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EDITORIAL

Mine Water Problems and Solutions in China

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Introduction

Mining can adversely affect the quantity and quality of groundwater and surface water in mining areas (Bebbington and Williams 2008; Vidic et al. 2013), threatening the sustainability of water resources (Yang et al. 2013) and the public health of local residents (Li et al. 2016; Wu and Sun 2016). Ecological degradation and health problems due to mine waste discharges have been reported worldwide (Esteller et al. 2015; Njinga and Tshivhase 2017; Wright et al. 2017), attracting attention from both policy makers and researchers.

China is currently the largest coal-producing country in the world (Wu et al. 2018) and the largest user of fossil fuels (Chen et al. 2013; Li et al. 2015); coal consumption was responsible for 63.7% of its total energy consumption in 2015 (Dong et al. 2017). The Belt and Road Initiative proposed by China will lead to faster economic development, at the cost of even greater energy consumption, potentially causing environmental and water resources problems (Howard and Howard 2016; Li et al. 2015, 2017a). China's mine water problems have caused economic losses and endangered human lives. Over 4500 deaths have been reported in China from 2000 to 2014 due to mine water inrush (Wu et al. 2018).

Editing a special issue on the topic of mine water problems and solutions in China has long been a dream of mine since completing my Ph.D., given the scale of China's mine water problems. A good thing is that many Chinese as well as many international mining hydrogeologists are now aware of these problems and are attempting to find feasible and flexible solutions to them (Wu et al. 2014). This special issue has enabled some of China's mine water researchers to share their results and practical experience globally.

Contributions to This Special Issue

This special issue of *Mine Water and the Environment* presents some of China's latest mine water related research. Over 30 submissions were received and 18 technical papers went through the peer review process in time and have been included. They present new approaches and/or novel concepts in mine water studies and provide fresh insights to some current and emerging mine water problems. These papers can be roughly classified into three groups based on their topics: mine water inrush and disaster, mine water quality and contamination, and techniques for mining and mine water studies.

China is more seriously impacted by mine water inrush than anywhere else in the world (Wu et al. 2018), which, along with the many fatalities associated with it, explains why so many submissions to the journal *Mine Water and the Environment* address this topic. In this special issue, we have seven technical papers discussing mine water inrush events or an inrush-related topic. Li et al. (2017b) established a set-pair analysis based model for water inrush risk assessment, while Lu et al. (2018) adopted an integrated method based on the fuzzy analytic hierarchy process and entropy for the assessment of the bed-separation water inrush risk. Though the approaches used by the two research teams are different, their case studies show that the two approaches were both applicable, depending on hydrogeological conditions of the specific mine. Wang et al. (2017) proposed using transient electromagnetic exploration (TEM) to predict and prevent potential groundwater inrush through the coal seam floor. The method would be useful in mine water inrush assessment and prevention.

Liu et al. (2017), Zhang et al. (2017), and Xu et al. (2018a) present case studies on overburden failure, water

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and sand inrush, and the height of the water-flowing fractured zone. These case studies provide practical experience for dealing with similar problems in other coal mines. The work of these authors also demonstrates the value of simulations as a mine water research tool. Cui et al. (2018) discussed the largest water inrush disaster in China, which occurred on August 7, 2005 at the Daxing coal mine, and caused 121 deaths. They described the process and features of the inrush, comprehensively analyzed the key controlling factors, and proposed ways to deal with such large disasters. These studies provide alternative options for assessing and predicting the risk of mine water inrush and should help reduce the number and severity of future inrush disasters.

Five technical papers belong to the second topic, mine water quality. Mining can certainly affect the geochemical characteristics and the geochemical evolution of groundwater, though in many mining areas, natural processes dominate the geochemical evolution of groundwater (Li et al. 2018a). Li et al. (2018b) investigated the hydraulic connectivity of different aquifers affected by coal mining using hydrochemical approaches, as well as the hydrogeochemical evolution and water quality of the groundwater. Similarly, Xu et al. (2018b) compared groundwater quality before and after coal mining. Both studies illustrate how mining can directly affect the hydrodynamics of groundwater in mining areas, which in turn influences how water quality evolves. Additionally, mine water is usually associated with various contaminants, such as trace metals, fluoride, or arsenic, which can adversely affect human health and reduce the suitability of the water for various uses (Wu et al. 2017a). Liu et al. (2018) presented a cumulative evaluation index based on Fick's law to assess and predict the transport of mine water contaminants in the Chenqi Basin, China. Their work suggests that mining can have varied influences on phreatic water quality in different regions.

Li et al. (2018c) assessed the effects of using coalbed methane co-produced water for irrigation. They found that irrigation with this water affects soil pH and sodium adsorption ratio (SAR), but that the metals dissolved in the water did not hurt the plants and soil. Finally, the potential failure of tailings released from an impoundment during a flash flood, which in addition to contaminating water and soil, can kill and injure people downstream, was investigated by Wu and Qin (2018). Their work indicates that a relatively inexpensive measure could be used to prevent one of the common causes of tailings dam failure, overtopping. Given the number of tailings dam failures around the world, and the downstream devastation that results, this paper may interest many readers of this journal.

