1 Growth and alkaline phosphatase activity of *Chattonella marina* and *Heterosigma akashiwo* in response to phosphorus limitation
Zhao-Hui Wang and Yu Liang

8 Distribution characteristics and indicator significance of Dechloranes in multi-matrices at Ny-Ålesund in the Arctic
Guangshui Na, Wei Wei, Shiyao Zhou, Hui Gao, Xindong Ma, Lina Qiu, Linke Ge, Chenguang Bao and Zwei Yao

14 Pretreatment of cyanided tailings by catalytic ozonation with Mn$^{2+}$/O$_3$
Yulong Li, Dengxin Li, Jiebing Li, Jin Wang, Asif Hussain, Hao Ji and Yijie Zhai

22 Effects of different sludge disintegration methods on sludge moisture distribution and dewatering performance
Lingyun Jin, Guangming Zhang and Xiang Zheng

29 Removal of tetracycline from aqueous solution by a Fe$_3$O$_4$ incorporated PAN electrospun nanofiber mat
Qing Liu, Yuming Zheng, Lubin Zhong and Xiaoxia Cheng

37 Feasibility of bioleaching combined with Fenton oxidation to improve sewage sludge dewaterability
Changgeng Liu, Panyue Zhang, Chenghua Zeng, Guangming Zeng, Guoyin Xu and Yi Huang

43 Mg$^{2+}$ improves biomass production from soybean wastewater using purple non-sulfur bacteria
Pan Wu, Guangming Zhang and Jianzheng Li

47 Influence of zeta potential on the flocculation of cyanobacteria cells using chitosan modified soil
Liang Li, Honggang Zhang and Gang Pan

54 Effects of two polybrominated diphenyl ethers (BDE-47, BDE-209) on the swimming behavior, population growth and reproduction of the rotifer *Brachionus plicatilis*
Jingjing Sha, You Wang, Jianxia Lv, Hong Wang, Hongmei Chen, Leilei Qi and Xuexi Tang

64 Immobilization of lead in anthropogenic contaminated soils using phosphates with/without oxalic acid
Xiaojuan Su, Jun Zhu, Qingling Fu, Jichao Zuo, Yonghong Liu and Hongqing Hu

74 Predicted no-effect concentrations for mercury species and ecological risk assessment for mercury pollution in aquatic environment
Meng Du, Dongbin Wei, Zhuowei Tan, Aiwu Lin and Yuguo Du

81 Investigation of physico-chemical properties and microbial community during poultry manure co-composting process
Omar Farah Nadia, Loo Yu Xiang, Lee Yei Lie, Dzulkornain Chairil Anuar, Mohammed P. Mohd Afandi and Samsu Azhari Baharuddin

95 Cu(II), Fe(III) and Mn(II) combinations as environmental stress factors have distinguishing effects on *Enterococcus hirae*
Zaruhi Vardanyan and Armen Trchounian

101 Evaluation of biostimulation and Tween 80 addition for the bioremediation of long-term DDT-contaminated soil
Bibiana Betancur-Corredor, Nancy J. Pino, Santiago Cardona and Gustavo A. Peñuela

110 Hg$^0$ removal from flue gas over different zeolites modified by FeCl$_3$
Hao Qi, Wenqing Xu, Jian Wang, Li Tong and Tingyu Zhu

118 Preparation and evaluation of aminopropyl-functionalized manganese-loaded SBA-15 for copper removal from aqueous solution
Di Lei, Qianwen Zheng, Yili Wang and Hongjie Wang
CONTENTS

128 Investigation of carbonyl compound sources at a rural site in the Yangtze River Delta region of China
Ming Wang, Wentai Chen, Min Shao, Sihua Lu, Limin Zeng and Min Hu

137 Low-carbon transition of iron and steel industry in China: Carbon intensity, economic growth and policy intervention
Bing Yu, Xiao Li, Yuanbo Qiao and Lei Shi

148 Synergistic effect of N- and F-codoping on the structure and photocatalytic performance of TiO₂
Jiemei Yu, Zongming Liu, Haitong Zhang, Taizhong Huang, Jiitan Han, Yihe Zhang and Daohuang Chong

