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SANTIAGO ANTÚNEZ DE MAYOLO
"Una Nueva Universidad para el Desarrollo"

Tecnologías para la descontaminación de cianuro de los efluentes de pequeñas operaciones mineras

Technologies for the decontamination of cyanide in the effluents of small mining operations



Colorado



- Arequipa

Dr. Christopher Bellona, Dr. Johan Vanneste, Dr. David Vuono, Dr. Linda Figueroa, Vincent Hammer, Inge Delius Cordova

Dr. Francisco Alejo Zapata, Dr. Henry Polanco Cornejo, Dr. Julia Zea Álvarez, Dr. Carlos Zevallos Rojas

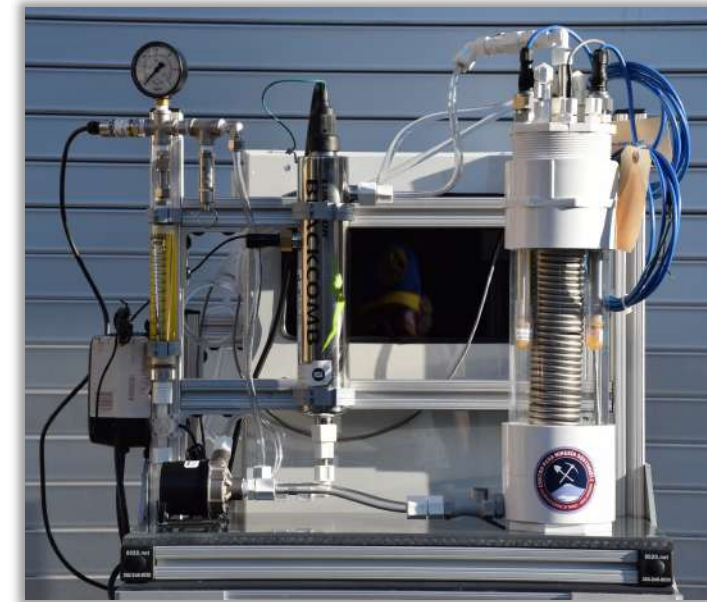
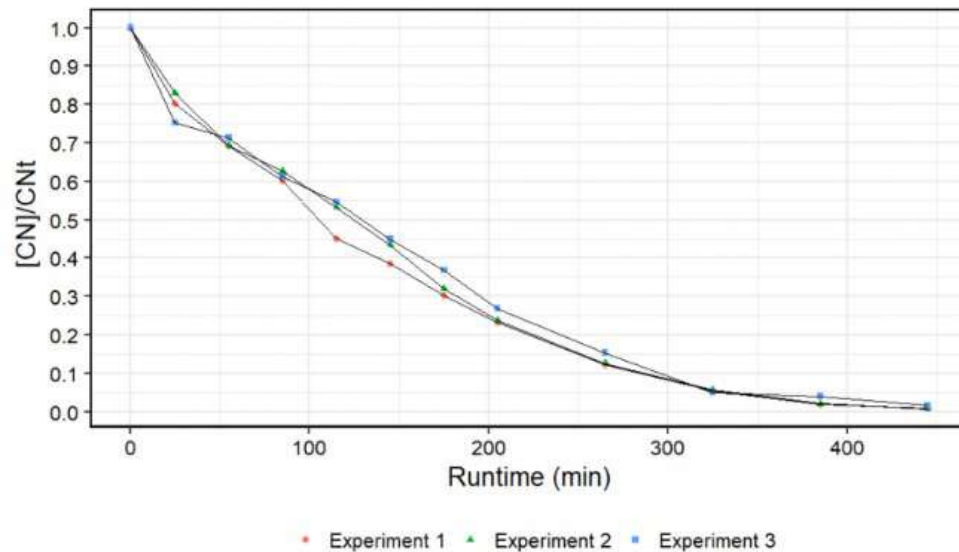
Problem statements and main goals

- **Cyanide is replacing mercury for gold extraction worldwide**
- **Cyanide is toxic and can cause environmental degradation**
- **Low-cost options needed to reduce cyanide consumption and discharges to the environment**

- **The overarching goal of the project was to develop and evaluate methods for improving cyanide management at gold extraction facilities**


Cyanide destruction using advanced oxidation was evaluated in Phase 1

- Advanced oxidation used to destroy cyanide (UV-H₂O₂, UV-TiO₂)
- Collaboration with UNSA resulted in published paper



