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Biological removal of cyanide compounds from electroplating wastewater (EPWW) by sequencing batch reactor (SBR) system

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Abstract

Biological treatment system especially, sequencing batch reactor (SBR) system could not be applied to treat the raw electroplating wastewater (EPWW) due to the low organic matter concentration of 10 ± 3 mg-BOD_5/L and toxic of high cyanide concentration of 23.0 ± 2.2 mg-CN/L. However, EPWW could be used as the nitrogen source for the bio-sludge of SBR system. And 10% of EPWW (the final cyanide concentration of 2.3 ± 0.2 mg/L) was most suitable to supplement into the wastewater as the nitrogen source. SBR system showed the highest COD, BOD_5, TKN and cyanide removal efficiencies of $79 \pm 2\%$, $85 \pm 3\%$, $49.0 \pm 2.1\%$ and $97.7 \pm 0.7\%$, respectively with 4-times diluted Thai-rice noodle wastewater (TRNWW) containing 10% EPWW and 138 mg/L NH_4Cl (BOD_5: TN of 100:10) at SRT of 72 ± 13 days (under organic and cyanide loadings of 0.40 kg-BOD_5/m^3 d and 0.0023 kg-CN/m^3 d, respectively). However, the effluent ammonia was still high of 22.6 ± 0.4 mg-N/L while the effluent nitrate and nitrite was only 9.9 ± 0.4 and 1.2 ± 0.9 mg-N/L, respectively. And SVI and effluent SS of the system were higher than 95 and 75 mg/L, respectively.

Keywords: Biological removal of cyanide; Cyanide; Electroplating wastewater; Environmental; Sequencing batch reactor (SBR); Treatment

1. Introduction

Many industries such as photo-processing, electroplating, gold mining and chemical-fertilizer generate large amount of wastewater containing high concentration of cyanide and cyanate compounds as serious hazardous substances due to their strong effects on both the environment and human [1–6]. The chemical treatment processes, especially, chemical oxidation and coagulation are common use and suitable to treat above wastewater due to the high concentration of cyanide compounds, but they produced large amount of hazardous sludge. Several researchers tried to apply the biological process to remove or degrade cyanide compounds and recover some valuable materials from the wastewaters [2,5,7–12]. For example, the combination of bio-sorption and biodegradation processes was applied for degradation of free and metal complexed cyanides and recover of metals from wastewater [9,10,12]. It is well documented that cyanide compounds at high concentration is toxic to the living organisms in aquatic environments. Many researchers reported that the cyanide compounds could be degraded and utilized by the microorganisms such as fungus and bacteria [9,12,13–18]. But, cyanide compounds at high concentration are toxic to the microorganisms or the bio-sludge of biological treatment system. Anyways, bioremediation of cyanide compounds from above wastewaters is of major importance, as it offers a potential alternative to chemical oxidation (conventional process) for the recovery of the cyanide compounds and using it as the nitrogen source for the bio-sludge of biological treatment system [19–24]. However, the bio-sludge of the biological treatment system required both carbon and nitrogen

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Nomenclature

AS	Activated sludge system
BOD_5	Biochemical Oxygen demand
COD	Chemical Oxygen demand
EPWW	Electroplating wastewater
HRT	Hydraulic retention time
MLSS	Mixed liquor suspended solids
SBR	Sequencing batch reactor
SRT	Solids retention time; Sludge age
SS	Suspended solids
SVI	Sludge volume index
TKN	Total kjeldahl nitrogen

sources for growth [19,22–24]. Then, the concentration of both cyanide and organic matter in the wastewater had to be considered [6,14,19,20,25].

To treat wastewater containing high cyanide concentration and low organic matter (BOD_5) as EPWW by biological wastewater treatment process might be difficult but the cyanide compounds of the EPWW might be used as the nitrogen source for the bio-sludge of the biological treatment process [2,6,19,20]. And the ammonia was the metabolite of the biodegradation of cyanide compounds [6,19,26].

