

## Article

# Photocatalytic Advanced Oxidation Processes for Neutralizing Free Cyanide in Gold Processing Effluents in Arequipa, Southern Peru

David C. Vuono <sup>1</sup>, Johan Vanneste <sup>1</sup>, Linda A. Figueroa <sup>1</sup>, Vincent Hammer <sup>1</sup>, Fredy N. Aguilar-Huaylla <sup>2</sup>, Aaron Malone <sup>3</sup>, Nicole M. Smith <sup>3</sup>, Pablo A. Garcia-Chevesich <sup>1,4</sup>, Héctor G. Bolaños-Sosa <sup>5</sup>, Francisco D. Alejo-Zapata <sup>6</sup>, Henry G. Polanco-Cornejo <sup>5,\*</sup> and Christopher Bellona <sup>1,\*</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Colorado School of Mines, Golden, CO 80401, USA; dvuono@mines.edu (D.C.V.); vanneste@mines.edu (J.V.); lfiguero@mines.edu (L.A.F.); vhammer@mymail.mines.edu (V.H.); pchevesich@mines.edu (P.A.G.-C.)

<sup>2</sup> School of Metallurgical Engineering, National University of San Agustín, Arequipa 04000, Peru; fredy\_aguilarh@hotmail.com

<sup>3</sup> Department of Mining Engineering, Colorado School of Mines, Golden, CO 80401, USA; amalone@mines.edu (A.M.); nmsmith@mines.edu (N.M.S.)

<sup>4</sup> International Hydrological Program — IHP, UNESCO, 11200 Montevideo, Uruguay

<sup>5</sup> School of Chemistry, National University of San Agustín, Arequipa 04000, Peru; hbolanos@unsa.edu.pe

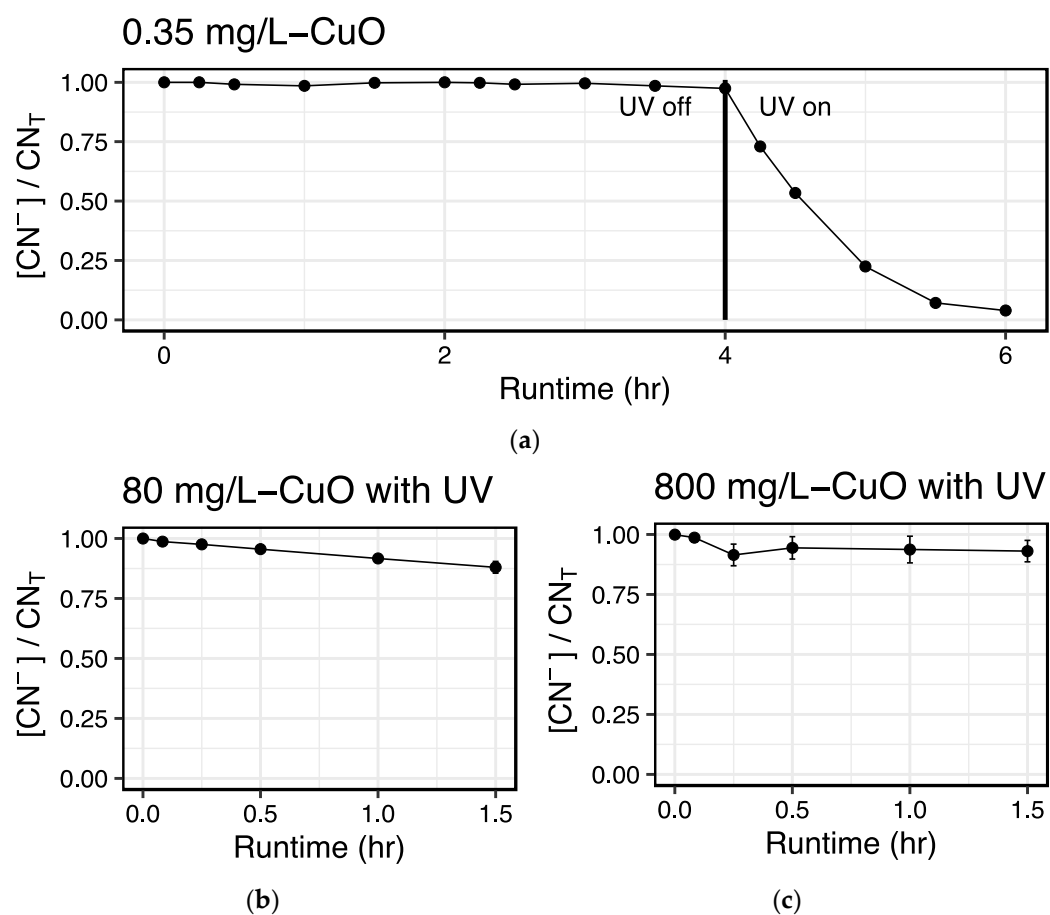
<sup>6</sup> School of Process Engineering, National University of San Agustín, Arequipa 04000, Peru; fa-lejo@unsa.edu.pe

\* Correspondence: hpolancoc@unsa.edu.pe (H.G.P.-C.); cbellona@mines.edu (C.B.); Tel.: +01-303-273-3061 (CB); Tel.: +51-942-503-982 (H.G.P.-C.)

## Supplementary Materials

### SI Results

Copper oxide (CuO) is a known catalyst for cyanide destruction in the presence of peroxide and UV. To test if CuO had an effect on cyanide destruction in real mining wastewater, we conducted experiments with 100 mg/L-CN, dosed with 1:1 ratio of peroxide, UV (254 nm, Lumenor), and at three different CuO concentrations: Low; 0.35 mg/L-CuO, medium; 80 mg/L-CuO, and high; 800 mg/L-CuO. Results show that in the absence of UV (< 4 hrs), CuO and peroxide has no effect on cyanide destruction (Figure S1A). When UV light is turned on (> 4 hrs), cyanide is rapidly destroyed and is attributed solely to the combination of UV and peroxide. When a medium dose of CuO is used, 12% of cyanide is destroyed over a 1.5 hour period (Figure S1B) while only 7% of cyanide is destroyed over 1.5 hour period for the high CuO dose (Figure S1C). These data suggest that UV is being shielded by CuO. For example, the medium CuO treatment likely sees some UV penetration as shown by the steady decrease in cyanide concentration over time. When compared to the high CuO treatment, cyanide concentration decreases within the first 25 minutes, but then remains unchanged for the rest of the experiment, indicating that there is likely no UV penetration into the solution. These results conclude that copper catalyzed destruction of cyanide does not have added destructive effect on overall cyanide concentration.



**Figure S1.** The effect of CuO on cyanide destruction in real mining wastewater, with 100 mg/L-CN, dosed with 1:1 ratio of peroxide, UV (254 nm, Lumenor), and at three different CuO concentrations: (a) Low; 0.35 mg/L-CuO, (b) medium; 80 mg/L-CuO, and (c) high; 800 mg/L-CuO.