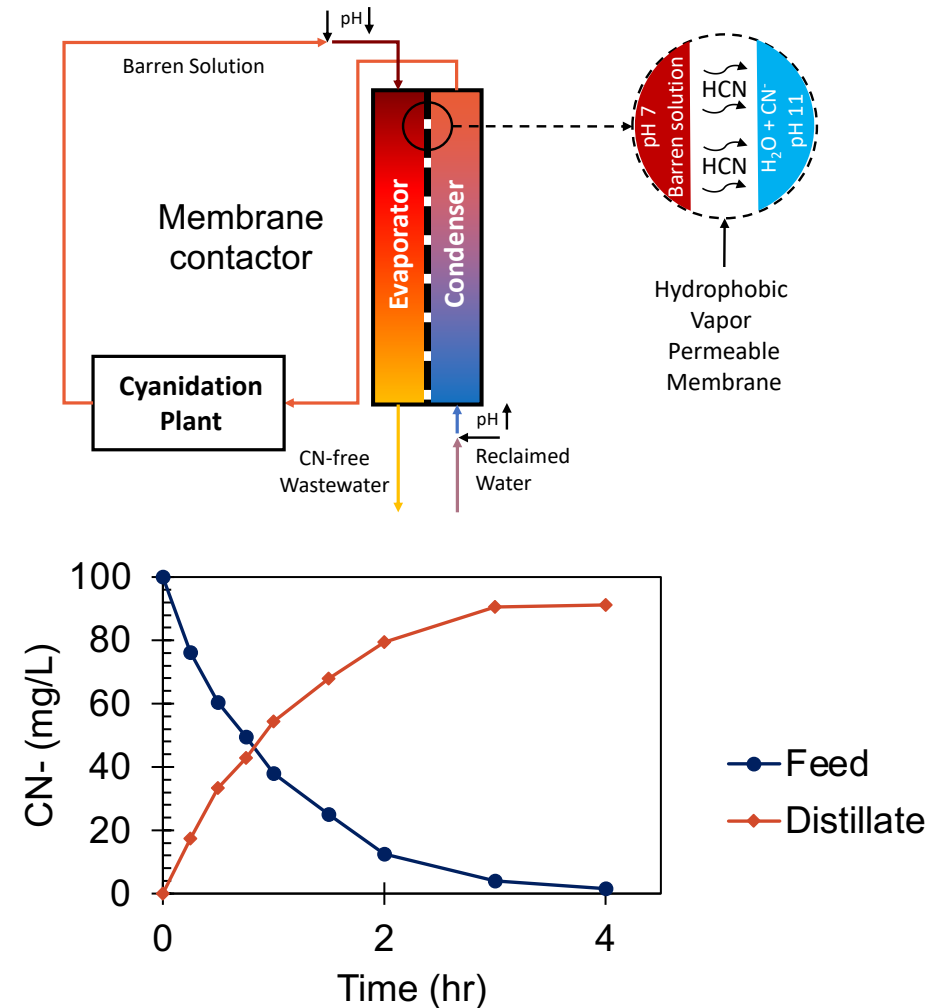
Article

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

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

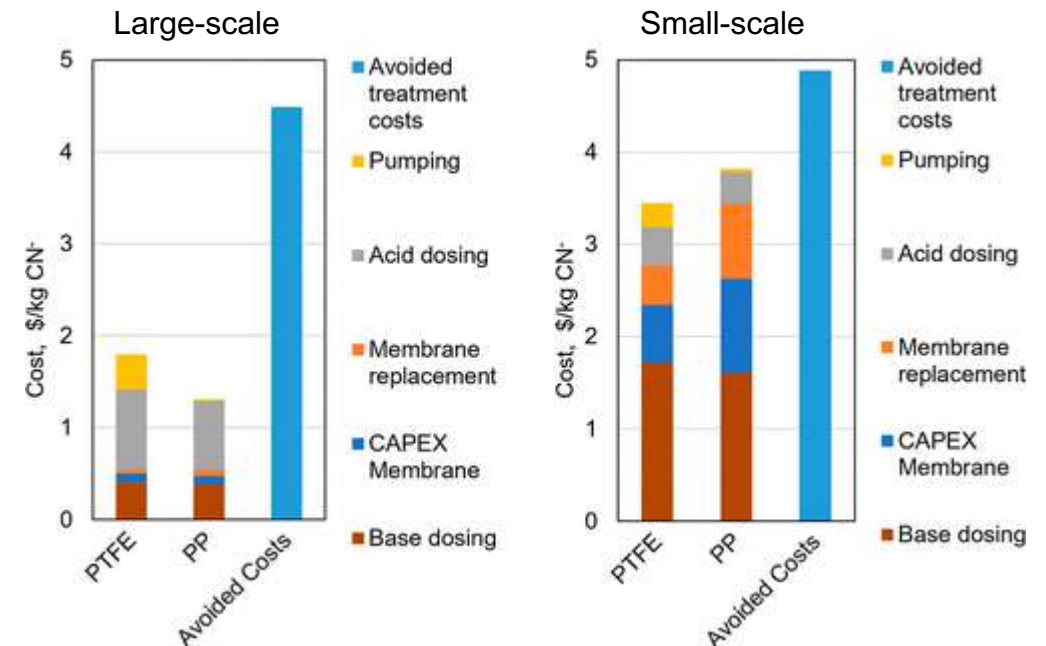
Cyanide recovery could be a beneficial alternative to cyanide destruction

