

# DEGRADATION OF CYANIDE CONTAMINANTS IN CTS BY ALKALI-HEAT CO-ACTIVATED PS: PERFORMANCE AND MECHANISM STUDY

Yunmei Wei\*, Yi Wen, Lianying Chen, and Shuang Chen

Key Laboratory of Three Gorges Reservoir Region's Eco-Environment, Ministry of Education,  
College of Environment and Ecology, Chongqing University, Chongqing, 400045, P.R. China

## ABSTRACT:

Cyanide tailings (CTs) is hazardous waste and must be treated for cyanide degradation to meet the disposal requirements of the "Technical Specification for Pollution Control of Cyanide Leaching Residue in Gold Industry" (HJ 943-2018). Alkali-heat co-activated persulfate (PS) technology, a common Advanced Oxidation Process (AOP), was adopted for cyanide degradation, and the effect of NaOH to PS addition ratio and reaction temperature were emphasized in this study. The results showed that the cyanide removal rate reached 86.3% at conditions of 60°C and NaOH:PS ratio 1:0.5. Leaching concentration of total cyanide after treatment was reduced to 0.2 mg/L, which could meet the requirement of HJ 943-2018.

**KEYWORDS:** Cyanide tailings; Persulfate; Resource recycling; Harmlessness treatment; Advanced oxidation

## 1 INTRODUCTION

CTs, with an annual production of roughly 100 million tons, were recently added to the "National Hazardous Waste List" in China. The cyanide concentration in the leachate of CTs far exceeded the disposal requirements in the "Technical Specifications for the Control of Cyanide Residue Pollution in the Gold Industry" (HJ 943-2018). The high concentration of cyanide in CTs is a key factor contributing to its environmental risk and inhibiting its deep resource utilization. The cyanides in the CTs mainly present as metal-cyanide complexes, and these complexes tend to show a high affinity with the mineral components in the CTs, which makes it difficult to be treated by conventional cyanide destruction methods. In this study, alkali-heat co-activated persulfate (PS) technology was used to decompose the cyanide pollutants in the CTs, in which alkali is used to promote desorption of cyanide from the solid matrix, and consequently the desorbed cyanide species were oxidized by the active species generated by PS activation.

## 2 MATERIAL AND METHODS

Cyanide tailings used in this study were collected from a gold smelter in Shandong, China. Chemical composition of CTs was determined by ARL PERFORM'X X-ray fluorescence spectrometer (XRF). The experimental operation is as follows: 1.00 g of CTs were accurately weighed into a 50 ml centrifuge tube, different masses of sodium persulfate and sodium hydroxide were added so that the mass ratios of sodium hydroxide to sodium persulfate were 0:1, 0.33:1, 0.4:1, 0.5:1, 0.67:1, 1:1. The reaction vessels were placed in a water bath shaker at 60°C during the whole experiment.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Characterization of physical and chemical properties of the CTs

Physical and chemical properties of CTs are shown in Table 1. The leaching concentration of total cyanide was 11.7 mg/L, exceeding the 5 mg/L required in the "Technical Specifications for the Control of Cyanide Residue Pollution in the Gold Industry" (HJ 943-2018). Thus, the target contaminants in this study were total cyanide. Si, Fe, S and Al were the top four elements in CTs, with corresponding amounts of 33.70%, 28.46%, 16.47% and 6.56%. Additionally, the CTs also contains a little amount of K, Ca, Mg, Na, Zn, Pb, Cu, and Mn.

### 3.2 Effect of NaOH:PS ratio on cyanide degradation

Santos et al. [1] found that the activation effect of PS was greatest when the ratio of NaOH to PS was between 0.25:1 and 1:1. The addition ratios of NaOH to PS were studied at 0:1, 0.33:1, 0.4:1, 0.5:1, 0.67:1 and 1:1 at 10% PS dosage and the results are shown in Fig. 1. The highest cyanide removal rate of 86.3% was achieved after 72h when NaOH:PS was 0.67:1. The corresponding removal rates were 17.7%, 71.0%, 52.4%, 46.8% and 5.9% for the addition ratios of 1:1, 0.5:1, 0.4:1, 0.33:1 and 0:1.

