higher than that of A1. The relative abundance of Bacteroidetes of A1 increased from 20.31% to 37.93%, which may be due to the key role of Bacteroidetes, as a kind of hydrolytic and fermentative bacteria, in the degradation of refractory organic pollutants of electroplating wastewater [35]. In addition, electroplating wastewater contains nitrogen, so Nitrospirae (0.99%) and Planctomycetes (0.99%) were found in A2, in which Nitrospirae, as a typical nitrifying bacteria [36,37], and Planctomycetes, a typical denitrifying bacteria [38], played an important role in the anammox process [39].

Similarly, Proteobacteria and Bacteroidetes were the dominant microbial populations, with relative abundance levels of 90.59% and 91.44%, which is consistent with conclusions made by Chen et al. [37]. In addition, the relative abundance of microorganisms varied before and after domestication, but the species of microorganisms remained almost unchanged. This indicates that the acclimation process has mainly taken place in the anoxic unit, and the refractory organic pollutants can be transformed into some small molecular compounds or some substances degraded in this region by the microorganism under anoxic conditions [40].

Figure 5B presents the variation of microbial community in different stages. In this study, the relative abundance of dominant genera was *Haliangium*, *Candidatus-Competibacter*, *Flavihumibacter*, and *AAP99*, with the sum relative abundance of 43.43% (A1), 27.09% (O1), 41.92% (A2), and 27.67% (O2). This conclusion was different from Huang et. [25] and Tang et al. [41], whose conclusions that the dominant genera of urban sewage treatment system were Blastocatella, *Flavobacterium*, *Meiothermus* and *Pseudomonons*. Additionally, the genus of *Ferriuginibacter*, *Hyphomicrobium*, and *Ldeonella* took up less than 5%.

Among them, *Haliangium* [42] and *Candidatus-Competibacter* [43,44] are dominant nitrification-denritrification functional genera. However, the toxic effect of refractory organic matter led to a decline in relative abundance, which explained the decrease of pollutant removal efficiency during the start-up operation period. The subsequent increase in the relative abundance of unassigned genera is most likely the reason for the increased removal efficiency of pollutants during the stable operating period. Besides, the key functional microorganisms related to nitrification-denritrification in two compartments also include *Lysobacter* [45], *Dechloromonas* [46,47], *Piscinibacter* [48], and *Geothrix* [49]. The above-mentioned microorganisms ensure the performance of nitrogen and carbon removal of the A/O process.

It is interesting that the microbial genus levels of the two functional units remained basically unchanged, but their relative abundance levels changed. This may be because the seed sludge contained a diversity of microorganisms, and the acclimation process only affects the microbial phylum level. However, the dominant genera of microbial communities in urban sewage treatment systems are *Chlorella*, *Flavobacterium*, and *Pseudomonas* [25,41]; the main genus of aquaculture chemical wastewater is Lactococcus, sulfonylureas and Bacillus [50]. Therefore, the type of wastewater is a factor that affects the microbial community.

3.3.3. Functional Microorganism about Nitrogen Removal

To study the core function microorganism at genus level, the changes of related species were investigated (Table 5). The functional microorganisms related to nitrification-denitrification are mainly divided into ammonia oxidizing bacteria (AOB), nitrite-oxidizing bacteria (NOB), and denitrifying bacteria (DNB). Among them, AOB bacteria accounted for the smallest proportion, mainly *Nitrosospira* and *Ellin6067*, which was inconsistent with the research conclusions of Change et al. [51], whose research conclusions pointed out that *Nitrosospira* was a common AOB bacteria genus in sewage treatment plants. This emphasized the role of *Ellin6067* in the treatment of electroplate wastewater. *SWB02* was the most abundant NOB in this study that oxidizes nitrites to nitrates [52] with a relative abundance of 0.71% (A1), 0.66% (A2), 1.41% (O1), and 0.74% (O2), respectively. The denitrifying bacteria headed by *Haliangium, Geothrix,* and *Terrimonas* accounted for the largest proportion, which suggests that the denitrifying bacteria genera had a dominant role in the system, with the sum relative abundances of 36.05% (A1), 45.82% (A2), 34.76% (O1), and 42.82% (O2), and a more stable operation period after abundance than the starting running period.

Very Functional Crowns	Relative Abundance (%)					
Key Functional Groups —		A1	A2	01	O2	
Ammonia oxidizing bacteria (AOB)	Nitrosospira	0.12	0.09	0.15	0.18	
Ŭ	Ellin6067	0.25	0.19	0.16	0.15	
	Sum	0.38	0.28	0.31	0.33	
Nitrite-oxidizing bacteria (NOB)	SWB02	0.71	0.64	1.41	0.74	
-	Piscinibacter	1.76	1.37	1.95	1.43	
	Sum	3.47	2.01	3.36	2.17	
Denitrifying bacteria (DNB)	Haliangium	32.33	40.01	30.25	37.37	

Table 5. Functional microorganism about pollutant removal.

Kay Functional Crowns	Relative Abundance (%)					
Key Functional Groups		A1	A2	01	O2	
	Geothrix	1.24	2.86	2.01	2.35	
	Terrimonas	0.54	1.95	0.57	1.71	
	Hyphomicrobiu	0.41	0.67	0.36	0.87	
	Ferruginibacter	0.35	0.93	0.37	0.89	
	Ideonella	0.40	0.26	0.45	0.26	
	Limnobacter	0.39	0.17	0.30	0.20	
	Propionivibrio	0.25	0.29	0.21	0.25	
	Paracoccus	0.27	0.16	0.20	0.18	
	Desulfomicrobium	0.15	0.32	0.25	0.19	
	Paludibaculum	0.13	0.07	0.29	0.20	
	Thauera	0.04	0.01	0.04	0.03	
	Denitratisoma	0.06	0.04	0.02	0.02	
	Bdellovibrio	0.11	0.11	0.10	0.12	
	Sphingopyxis	0.12	0.09	0.11	0.11	
	Defluviicoccus	0.08	0.11	0.07	0.27	
	SM1A02	0.09	0.08	0.11	0.09	
	Pelomonas	0.05	0.11	0.13	0.10	
	Faecalibacterium	0.08	0.12	0.06	0.09	
	Ottowia	0.12	0.05	0.06	0.05	
	Defluviimonas	0.08	0.10	0.07	0.06	
	Stella	0.08	0.06	0.09	0.08	
	Acidovorax	0.09	0.04	0.08	0.05	
	Comamonas	0.07	0.06	0.06	0.05	
	Thermomonas	0.05	0.03	0.10	0.05	
	Fodinicola	0.03	0.07	0.06	0.05	
	Methyloversatilis	0.03	0.06	0.06	0.07	
	Hydrogenophilaceae	0.03	0.03	0.02	0.03	
	Sum	37.67	48.85	36.49	45.78	

Table 5. Cont.

4. Conclusions

The A/O process in this paper has a high ability to remove electroplating wastewater, and better tolerance was achieved for sodium dodecyl benzene sulfonate. When the optimal HRT, internal circulation, and DO were 12 h, 200%, and 2–3 mg/L, the removal efficiency of COD, NH_4^+ -N, and TN was 82.87%, 66.47%, and 53.28%, respectively. Proteobacteria and Bacteroides were the dominant bacteria phyla and *Haliangium* was the leading bacteria genus, which degraded the nitrogen in electroplating wastewater.

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