157 Pollution levels and characteristics of phthalate esters in indoor air of offices
Min Song, Chenchen Chi, Min Guo, Xueqing Wang, Lingxiao Cheng and Xueyou Shen

163 Characteristics and anthropogenic sources of carbonyl sulfide in Beijing
Ye Cheng, Chenglong Zhang, Yuanyuan Zhang, Hongxing Zhang, Xu Sun and Yujing Mu

171 Oxidation of diesel soot on binary oxide CuCr(Co)-based monoliths
Sergiy O. Soloviev, Andriy Y. Kapran and Yaroslava P. Kurylets

178 Effects of introducing energy recovery processes to the municipal solid waste management system in Ulaanbaatar, Mongolia
Kosuke Toshiki, Pham Quy Giang, Kevin Roy B. Serrona, Takahiro Sekikawa, Jeoung-soo Yu, Baasandash Choijil and Shoichi Kunikane

187 Toluene decomposition performance and NOx by-product formation during a DBD-catalyst process
Yufang Guo, Xiaobin Liao, Mingli Fu, Haibao Huang and Daiqi Ye

195 Changes in nitrogen budget and potential risk to the environment over 20 years (1990-2010) in the agroecosystems of the Haihe Basin, China
Mengmeng Zheng, Hua Zheng, Yingxia Wu, Yi Xiao, Yihua Du, Weihua Xu, Fei Lu, Xiaoke Wang and Zhiyun Ouyang
Pretreatment of cyanided tailings by catalytic ozonation with Mn$^{2+}$/O$_3$

Yulong Li, Dengxin Li*, Jiebing Li, Jin wang, Asif Hussain, Hao Ji, Yijie Zhai

College of Environmental Science and Engineering, State Environmental Protection Engineering Center for Pollution Treatment and Control in Textile Industry, Donghua University, Shanghai 201620, China

ARTICLE INFO

Article history:
Received 15 March 2014
Revised 7 May 2014
Accepted 11 May 2014
Available online 15 November 2014

Keywords:
Cyanided tailings
Pretreatment
Mn$^{2+}$/O$_3$
Catalytic ozonation

ABSTRACT

The increasing amount of cyanided tailings produced as a by-product has gained significant attention in recent years because of the rapid development of the gold industry and extensive exploitation of gold mineral resources. The effective use of these secondary resources is becoming an important and urgent problem for all environmental protection staff. Manganese-catalyzed ozonation for the pre-oxidation of cyanided tailings was studied and the effects of Mn$^{2+}$ dosage, initial sulfuric acid concentration, ozone volume flow, temperature and agitation speed on pretreatment were examined. The optimum reaction conditions were observed to be: ore pulp density 2.5%, agitation speed 700 r/min, temperature 60°C, Mn$^{2+}$ dosage 40 g/L, ozone volume flow 80 L/hr, initial sulfuric acid concentration 1 mol/L, and reaction time 6 hr. Under these conditions, the leaching rate of Fe and weight loss could reach 94.85% and 48.89% respectively. The leaching process of cyanided tailings by Mn$^{2+}$/O$_3$ was analyzed, and it was found that the leaching of pyrite depends on synergetic oxidation by high-valent manganese and O$_3^-$, in which the former played an important part.

© 2014 The Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V.

INTRODUCTION

Catalytic ozonation has recently gained significant attention as an effective process used for organic removal from water (Lkhlaq et al., 2014; Nie et al., 2013; Liu et al., 2013; Wang et al., 2013; Nawrocki and Kasprzyk-Hordern, 2010). Catalytic ozonation is aimed at oxidative degradation of organic matter that cannot be oxidized by ozone alone at ordinary temperatures and pressures. This technology can also strengthen the oxidative degradation of organic pollutants that are intractable or highly stable (He et al., 2008). Metal catalytic ozonation technology, along with other advanced oxidation technologies such as O$_3$/H$_2$O$_2$, UV/O$_3$, TiO$_2$/UV and UV/H$_2$O$_2$, is mainly used to generate oxidative free radicals (hydroxyl radicals) in the reaction process to oxidize and decompose the organic pollutants in water (Mehrjouei et al., 2012; Anipsitakis and Dionysiou, 2004; Yang et al., 2005; Nahum et al., 2013; Saritha et al., 2007).