### 3.3 Effect of activation temperature on cyanide degradation

The effect of different activation temperatures on cyanide degradation was investigated (NaOH: PS=0.5:1, PS addition =10%) and the results were shown in Fig.2a. When the temperature was 25°C, the cyanide was almost not decomposed. When the temperature was raised to 70 °C, the rate of cyanide elimination rose to 80.1%, indicating that more sulfate radicals were produced from PS as temperature rose[2-3]. From Fig. 2a, we can find

that higher temperature not only promoted cyanide removal but also accelerates the degradation process. By raising the temperature from 25°C to 70°C, the first-order reaction rate constant enhanced from  $1.7\times10^{-5}\text{ min}^{-1}$  to  $1.5\times10^{-3}\text{ min}^{-1}$ .

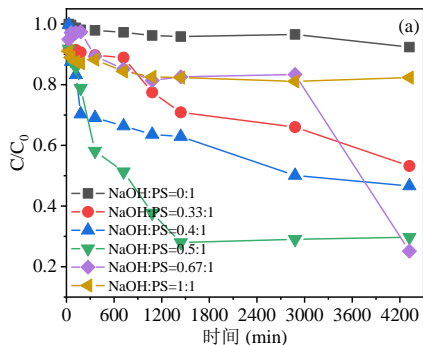


Fig. 1 Effect of NaOH to PS ratio on cyanide degradation

**3.4 Leaching toxicity analysis of treated CTs**

According to the "Technical Specifications for the

Control of Cyanide Residue Pollution in the Gold Industry" (HJ 943-2018), The leaching concentration of total cyanide determined by the national standard leaching method decreased from 11.7 mg/L to 0.2 mg/L after treated by the alkali-heat co-activated persulfate method, which could meet the requirement of 5 mg/L in HJ 943-2018.

#### 4 CONCLUSIONS

In this study, alkali-heat co-activated persulfate was used to degrade cyanide in CTs. The addition ratio of NaOH to PS and temperature had significant effect on cyanide degradation by activated PS. The best cyanide degradation was achieved when the NaOH:PS addition ratio was 0.67:1, with a removal rate of 86.3%. With the increase of activation temperature, the cyanide removal rate could be increased to 80.1%. The leaching concentration of total cyanide decreased from 11.7 mg/L to 0.2 mg/L under optimal conditions, satisfying the toxic leaching requirements of "Technical Specifications for Cyanide Residue Pollution Control in the Gold Industry".

Table 1 Physicochemical properties of cyanide tailings

items	Total cyanide(mg/kg)	WAD-cyanide(mg/kg)	SCN <sup>-</sup> (mg/kg)	pH (1:1.25H <sub>2</sub> O)	Water content (%)	Leaching toxicity of total cyanide (mg/L)
results	1580	16	2899	9.67	19.31	11.7

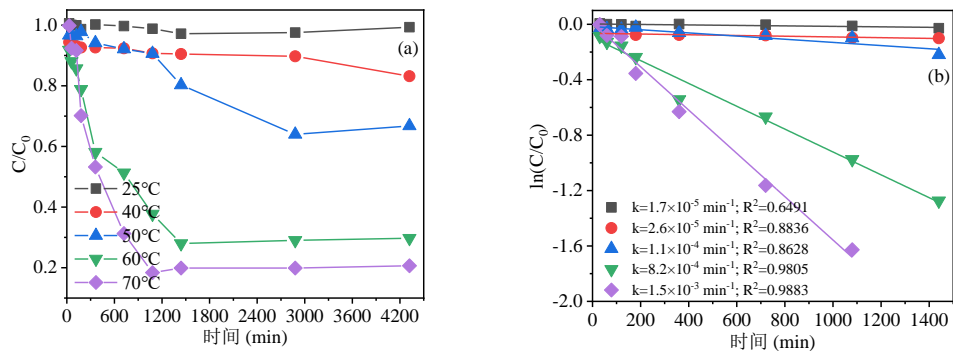


Fig. 2 Effect of different reaction temperatures on cyanide degradation (a) and fitting results by the first-order kinetic model (b). (Experimental conditions: NaOH to PS ratio is 0.5:1, PS dosage is 10%, and L/S ratio is 10:1)

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