- Lost economic value of free cyanide
- Lab-scale membrane contactor system constructed to recover cyanide from mining effluent
- More than 95% of cyanide can be recovered from real mining effluent



Cyanide recovery is economically feasible

- Economic analysis shows economic viability of cyanide recovery
- Applicable for small- and large-scale gold processing plants
- Developed technology competitive with alternate cyanide recovery and treatment technologies



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Article

Membrane Contactors as a Cost-Effective Cyanide Recovery Technology for Sustainable Gold Mining

Vincent Hammer, Johan Vanneste,* David C. Vuono, Francisco D. Alejo-Zapata, Henry G. Polanco-Cornejo, Julia Zea, Héctor G. Bolaños-Sosa, Carlos A. Zevallos Rojas, Linda A. Figueroa, and Christopher Bellona

Cite This: <https://doi.org/10.1021/acsestwater.3c00026>

Read Online

Development of Pilot-Scale System

- Scaled-up membrane system with prefiltration
- Design of pilot scale system based on bench scale findings
- Solar array for off-grid operation



“Mariposa” Solar system



Untreated mining wastewater



Ultrafiltration



Membrane contactor

Cyanide recovery

Shipment of mobile pilot-scale cyanide treatment system to UNSA

La República

SOCIEDAD

09 DIC 2022 | 9:49 |

Desarrollan tecnología para extraer cianuro de los relaves de oro

Prototipo. Químico se utiliza en producción aurífera. La propuesta es recuperarlo de los relaves y volverlo a reusar. Con prototipo se cuidará medio ambiente y se ahorrará dinero.



andina
AGENCIA PERUANA DE NOTICIAS

Aporte ambiental en Arequipa: investigadores crean equipo que descontamina agua de relaves

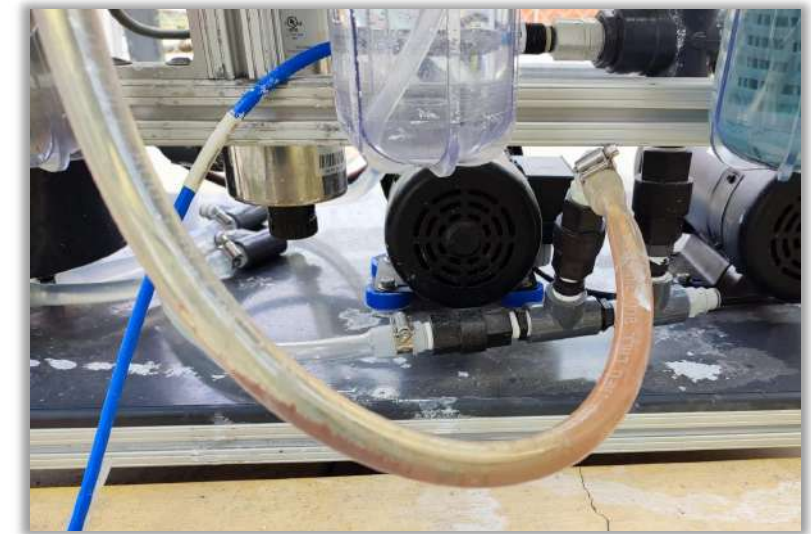
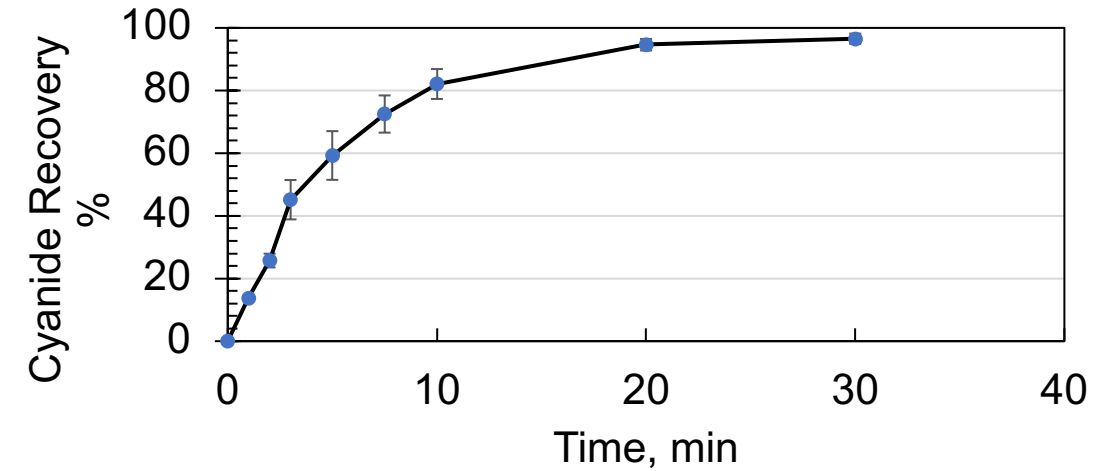
'La Mariposa' takes flight in Peru to capture cyanide used by small-scale gold miners