Scheiner and Linstrom (1973) were the first to recover gold from their respective ores by treating the slurry with an acid-salt mixture and ozone. In recent years, catalytic ozonation has undergone significant development and has been used in many metallurgical industries. Among the types of metal catalytic ozonation that have been applied to homogeneous catalysis, Fe$^{3+}$ and Mn$^{2+}$ have gained significant attention because of their good catalytic performance, with many studies focused on the degradation effects of organic pollutants (Lan et al., 2013; Hou et al., 2013; Martins and Quinta-Ferreira, 2009; Xiao et al., 2008a). In order to oxidize gold-bearing minerals, recover the gold and reuse the iron, this research used Mn$^{2+}$ as a catalyst and investigated the effects of Mn$^{2+}$ dosage, catalytic ozonation, initial H$_2$SO$_4$ concentration, O$_3$ volume flow, reaction temperature and agitation speed on the pretreatment of cyanided tailings by the Mn$^{2+}$/O$_3$ catalytic ozonation system.

* Corresponding author. E-mail: lidengxin@dhu.edu.cn (Dengxin Li).
1. Materials and methods

1.1. Chemicals and reagents

Sulfuric acid (AR), nitric acid (AR), ammonia (AR), manganese sulfate (AR), hydrochloric acid (AR), sulfosalicylic acid, hexamethylenetetramine, iron standard solution (0.010 mol/L), EDTA standard titration solution (0.01 mol/L) were all provided by Sinopharm Chemical Reagent Co. Ltd. (China).

1.2. Apparatus and instruments

The mineralogical composition of cyanided tailings was studied by X-ray diffractometry (XRD, D/Max-2550 V, RIGAKU, Japan) at 40kV×30mA, Cu Kα radiation (λ=1,54056 Å) and 2θ from 5 to 90°. The mineral scanning image of cyanided tailings was obtained by scanning electron microscopy (SEM, JSM-5600-LV, JEOL, Japan) at 2000 magnification. Spectra of O, Si, S, Fe, Cu, and Pb were analyzed by a Energy Dispersive Spectrometer (EDS, IE300X, Oxford, England) and X-ray fluorescence (XRF, XRF-1800, SHIMADZU, Japan) for the cyanided tailings.

1.3. Experiments

The cyanided tailings were from Henan Province, China. In this experiment, Mn²⁺ as a catalyst along with a typical liquid-solid chemical reaction and stirred-tank reactor was used to preprocess the cyanided tailings by catalytic ozonation. The principal reaction was conducted in a tailor-made cylindrical three neck flask (0.5 L), and the flask was placed in an oil bath equipped with an electronic thermometer and snakelike condenser tube for cooling. The heating medium was dimethyl silicone and we used a constant temperature magnetic mixer to guarantee the mix rate and temperature. In addition, an ozone generating device and an exhaust emission device were added in the main reactor.

The cyanided tailings were dried, ground and sieved to 300 mesh particle size before use. The ore pulp solution (density 2.5%, weight = 200 g) was prepared in the cylindrical three neck flask at constant temperature. When the solution rose to the desired temperature, the ozone was bubbled into the solution through a porous nozzle. After pretreatment was carried out for a specified time, the hot solution was filtered and the leaching rate (PFe, %) of iron in the filtrate was calculated using Eq. (1), whereas the weight loss (W, %) of the filter cake after washing with water several times and drying in an oven to constant weight was calculated by Eq. (2). The effect of pretreatment was evaluated through leaching rate of Fe and weight loss. The higher the leaching rate of Fe and the weight loss were, the better the effect of pretreatment and the effect of subsequent cyaniding was. The iron content was determined by EDTA complexometric titration.

\[ W = \frac{\text{original sample quantity} - \text{sample quantity after preoxidation}}{\text{original sample quantity}} \times 100\% \]  

\[ P_{Fe} = \frac{\text{leached iron quantity}}{\text{original iron quantity}} \times 100\% \]

2. Results and discussion

2.1. Characterization of cyanided tailings

The phase analysis results of XRD showed that the main metal mineral and main gangue mineral were pyrite (FeS₂) and quartz (SiO₂) respectively, suggesting that the gold was contained in pyrites, which are gold-bearing minerals, in the form of fine-grained gold (Fig. 1).