Advanced techniques for mining and new methodologies for mine water studies are always desired by the industry and the scientific community, and are addressed in this issue with six additional technical papers. Sun et al. (2017) proposed a roadway backfill approach with aeolian sand, fly ash, and Portland cement as the backfill materials. Their theoretical analysis, experiments, and physical simulations indicated that this approach would permit mining while preserving the existing surface water in China's sensitive western eco-environmental area. Gui et al. (2018) presented some techniques to identify bed separation and bed separation water, which can threaten safe coal mining, and reported the successful use of these techniques in a coal mine in eastern China.

Determining the water source is also very important in preventing water inrush disasters. Xu et al. (2018c) proposed an approach to identify the source of water using comprehensive fuzzy evaluation of the groundwater ions. Similarly, Qiao et al. (2017) suggested using hydrochemical and hydrodynamic data conjunctively to identify water-rich locations in a mine area. Gu et al. (2017a, b) established a spatial mixing model that uses hydrochemical and isotopic data to analyze groundwater dynamics and identify water sources. Their work shows how, by linking hydrochemical and hydrodynamic data, we can better understand groundwater circulation, and thereby prevent mine water disasters.

Final Remarks

Though Chinese researchers have achieved remarkable accomplishments, challenges and problems remain. In particular, there is still a long way to go to achieve sustainability between anthropogenic activities and nature (Li et al. 2017a). Some of the existing problems and challenges are summarized here to draw attention from researchers and decision makers.

- Mine water research is becoming more complicated due to the combined impacts of environmental changes (e.g. climate change and geological evolution) and human activities (e.g. deeper mining and hydraulic fracturing). This is especially true in northwest China where natural gas, oil, and coal are abundant, but human activities are extensive, and the environment is fragile (Wu et al. 2017b).
- Mines remain a potential source of contamination for a long time, even after closure (Bebbington and Williams 2008). However, mine closure planning in China is still very poor and there is inadequate monitoring of mined areas to address the long-term impacts from tailings piles, waste rock dumps, and open pits.
- The number of mine hydrogeologists and technical personnel with related skills is still inadequate, and the cultivation of mine water students and training of mine water workers are not well planned (Wu 2014). This will affect the continuity of mine water research and our effectiveness in solving mine water problems.

- Rapid water source discrimination, the availability of relevant information, and the automation of mine water inrush source identification is still very limited, which affects the efficiency of water source discrimination, which could be used to prevent serious mine water inrush disasters (Zhai et al. 2017).

However, I believe we can solve most mine water problems with advanced science and technology, sound decision making, and continued scientific research. Nothing is impossible to a willing heart. To facilitate the advancement of mine water science and research in China, I suggest that the following aspects be carefully considered.

- The uncertainties associated with mine water research could be reduced by incorporating concepts and techniques from other disciplines. Interdisciplinary and multidisciplinary research must be promoted. For example, metadata and the contextual spatial information gathered and analyzed by geographical information techniques can be used for tracing disaster events (de Bruijn et al. 2018). This technique can be adopted by relief organizations to respond to mine water disasters. If researchers from different disciplines and research fields work together on mine water research projects, many problems can be effectively and efficiently solved.
- Mine water research should not be limited to mine water professionals. The general public should be encouraged to participate in this campaign. Citizen science is an essential supplement to professional science (Li et al. 2017c), which can fill data gaps when monitoring is insufficient. For example, citizens can be trained to monitor water quality and water flow after mine closure.
- Increased international collaboration is also needed to solve China's mine water problems and boost its mine water research and should be enhanced (Chen et al. 2018; Li et al. 2018d). The International Mine Water Association (IMWA) has proven to be a good source of collaboration. Experienced mine hydrogeologists in IMWA can help China to solve its many mine water problems.
- The next generations are the hope of our future (Li et al. 2017d). Therefore, education resources and training opportunities are required. China recently implemented a Double First Class University Plan aiming at creating world class universities and disciplines by the end of 2050 (Anonymous 2017). In the context of this plan, disciplines that are sponsored as first class will receive more government investment, while unsponsored disciplines may be disadvantaged, because educational resources are limited, especially in western China (Li and Qian 2018). Although hydrogeology and mine water related disciplines in China are not generally considered first class disciplines, they are very important. Enough investment should go to the non-first class disciplines, including hydrogeology.
- Water systems can be affected by mining activities, even at an early stage of mine production (Li et al. 2013). Scientific research is needed to predict, prevent, and solve mine water problems at all stages of mining. China's central government (e.g. Ministry of Science and Technology of China) and agencies (e.g. National Natural Science Foundation of China) should support more mine water related research. With sufficient financial budgets for scientific research, China's scientists can develop more effective techniques and methodologies to solve its mine water problems.
- Wise policies regarding economic development, energy utilization, and mine exploitation by the local and central government are necessary. China should find a more sustainable way of developing its economy.

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