MINES NEWSROOM



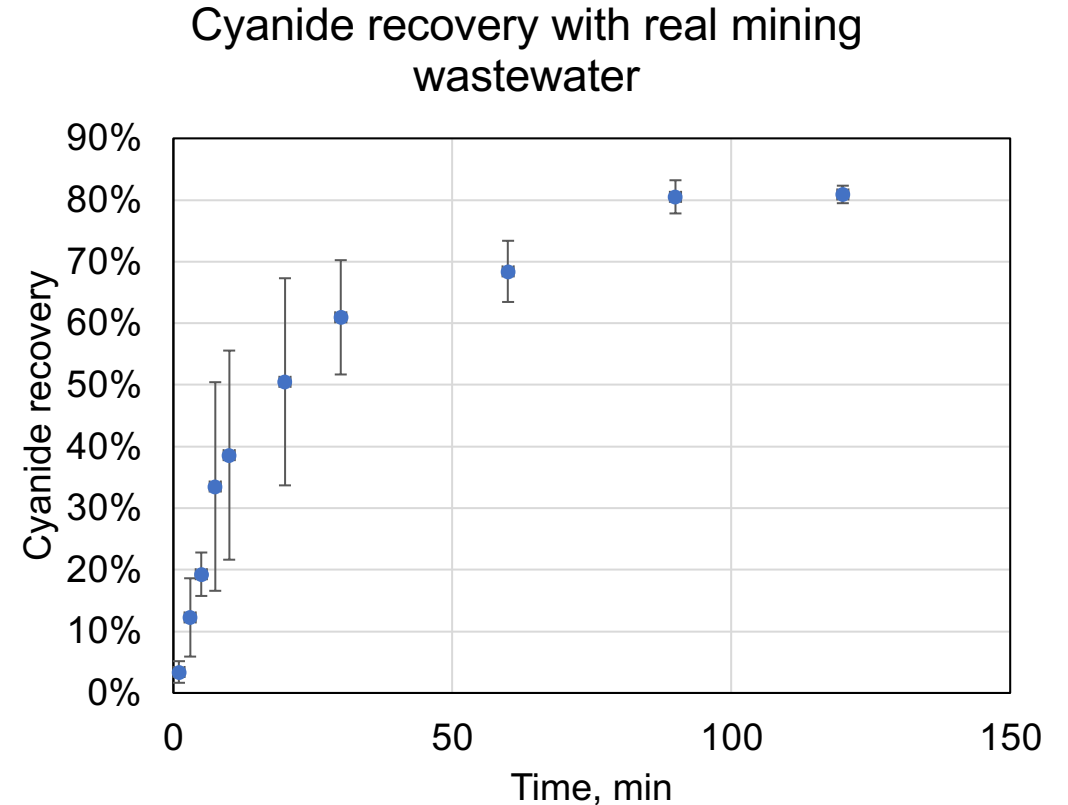
Recovery of cyanide at the pilot-scale in Peru

- Experimentation with synthetic waters show process is effective at pilot-scale
- 96% free cyanide recovery was achieved after 30 minutes
- Experiments with real mining wastewater resulted in precipitation of metals

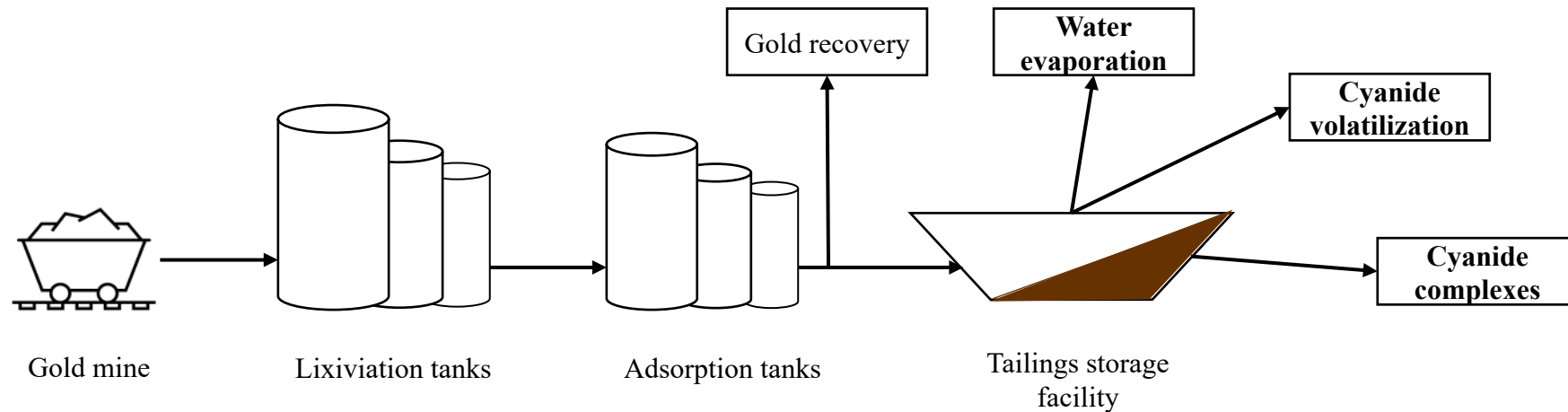


Cyanide recovery from real mining wastewater at pilot-scale

- Recovery of free cyanide with real mining wastewater slower than synthetic
- 81% recovery after 90 minutes
- Metals precipitates need to be pre-filtered