The surface scanning images (magnified 2000×) and XRS images are shown in Figs. 2 and 3 respectively. The X ray fluorescence results for the cyanided tailings composition are as following: Au 2.21%, Ag 40.4%, Cu 3.84%, Fe 22.91%, Pb 3.84%, and S 25.14%.
From the SEM image, the intensive distribution areas of O, Si, S and Fe can be seen to be very large and similar, suggesting that the elements O, Si, S and Fe are in the same mineral form (Fig. 3). This was also confirmed by the results of XRD analysis, therefore we conclude that the main gangue mineral in the cyanided tailings was quartz (SiO$_2$), and the pyrite (FeS$_2$) was the main gold-bearing mineral. Small amounts of elements Cu and Pb were also detected.

2.2. Comparison of ozonation alone and Mn$^{2+}$-catalyzed ozonation

The oxidation rate of ozonation without Mn$^{2+}$ ion was observed to be slow, with low iron leaching rate (57.04%) and long reaction time (9 hr) (Fig. 4) due to the slow mass transfer of ozone in water, which influenced the oxidation ability of ozone. We observed that the iron leaching rate was increased up to 94.48% with the addition of Mn$^{2+}$ in the system with a comparatively short reaction time (6 hr), suggesting that the catalytic oxidation could be improved in the presence of Mn$^{2+}$ due to the fast mass transfer of ozone.

2.3. Effects of experimental conditions

An increase in iron leaching rate was observed with the increase of Mn$^{2+}$ dosage, with a similar trend in weight loss at the optimum dosage (40 g/L) of Mn$^{2+}$ ions, and further increase in dosage, such as 50 g/L, resulted in the rapid reduction of iron leaching rate and weight loss (Fig. 5a).
may be because the excess Mn^{2+} consumed the high valence manganese that was generated in the reaction system, so that the oxidation ability of the system was reduced. The initial concentration of sulfuric acid was observed to have a significant effect on pretreatment (Fig. 5b). The leaching rate of Fe first increased and then decreased with the increase in the initial concentration of sulfuric acid, and a drastic change was observed from 0.7 to 1.0 mol/L. It was also observed that the tailings gained weight at a low initial concentration. The weight loss increased rapidly when the initial concentration was raised to 0.5 mol/L, whereas little change was observed in weight loss above 1.0 mol/L.

At a low initial concentration, the filter cake was observed to be black due to the generation of MnO2 precipitate. The Mn^{2+} was easily oxidized to MnO2 in weakly acidic conditions. The MnO2 precipitation reduced the oxidation reaction rate of cyanide tailings, because it coated the sample surface and added to the tailing weight. Too high acidity also had adverse effects, and the relevant literature (Viñals et al., 2005) shows that the ozone concentration in solution decreases significantly with higher initial concentration. That was not conducive to leaching, but the weight loss rate was not reduced, because excess acid could react further with the gangue mineral.

Fig. 5c shows that with the increase of O3 volume flow, the leaching rate of Fe and the weight loss both rose significantly. When the agitation speed was more than 700 r/min, the leaching rate of Fe did not change significantly. These results showed that the increase of agitation speed increased ozone mass transfer in the liquid phase, and the mass transfer and diffusion may play a leading role in the reaction process.

The leaching rate of Fe showed an almost linear dependence on reaction time (Fig. 5f). When the reaction was longer than 6 hr, the leaching rate of iron remained constant at 94.48%. These results showed that the reaction was essentially over and the pyrite was almost completely oxidized at the reaction time 6 hr.

