

Mine closure in China – problems, strategies and forecasts

J.W. Zhou School of Environmental Studies, China University of Geosciences, China; and Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Canada

A.G. Zhou School of Environmental Studies, China University of Geosciences, China

D. van Zyl Norman B. Keevil Institute of Mining Engineering, University of British Columbia, Canada

Z.H. Tang School of Environmental Studies, China University of Geosciences, China

J.W. Bu School of Environmental Studies, China University of Geosciences, China

Abstract

There are currently 112,983 mines in China, among them are 75,748 open pit mines, and one third of all the mines will be closed within ten years. The main challenges for mine closure include physical stability problems, land destruction, loss of water resources, water and soil pollution, and large volume waste. Many pieces of legislation and regulations concerning mine closure have been issued by different government departments to protect the environment. From 2001 to 2008, CNY 15.9 billion (equivalent to US\$ 2.373 billion) was spent to deal with the recovery and management, 1,418 mine sites were restored and remediated relying on these funds, more than 80% of the money was used to control geologic hazards and land reclamation at mine sites. China has established 61 national mine parks on mine sites, and 18 of them have been opened to the public by December of 2010. In the "Twelfth Five-Year Plan" (2011–2015) published on March 16, 2011, China has set the target of "green mining" and environmental protections by the mining industry. Based on the current situation in China, the following are high priorities in the opinions of the authors: (1) More practical laws and regulations should be developed and implemented to improve mine closure practices, strengthening regulatory enforcement is important for future mine closure and reclamation. (2) Consistent application of the "polluter pays principle" should be adopted. (3) An interagency report review board, governed by the Ministry of Land and Resources, should be established to provide comprehensive review mechanisms. (4) Research should be conducted on new mining and processing technologies for the mining industry as well as reclamation technologies for mine closure projects. (5) Companies should establish special management units and monitoring systems to deal with mining environmental protection. (6) Community committees should be formed in all the mining regions to facilitate participation of civil society in the decision-making processes.

1 Introduction

By 1999, 171 kinds of minerals have been discovered in China, and the reserves for 155 minerals have been investigated. Among them are eight energy minerals, 54 metallic minerals and 90 non-metallic minerals. There are more than 200,000 mine pits in the whole country, nearly 20,000 of them have been surveyed through detailed investigation. According to the national mine geo-environmental survey in 2005, there were 9.817 million mine employees in China that mined 8.212 billion tons of ore (Zhang et al., 2009).

Ten of China's provinces are rich in mineral resources: Shanxi, Hubei, Hunan, Jiangxi, Shandong, Jiangsu, Guangdong, Ningxia, Shaanxi, and Guizhou. Among the 112,983 mines surveyed before 2005, 75,748 of them are open pit mines and 37,235 are underground mines. The status of these mines is as follows: 97,512 are operating mines, 3,775 are under construction, and 11,696 have been closed (Liu, 2009).

2 Challenges for mine closure

With the development of Chinese mining industry in the past 50 years, more than 300 new cities were built that are completely dependent on nearby mines and many people moved to these cities for a livelihood. However, after years of exploitation, more and more mines are becoming exhausted. At the same time a large number of environmental issues continue to emerge, and the environment surrounding the mines is

changing for the worse. This is the biggest challenge with respect to sustainable development for the Chinese mining industry.

According to the data from Ministry of Land and Resources (MLR), mining environmental problems include physical stability problems, land destruction, loss of water resources, water and soil pollution and large volume mine waste (Jiang et al., 2005).

Physical stability problems are defined as the deformation and failure of rock and soil caused by mechanical reasons, including slope failures and underground mining issues. These include landslides, structural collapse, debris flow, subsidence, development of ground fissures, etc. Mining geologic hazards are defined as significant physical stability problems that can result in significant economic loss or the loss of life or injury of the public. Land destruction is defined as the loss or partial loss of their original functions of farmland, woodland, grassland and other land resources (Xu, 2005). The following sections provide further statistics related to these major environmental problems.

2.1 Physical stability problems

In 2005 a survey showed that there were more than 12,379 mining geologic hazards which caused 4,251 cases of loss of life or injuries at a direct economic loss of CNY 16.16 billion (equivalent to US\$ 2.412 billion). Among these hazards there were 4,489 cases of land subsidence, 3,019 cases of ground fissure, and 3,016 cases of landslides, collapses and debris flow (Tan, 2010).

Land subsidence is the most serious problem in many coal mining districts. Shanxi is the biggest coal production province in China and more than 500 residents died as a result of land subsidence. In Heilongjiang, the surface of the city of Qitaihe sunk 2.5 m to about 6.5 m at one coal mine up to 2005, while the surface area impacted by subsidence at the Jixi coal mine sites was 193 km² (Zhang et al., 2009).