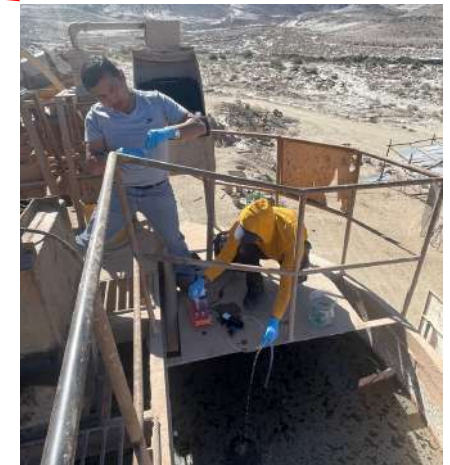


Opportunities for cyanide recovery at gold processing facilities

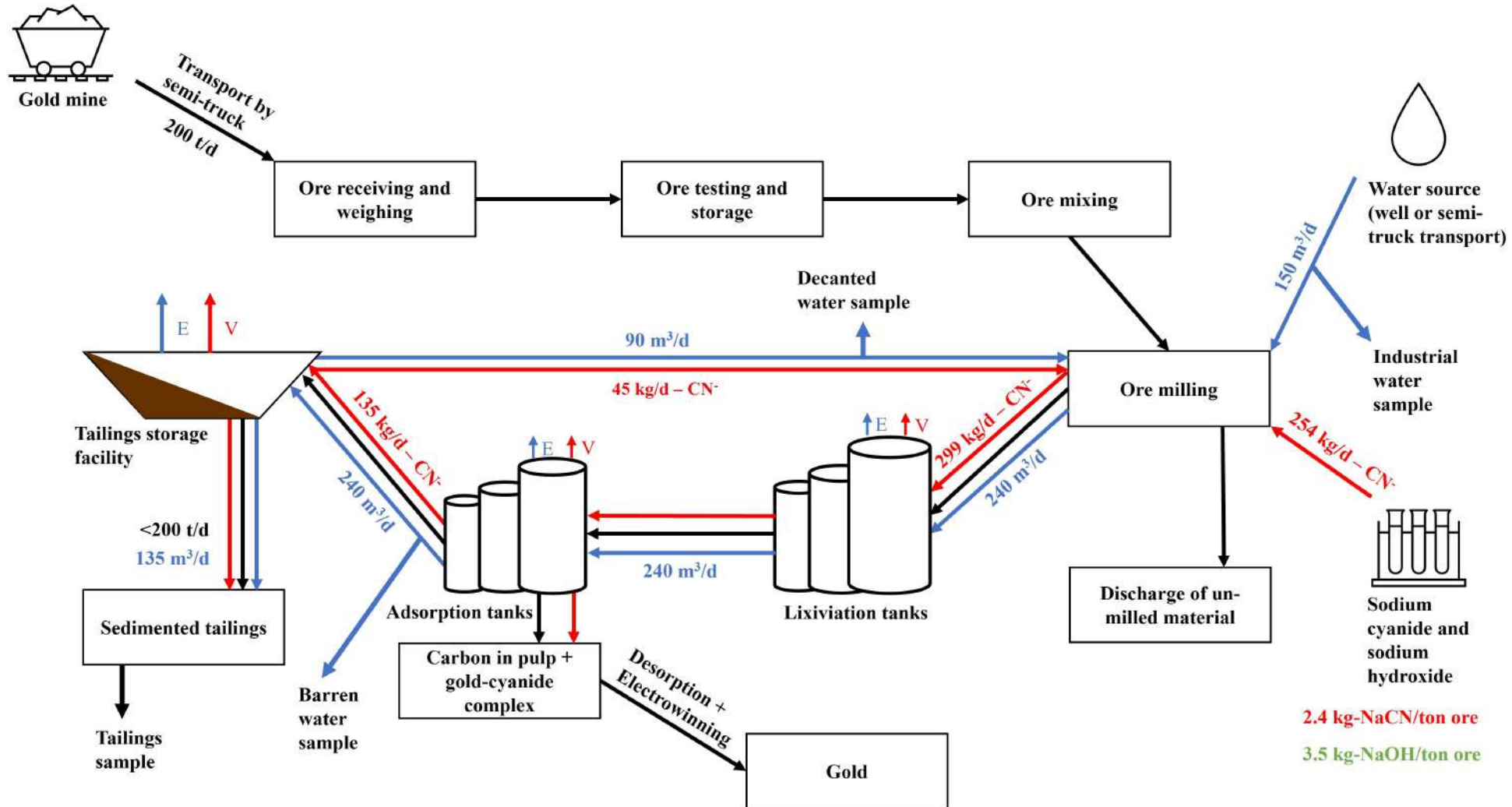


- Analysis of gold processing operations was performed to:
 - Determine cyanide concentrations within and losses from the system
 - Collect water quality data
 - Evaluate mining effluent for potentially valuable metals
 - Conduct water and chemical balances across systems