2.4. Experiment under optimum pretreatment conditions

Through a series of experiments, we determined that the optimum pretreatment conditions were ore pulp density of 2.5%, the agitation speed of 700 r/min, reaction temperature of 60°C, reaction time of 6 hr, MnSO4 dosage of 40 g/L, initial sulfuric acid concentration of 1 mol/L, O3 volume flow of 80 L/hr and O3 mass flow of 15 g/hr. The leaching rate of Fe and weight loss could reach 94.85% and 48.89% respectively under the optimum pretreatment conditions. The oxidized slag under the optimum pretreatment conditions was studied by X-ray diffraction and EDS. The phase analysis and surface scanning results are shown in Figs. 6 and 7 respectively. After pretreatment the pyrite was almost undetectable. The regional distribution of S, Fe became more sparse. These results showed that the pretreatment was very effective.
Ma and Graham (1999) used Mn\(^{2+}\) as a catalyst to degrade atrazine through ozonation, and they inferred that the reaction followed a reaction mechanism involving hydroxyl radicals. The specific reactions were as follows.

\[
\begin{align*}
\text{Mn}^{2+} + \text{O}_3 + 2\text{H}^+ &\rightarrow \text{Mn}^{3+} + \text{O}_2 + \text{H}_2\text{O} \quad (3) \\
\text{MnO}_2 + \text{H}_2\text{O} &\rightarrow \text{MnO}_2-\text{H}_2\text{O} \quad (4) \\
\text{MnO}_2-\text{H}_2\text{O} &\rightarrow \text{MnO}_2-\text{OH}^- + \text{H}^+ \quad (5) \\
\text{MnO}_2-\text{OH}^- + \text{O}_3 &\rightarrow \text{MnO}_2-\text{OH} \\
\text{MnO}_2-\text{OH}^- &\rightarrow \text{MnO}_2-\text{OH}^- + \text{M} \rightarrow \text{P} \quad (7)
\end{align*}
\]

where, \(\text{M}\) is target pollutant and \(\text{P}\) is reaction product.

Xiao et al. (2008b) used Mn\(^{2+}\) as catalyst to degrade dichlorophenol through ozonation and they found that adding hydroxyl radical scavengers had deadening effects on the reaction. The presence of hydroxyl radicals was
proved by electron spin resonance. Andreozzi et al. (1992) used Mn2+ as catalyst to catalyze and ozonize organics. They found that in the reaction process the target organic and Mn2+ first formed a complex, which made ozonation easier. The relevant reactions were as follows.

\[
\begin{align*}
\text{MnO}^- + 2\text{H}^+ & \rightarrow \text{MnOH}_2^+ \quad (8) \\
\text{MnOH}_2^+ + \text{A} & \rightarrow \text{Mn}^-\text{A} + \text{H}_2\text{O} \quad (9) \\
\text{Mn}^-\text{A} + \text{O}_3 & \rightarrow \text{by-products} \quad (10)
\end{align*}
\]

where, MnO- and MnOH2+ were the active centers on the catalyst surface. A represents the target organic pollutants. Okawa et al. (2005) also agreed with this point in their research on ozonation of chlorinated organic compounds in acetic acid solution. Wu et al. (2008) studied the catalytic properties of different metal ions and found that the catalytic mechanism of Mn2+ was different from other metal ions. According to the experimental results, they proved that Mn3+ and Mn7+ were the main oxidants and that hydroxyl radicals were not the main active species, because adding hydroxyl radical scavengers had no effect on the reaction. High valence manganese metal ion had a strong oxidizing effect, but it could not oxidize all organic compounds. It oxidized the organics with selectivity. Zang et al. (2009) studied the mechanism of Mn2+ catalytic ozonation of oxalic acid and found that it included three parts: direct ozonation, oxidation by hydroxyl radical produced from the decomposition of dissolved ozone, and oxidation by Mn4+ and Mn7+. The oxidation by high valence manganese was the main reactant in acidic conditions, and the hydroxyl radicals were the main reactant in neutral or alkaline conditions.

In this article, the cyanided tailings were a chemical mixture that contained a variety of minerals, and its main chemical composition was FeS2. In the initial experiments, the sample ore had almost no reaction when we used ozone alone to oxidize the cyanided tailings in alkaline conditions, and that showed that the oxidation mechanism involving hydroxyl radicals was not applicable.