The SBR system is a modified activated sludge (AS) system used in solving the low-density bio-sludge and bulking sludge problems due to the large volume of clarifier [19]. Also, the SBR system can easily be modified for both carbon and nitrogen (especially, cyanide and by-products of bio-degradation of cyanide) removal, with the appropriate operational program. In this study, the biological treatment of EPWW by SBR system was tested. The application of EPWW as the nitrogen source for non-nitrogen compound contained wastewater (both synthetic wastewater and industrial wastewater: Thai rice noodle wastewater; Khanom-chin: TRNWW) on the efficiency of SBR system and bio-sludge quality was also studied.

2. Materials and methods

2.1. Wastewater (WW)

Three types of wastewater were used in this study as electroplating wastewater (EPWW), Thai rice noodle wastewater (Khanon-chin: TRNWW) and synthetic wastewater (SWW), were mentioned as follows:

2.1.1. Electroplating wastewater (EPWW)

EPWW was collected from the electroplating factory in Nakhonpathom province, Thailand. The chemical property of this EPWW was shown in Table 1.

2.1.2. Thai rice noodle wastewater (Khanom-chin: TRNWW)

TRNWW was collected from the Thai rice noodle (Khanom-chin) factory in Rajchaburi Province, Thailand. The chemical property of TRNWW was shown in Table 1.

2.1.3. Synthetic wastewater (SWW)

SWW was prepared to have the BOD_5 concentration of 400 mg/L. The chemical composition of SWW was shown in Table 1. The SWW containing EPWW (SWW-EPWW) was prepared with various concentration of glucose and 10% EPWW. The chemical composition of SWW-EPWW was shown in Table 1.

Table 1
Chemical composition and properties of electroplating wastewater (EPWW), Thai-rice noodle (Khanom-chin) wastewater: TRNWW and synthetic wastewater (SWW)

Raw wastewater			Synthetic wastewater			
Chemical properties of raw wastewater			Synthetic wastewater (SWW)[b]		Synthetic wastewater with cyanide (SWWC)	
Parameters	Electroplating wastewater (EPWW)	Thai rice noodle (Khanom-chin: TRN) wastewater	Parameters	Concentration (mg/L)	Parameter	Concentration (mg/L)
COD (mg/L)	516 ± 36	11,791 ± 1133	Glucose (mg/L)	560	Glucose (mg/L)	[c]
BOD_5 (mg/L)	10 ± 3	8398 ± 1117	NH_4Cl (mg/L)	153	Urea (mg/L)	153
pH	12.5 ± 0.4	5.5 ± 0.2	$FeCl_2$ (mg/L)	3.5	$FeCl_2$ (mg/L)	3.5
Cyanide as mg CN/L	23.0 ± 2.2	ND[a]	$NaHCO_3$ (mg/L)	65	$NaHCO_3$ (mg/L)	65
Cyanide as mg N/L	13.0 ± 0.0	ND[a]	KH_2PO_4 (mg/L)	6	KH_2PO_4 (mg/L)	6
TKN (mg/L)	25.0 ± 1.2	ND[a]	$MgSO_4.7H_2O$ (mg/L)	1.3	$MgSO_4.7H_2O$ (mg/L)	1.3
NH_4^+ (mg/L)	4.4 ± 0.3	ND[a]			EPWW (%)	10
NO_2^- (mg/L)	0.03 ± 0.02	0.24 ± 0.02				
NO_3^- (mg/L)	1.96 ± 0.07	ND[a]				
Total nitrogen:TN (mg/L)	39.5 ± 0.3	0.24 ± 0.02				
Cu^{2+} (mg/L)	27.0 ± 0.5	ND[a]				

[a] ND: Non-detective.
[b] SWW containing 400 mg/L BOD_5.
[c] Amount of glucose was varied at 0, 280, 370, 560, 840 and 1120 mg/L.