Gold processing facility locations

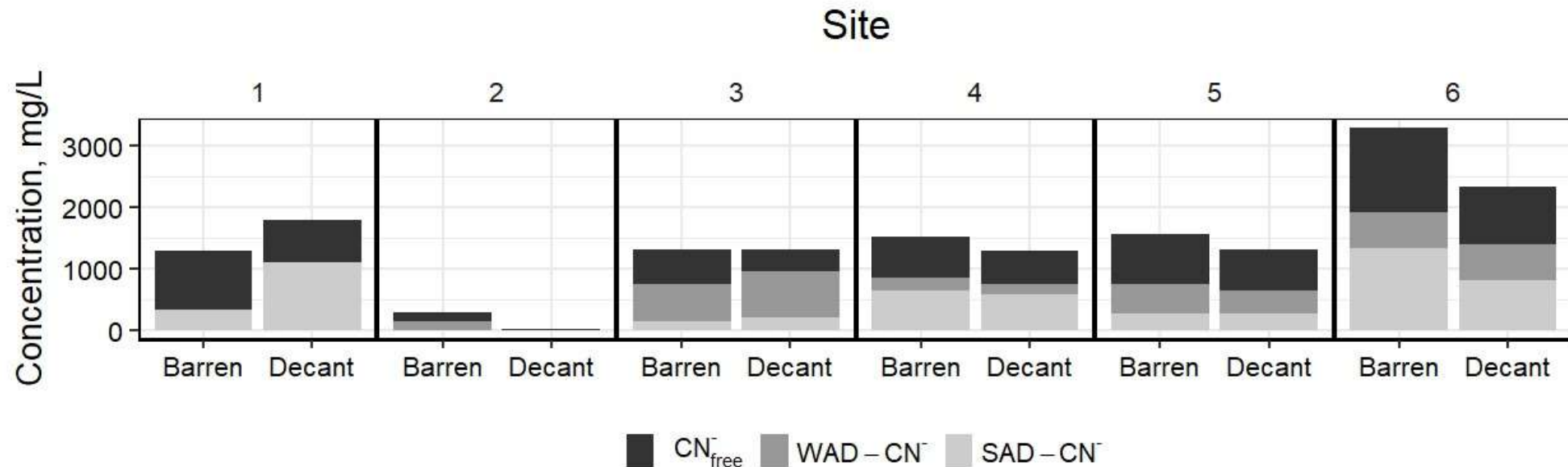


System analysis – Process flows



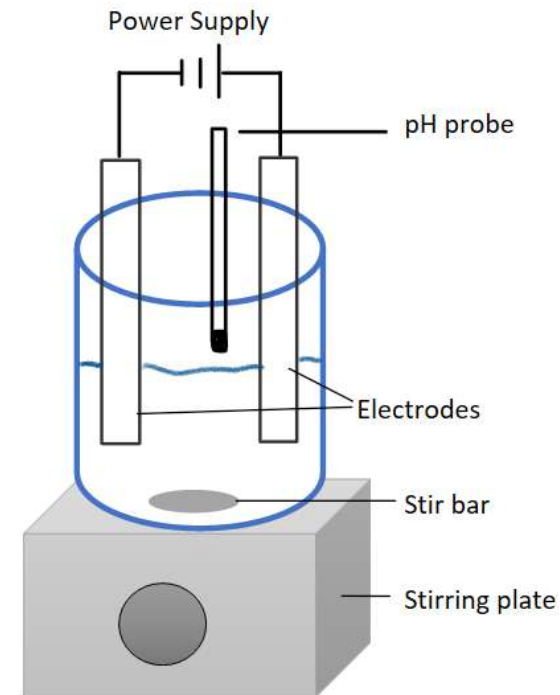
Cyanide and cyanide species at ore processing facilities

- High variation of free cyanide, WAD, and SAD concentrations
- Excess cyanide is beneficial for gold cyanidation and improves prospects for cyanide recovery
- High concentrations of metal-cyanide complexes are challenging but may allow for metals and cyanide recovery



Electrochemical Treatment

- Electrochemical system used to oxidize cyanide and recover copper and other heavy metals
 - Graphite anode and copper cathode
- Experiments run with synthetic and real gold process wastewaters
 - Evaluating effects of high salinity, copper concentrations, and applied voltage