In the course of the experiment we could observe a special purple red color under the case of sufficient sulfuric acid, which illustrated that Mn3+ was generated in the reaction process (Li et al., 2003). When adding ozone in the solution, the Mn2+ was first oxidized into Mn4+ or Mn3+. The Mn4+ could react with Mn2+ to give Mn3+. The Mn4+ could also be oxidized to Mn7+. The Mn4+ existed in the hydrated state of MnO2H2O, which could adsorb OH- from the solution, and in this case the ozone could react with the surface-bound OH- to give hydroxyl radicals on the surface of the manganese dioxide. All of the Mn3+, Mn7+ and MnO2OH species could oxidize the pyrite, and at the same time they were reduced to Mn2+. The possible reactions involved in the experiment were as follows.

\[
\begin{align*}
2\text{FeS}_2 + \text{SO}_3 + \text{H}_2\text{O} & \rightarrow \text{Fe}_2(\text{SO}_4)_3 + \text{H}_2\text{SO}_4 \quad (11) \\
\text{Mn}^{2+} + \text{O}_3 + 2\text{H}^+ & \rightarrow \text{Mn}^{3+} + \text{O}_2 + \text{H}_2\text{O} \quad (12) \\
\text{MnO}_2 + \text{H}_2\text{O} & \rightarrow \text{MnO}_2\cdot\text{H}_2\text{O} \quad (13) \\
\text{MnO}_2\cdot\text{H}_2\text{O} & \rightarrow \text{MnO}_2\cdot\text{OH}^- + \text{H}^+ \quad (14) \\
\text{MnO}_2\cdot\text{OH}^- + \text{O}_3 & \rightarrow \text{MnO}_2\cdot\text{OH} \quad (15)
\end{align*}
\]

\[\text{Intensity(CPS)}\]

\[\begin{array}{c@{\hspace{6pt}}c}
\text{2θ (degree)} & \text{Intensity (CPS)} \\
0 & 0 \\
10 & 0 \\
20 & 0 \\
30 & 0 \\
40 & 0 \\
50 & 0 \\
60 & 0 \\
70 & 0 \\
80 & 0 \\
90 & 0 \\
100 & 0
\end{array}\]

Fig. 6 – X-ray diffractometry (XRD) of the cyanided tailings after pretreatment.

Fig. 7 – Energy Dispersive Spectrometer (EDS) surface scanning of S and Fe.
MnO₂−OH + FeS₂→P

2MnO₂−H₂O + O₃→2MnO₄⁻ + 2H⁺ + H₂O

Mn²⁺ + MnO₂−H₂O + 4H⁺→2Mn³⁺ + H₂O

Mn²⁺ + O₃ + H⁺→Mn³⁺ + O₂ + OH⁻

8H₂O + 15Mn³⁺ + FeS₂→16H⁺ + Fe³⁺ + 2SO₄²⁻ + 15Mn²⁺

5MnO₂ + FeS₂ + 24H⁺→5Mn²⁺ + 2SO₄²⁻ + Fe³⁺ + 12H₂O

3. Conclusions

The method of using ions (Mn²⁺) as a catalyst to preprocess cyanided tailings through metal catalytic ozonation was proved to be an effective technique, with a high leaching rate and a fast reaction rate.

The Mn²⁺ dosage, initial concentration of sulfuric acid, ozone volume flow, temperature and agitation speed were studied for their effects on pretreatment. The leaching rate of Fe increased and then decreased along with the increase of Mn²⁺ dosage and ozone volume flow. The Mn²⁺ dosage and ozone volume flow both had optimum values. The initial concentration of sulfuric acid had a major impact on pretreatment and the ozone mass flow rate had a fast reaction rate. The change of temperature and ozone volume flow, temperature and agitation speed were found to have little effect on pretreatment and the ozone mass flow rate. The Mn²⁺ dosage had a significant effect on the reaction rate.

The leaching rate of Fe and weight loss could reach 94.85% and 48.89% respectively under the optimum pretreatment conditions, which were: ore pulp density (2.5%), agitation speed (700 r/min), temperature (60°C), Mn²⁺ dosage (40 g/L), ozone volume flow (80 L/hr), initial sulfuric acid concentration (1 mol/L), reaction time (6 hr).