2.2 Land destruction

In 2005, the total area disturbed by mining in China was 5.819 million ha, it was estimated that one quarter of this area was completely destroyed, i.e. a total area of about 1.439 million ha. Of the destroyed area there were 2.956 million ha of arable lands, 1.365 million ha of woodlands, 1.638 million ha of grasslands, and 0.843 million ha of other land designation.

2.3 Loss of water resources

The mining industry uses large quantities of water. A large volume of groundwater is pumped to surface to reduce the water level in underground mines. In China, the total amount of water pumped from mines is about 4.294 billion cubic meters every year and the water used in mineral processing is about 1.8 billion cubic metres every year. Discharges from the mining industry represent over 10% of the total wastewater discharge in China in 2005 (Tan, 2010). In Shanxi and Inner Mongolia, many people do not have enough water for daily consumption as a result of the gradually exhausted water resources in villages and cities because of mining.

2.4 Water and soil pollution

Water and soil pollution has become the most serious environmental problem in China. Mining is the major source of environment pollution, including acid rock drainage (ARD), contaminated drainage and discharge, and large volume waste (heap leach waste, waste dumps, etc.). In one such case the clay liner of the tailings impoundment developed a breach as a result of continuous rainfall on July 3, 2010 at the Zijinshan copper mine in Shanghang, Fujian province owned by the Zijin Mining Group. This resulted in 9,100 cubic metres of acidic water with high concentrations of copper and sulphate flowing into the Tingjiang River, polluting a section of the river and killing 1,890 tons of fish.

2.5 Large volume mine waste

Large quantities of mine waste result in soil and water pollution and land destruction. According to statistics, up to 2005 the accumulated waste was 21.96 billion tons most of which consisted of waste rock and tailings.

The proportions of mine waste from energy mining (e.g. coal), metal mining and non-metal mining are 39%, 52% and 9% respectively.

3 Countermeasures by the Chinese government

3.1 Mine closure legislation and regulation

3.1.1 Current situation of legislation and regulations

The responsibility to regulate and govern mineral resources, mining activities, environmental protection, and land reclamation/rehabilitation lies primarily with the Ministry of Land and Resources (MLR, 2009), which is under the jurisdiction of the Chinese State Council. Also, there are other ministries or departments administering mine closure and reclamation, such as the Ministry of Environmental Protection (MEP) and the Environment and Resources Protection Committee (ERPC).

The promulgation of the Provisions on land reclamation in 1988 marked the commencement of legalisation and standardisation of mine land reclamation programs in China. It is the first regulatory document specifically designed for the reclamation of damaged land including mined land (Cao, 2007; Chen, 2010). With China's rapid economic development and the intensity of mining activities, many new legislation and regulations were issued by different government departments. Table 1 provides a listing of legislation, regulations and policies related to mine closure (Interdisciplinary Research Group, 2010).

Table 1 Regulations, laws and policies pertaining to mine closure and reclamation in China

Title	Promulgation Date	Issuing Department*	Relevant Articles/Chapters
Provisions of the P.R. China on Land Reclamation	09-11-1988	SC	Article 2, 3, and 4
Environmental Protection Law of the P.R. China	26-12-1989	SCNPC	Chapter 1(2), 1(7); Chapter 4(24), 4(25), 4(26)
Law of the P.R. China on Safety in Mines	07-11-1992	SCNPC	Article 19
Decision of the State Council on Several Issues Concerning Environmental Protection	03-08-1996	SC	Article 4; Article 6
Mineral Resources Law of the P.R. China	01-10-1986 revised 29-08-1996	SCNPC	Chapter 2(15); Chapter 2(21); Chapter 4(32)
Regulation of Environmental Management on Construction Project	29-11-1998	SC	
Regulation on the Implementation of the Land Administration Law of the P.R. China	04-01-1991, revised 27-12-1998	SC	Articles 16, 23, and 28
Law of the P.R. China on Appraising of Environment Impacts	28-10-2002	SCNPC	Articles 10, 16, and 17
Regulation on the Prevention and Control of Geologic Disasters	24-11-2003	SC	
Land Administration Law of the P.R. China	25-06-1986, revised 28-8-2004	SCNPC	Article 5