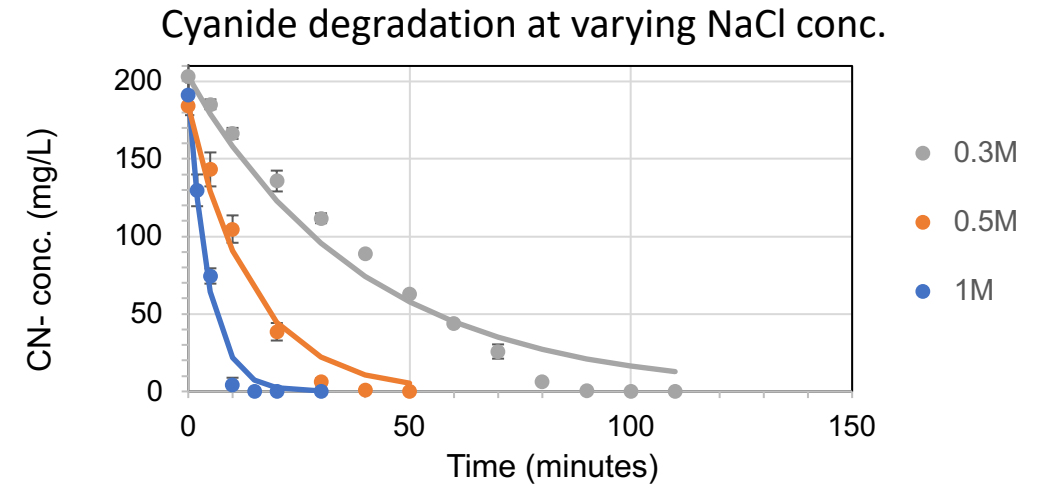


Experiment setup and electrode materials

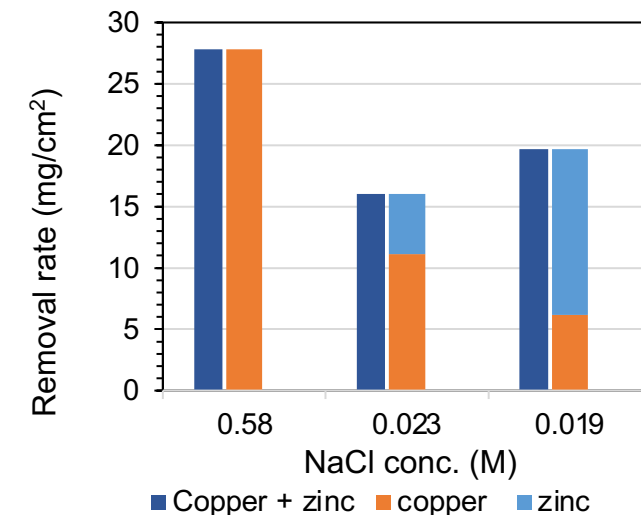


Electrochemical Treatment Key Findings

- Process parameter evaluation
 - Degradation of cyanide follows a first order reaction
 - Increased applied voltage and NaCl concentration leads to an increased rate of cyanide degradation
- Heavy metal recovery
 - For real wastewater experiments, an increased applied voltage and higher NaCl concentration led to more removal of metals from wastewater
 - Some results differed for synthetic wastewaters compared to real wastewaters



Removal of metals in real wastewater at varying NaCl conc.

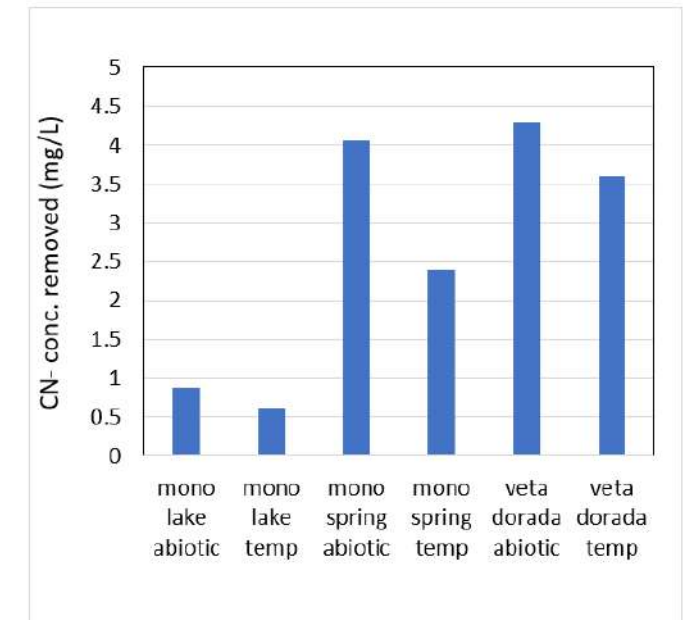
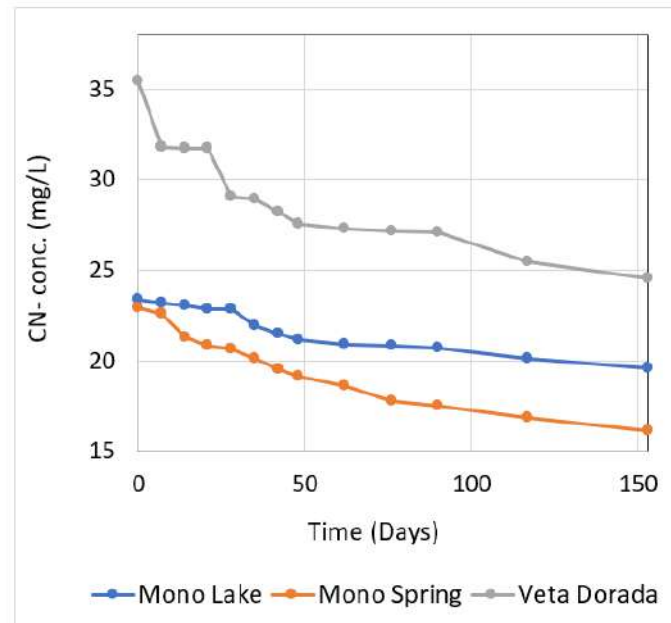