Oxidation by high-valent manganese played a major role in the reaction process. The Mn²⁺ was first oxidized into Mn⁴⁺ or Mn⁵⁺. The Mn⁴⁺ could react with Mn⁴⁺ to give Mn⁵⁺. The Mn⁴⁺ could also be oxidized into Mn⁵⁺. The Mn⁴⁺ existed in the hydrated state of MnO₂−H₂O, which could adsorb OH⁻ from the solution, and in this case the ozone could react with the surface-bound OH⁻ to give hydroxyl radicals on the surface of the manganese dioxide. All of the Mn³⁺, Mn⁴⁺ and MnO₂−OH species could oxidize pyrite, and at the same time they were reduced to Mn²⁺.

Acknowledgments

This work was supported by the Innovation Foundation of Donghua University for Doctoral Candidates (No. BC201132) and the Shanghai Leading Academic Discipline Project (No. B604).

REFERENCES


# Editorial Board of Journal of Environmental Sciences

## Editor-in-Chief

**X. Chris Le**  
University of Alberta, Canada

## Associate Editors-in-Chief

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jiuhui Qu</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Sha Tao</td>
<td>Peking University, China</td>
</tr>
<tr>
<td>Nigel Bell</td>
<td>Imperial College London, UK</td>
</tr>
<tr>
<td>Po-Keung Wong</td>
<td>The Chinese University of Hong Kong, Hong Kong, China</td>
</tr>
</tbody>
</table>

## Editorial Board

### Aquatic environment

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baoyu Gao</td>
<td>Shandong University, China</td>
</tr>
<tr>
<td>Maosheng Fan</td>
<td>University of Wyoming, USA</td>
</tr>
<tr>
<td>Chihpin Huang</td>
<td>National Chiao Tung University</td>
</tr>
<tr>
<td>Ng Wen Jern</td>
<td>Nanyang Environment &amp; Water Research Institute, Singapore</td>
</tr>
<tr>
<td>Zijian Wang</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Xiu Wang</td>
<td>The Ohio State University, USA</td>
</tr>
<tr>
<td>Xuyang Wang</td>
<td>Queen’s University, Canada</td>
</tr>
<tr>
<td>Min Yang</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Zhili Wang</td>
<td>Beijing Normal University, China</td>
</tr>
<tr>
<td>Xingen Yu</td>
<td>University of Science &amp; Technology of China, China</td>
</tr>
</tbody>
</table>

### Terrestrial environment

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Christopher Anderson</td>
<td>Massey University, New Zealand</td>
</tr>
<tr>
<td>Zucong Cai</td>
<td>Nanjing Normal University, China</td>
</tr>
<tr>
<td>Xinbin Feng</td>
<td>Institute of Geochemistry, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Hongping Hu</td>
<td>Huazhong Agricultural University, China</td>
</tr>
<tr>
<td>Ken-Che Lam</td>
<td>The Chinese University of Hong Kong, China</td>
</tr>
<tr>
<td>Erwin Klumpp</td>
<td>Research Centre Juelich, Agrosphere Institute, Germany</td>
</tr>
</tbody>
</table>

### Atmospheric environment

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peijun Li</td>
<td>Institute of Applied Ecology, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Michael Schloter</td>
<td>German Research Center for Environmental Health, Germany</td>
</tr>
<tr>
<td>Xuejun Wang</td>
<td>Peking University, China</td>
</tr>
<tr>
<td>Lihong Zhu</td>
<td>Zhejiang University, China</td>
</tr>
<tr>
<td>Jinmin Chen</td>
<td>Fudan University, China</td>
</tr>
<tr>
<td>Abdelwahid Mellouki</td>
<td>Centre National de la Recherche Scientifique, France</td>
</tr>
<tr>
<td>Yueji Mu</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Min Shao</td>
<td>Peking University, China</td>
</tr>
<tr>
<td>James Jay Schauer</td>
<td>University of Wisconsin-Madison, USA</td>
</tr>
<tr>
<td>Yuesi Wang</td>
<td>Institute of Atmospheric Physics, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Xin Yang</td>
<td>University of Cambridge, UK</td>
</tr>
</tbody>
</table>

### Environmental biology

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yong Cai</td>
<td>Florida International University, USA</td>
</tr>
<tr>
<td>Henner Holbert</td>
<td>RWTH Aachen University, Germany</td>
</tr>
<tr>
<td>Jae-Seong Lee</td>
<td>Sungkyunkwan University, South Korea</td>
</tr>
<tr>
<td>Christopher Rensing</td>
<td>University of Copenhagen, Denmark</td>
</tr>
<tr>
<td>Bojan Sedmak</td>
<td>National Institute of Biology, Slovenia</td>
</tr>
<tr>
<td>Lirong Song</td>
<td>Institute of Hydrobiology, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Chunxia Wang</td>
<td>National Natural Science Foundation of China</td>
</tr>
<tr>
<td>Gehong Wei</td>
<td>Northwest A &amp; F University, China</td>
</tr>
</tbody>
</table>

### Environmental catalysis and materials

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daguang Yin</td>
<td>Tongji University, China</td>
</tr>
<tr>
<td>Daqiang Yin</td>
<td>The Ohio State University, USA</td>
</tr>
<tr>
<td>Jingwen Chen</td>
<td>Dalian University of Technology, China</td>
</tr>
<tr>
<td>Jianying Hu</td>
<td>Peking University, China</td>
</tr>
<tr>
<td>Guibin Jiang</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Siujin Liu</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Tsuyoshi Nakanishi</td>
<td>Gifu Pharmaceutical University, Japan</td>
</tr>
<tr>
<td>Willie Peijnenburg</td>
<td>University of Leiden, The Netherlands</td>
</tr>
<tr>
<td>Bingsheng Zhou</td>
<td>Institute of Hydrobiology, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Hong He</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Junhua Li</td>
<td>Tsinghua University, China</td>
</tr>
<tr>
<td>Wenfeng Shangguan</td>
<td>Shanghai Jiao Tong University, China</td>
</tr>
<tr>
<td>Ralph Y. Yang</td>
<td>University of Michigan, USA</td>
</tr>
</tbody>
</table>

### Municipal solid waste and green chemistry

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zongwei Cai</td>
<td>Hong Kong Baptist University, Hong Kong, China</td>
</tr>
<tr>
<td>Jiping Chen</td>
<td>Dalian Institute of Chemical Physics, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>Minghui Zhong</td>
<td>Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences, China</td>
</tr>
</tbody>
</table>

### Environmental analysis and method

<table>
<thead>
<tr>
<th>Name</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zixuan Wang</td>
<td>Qingcai Feng</td>
</tr>
<tr>
<td>Suqin Liu</td>
<td>Tsixuan Wang</td>
</tr>
<tr>
<td>Zhengang Mao</td>
<td>Catherine Rice (USA)</td>
</tr>
<tr>
<td>Pu Li</td>
<td>Kuo Liu</td>
</tr>
</tbody>
</table>

---

Copyright© Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. Published by Elsevier B.V. and Science Press. All rights reserved.
Aims and scope
Journal of Environmental Sciences is an international academic journal supervised by Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences. The journal publishes original, peer-reviewed innovative research and valuable findings in environmental sciences. The types of articles published are research article, critical review, rapid communications, and special issues.
The scope of the journal embraces the treatment processes for natural groundwater, municipal, agricultural and industrial water and wastewaters; physical and chemical methods for limitation of pollutants emission into the atmospheric environment; chemical and biological and phytoremediation of contaminated soil; fate and transport of pollutants in environments; toxicological effects of terrorist chemical release on the natural environment and human health; development of environmental catalysts and materials.

For subscription to electronic edition
Elsevier is responsible for subscription of the journal. Please subscribe to the journal via http://www.elsevier.com/locate/jes.

For subscription to print edition
China: Please contact the customer service, Science Press, 16 Donghuangchenggen North Street, Beijing 100717, China. Tel: +86-10-64017032; E-mail: journal@mail.sciencep.com, or the local post office throughout China (domestic postcode: 2-580).
Outside China: Please order the journal from the Elsevier Customer Service Department at the Regional Sales Office nearest you.

Submission declaration
Submission of the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis), that it is not under consideration for publication elsewhere. The publication should be approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out. If the manuscript accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder.

Editorial
Authors should submit manuscript online at http://www.jesc.ac.cn. In case of queries, please contact editorial office, Tel: +86-10-62920553, E-mail: jesc@rcees.ac.cn. Instruction to authors is available at http://www.jesc.ac.cn.