Biological Treatment of Cyanide

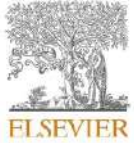
- Biological treatment of cyanide → tested different inoculums to see which microbial communities were best at degrading cyanide
- 3 trials conducted → Small removal of cyanide seen
 - Highest cyanide removal seen for Veta Dorada and Mono Spring inoculums



Removal of cyanide for different inoculums



Mercury and cyanide co-processing



Contents lists available at ScienceDirect

Science of the Total Environment

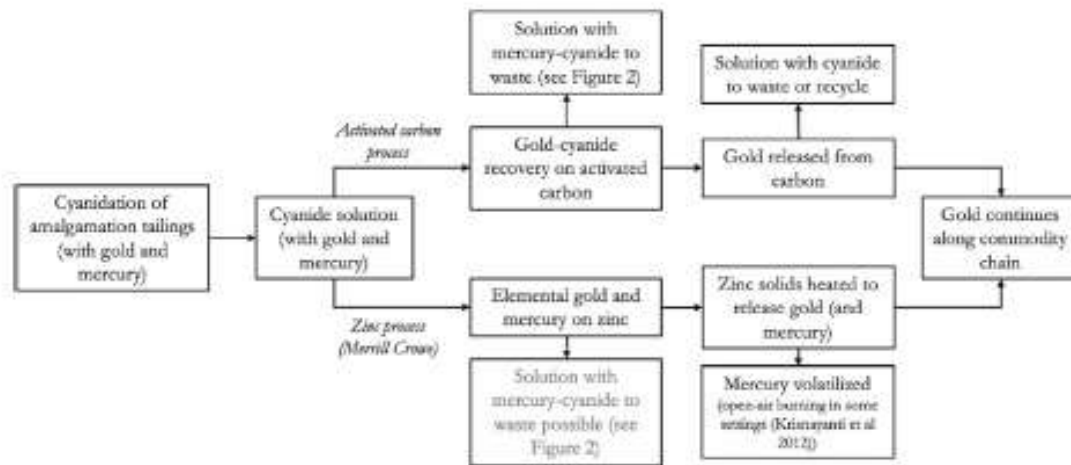
journal homepage: www.elsevier.com/locate/scitotenv



Review

Transitional dynamics from mercury to cyanide-based processing in artisanal and small-scale gold mining: Social, economic, geochemical, and environmental considerations

Aaron Malone^{a,b,c,*}, Linda Figueroa^{a,d}, Weishi Wang^{a,d}, Nicole M. Smith^{a,c}, James F. Ranville^{a,e}, David C. Vuono^{a,d}, Francisco D. Alejo Zapata^{a,f}, Lino Morales Paredes^{a,f}, Jonathan O. Sharp^{a,d}, Christopher Bellona^{a,d}



- Review to evaluate the drivers and impacts of cyanide and mercury co-processing at gold-extraction sites
- While mercury use is decreasing, amalgamation tailings are co-mingled with ore processed with cyanide
- Mercury-cyanide complexes formed during processing may increase mercury mobility in environment
- Significant research gaps exist regarding extent of issue
- Interim policy responses needed

Conclusions

- Free cyanide can be effectively recovered using membrane contactors which is more economical than cyanide treatment
- Pilot scale tests underway in Peru to demonstrate technology developed
- Analysis of gold processing facilities supports implementing cyanide recovery and reveals opportunities to improve the economics of gold mining
- Electrochemical oxidation can both degrade cyanide and recover metals from barren solution



Questions?

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Thank You! – ¡Muchas Gracias!



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