Title	Promulgation Date	Issuing Department*	Relevant Articles/Chapters
Law of the P.R. China on the Prevention and Control of Environmental Pollution by Solid Wastes	30-10-1995, revised 29-12-2004	SCNPC	Article 36
Notice of the State Council on Issuing the “Eleventh Five-Year Plan” for National Environmental Protection	22-11-2007	SC	Part III: Chapter 3(3), Chapter 4(5); Part V: Chapter 4(2), Chapter 5(3)
Regulation on Land Survey	07-02-2008	SC	
Technical Standards of Land Reclamation (industry standard)	Trial 09-2008	MLR	Part II
Notice of the State Council on Issuing the Outline of the National Overall Planning on Land Use (2006–2020)	06-10-2008	SC	Chapter 3(2); Chapter 4(2), 4(4); Chapter 5(2), 5(3)
Standard of Programming on Mining Geo-environmental Protection and Reclamation	DZ/T223-2009	MLR	All
Provisions on the Protection of the Geologic Environment of Mines	02-03-2009	MLR	All
Regulation on Environmental Impact Assessment of Planning	17-08-2009	SC	Article 11
Regulation on Land Reclamation	05-03-2011	SC	Chapter 1(3); Chapter 2(10), 2(13), 2(14)

* Remarks: SC-State Council; SCNPC- Standing Committee of the National People's Congress; MLR - Ministry of Land and Resources.

3.1.2 The shortcomings of legislation and regulations

The following shortcomings of the legislation and regulations for mine closure are based on the experience of the authors as well as the literature.

1. The promulgation of regulations and legislations is not enough. Not only the governments, but also many companies are aware of environmental protection in mining operations and related activities. Some local governments only focus on the immediate outcomes of economic development and they do not care about the environmental benefits and environmental protection. Some companies are just concerned about their economic interests and do not invest money to protect the environment (Liang, et al., 2007).
2. The regulations and legal systems for mining and the environment are not perfect. From Table 1, it is interesting to note that there were just a few of the chapters and sections concerned with environmental protection and land reclamation before 2005. This is one of the main reasons that there are so many environmental issues at mine sites and explains why these impacts are so severe in many cases (Jiang and Liu, 2005).
3. The responsibilities and relationships among the different ministries or departments responsible for mining environmental controls are not clear in most of the legislation and regulations. Before 2000, mineral exploration was administrated by more than 10 departments. It was difficult to distinguish the responsibilities between these different departments, and it was also difficult to regulate the behaviour of the mining companies effectively.
4. In recent years the government of most provinces tried to establish a financial assurance program for mine closure and reclamation. However, there are many inconsistencies among the provinces'

provisions, as manifested by implementation by the sector, cost estimation, scope of application, etc. As a result there is not much optimism about their successful implementation (Liu, 2008).

3.2 Research and practice of mine closure and reclamation

3.2.1 Survey and assessment of national mine geological environment

Under the unified arrangement and deployment of MLR, a survey and assessment of national mine geological environment was initiated by most provinces in 2002. That was the first nationwide and comprehensive survey on mine environmental issues in China.

This survey included three levels: (1) nationwide through investigations in the provinces (direct-controlled municipal and autonomous regional governments); (2) comprehensive survey in 6 large regional areas, North China, Northeast China, Northwest China, Southwest China, Central South China and East China; (3) special investigations in typical areas, such as coal mining in Shanxi, Shaanxi and Inner Mongolia, the gold ore zone in Xiao Qinling, etc. By the end of 2005, this survey was basically completed. This established the database for the national mining environment (Xu, 2008).

3.2.2 Supervision and management of mine closure

As shown in Table 1, many laws, regulations, and policies have been issued for protecting the environment at mine sites. The most important with respect to mine closure are as follows: (1) financial assurance provisions for the closure and reclamation of mine sites was formally tabled; (2) the provisions for the protection of the geologic environment of mines was promulgated; (3) the national and provincial plans for protecting the mining environment and reclamation were completed; (4) and some standards of protecting the mining environment and reclamation were formulated.

According to the national plan, 73 priority sites with a total area of 286,100 km² were selected for rehabilitation in recent years. And the plan of mine reclamation is also formulated in some cities or counties on the basis of the national plan and provincial plan.

3.2.3 Funding for mine closure

Because the policies for mine reclamation were issued in 2009, some companies did not set aside enough financial security to restore the environment. In some areas, because of bankruptcy or disintegration, no company was found to be responsible for the closure of sites. It was found that there was not enough money from companies for reclamation due to many historical debts. Therefore, mine closure and reclamation of old mine sites would need funding from the governments (Cheng, 2010).

From 2001 to 2008, RMB 15.9 billion (equivalent to US\$ 2.373 billion) was spent to deal with the reclamation and management of historic properties. Among them, 5.0 billion was from central finance, 6.2 billion was from local finance and 4.7 billion was from companies (Liu, 2009). During this period, 1,418 mine sites were restored and remediated, but more than 80% of the money was used to control geologic hazards and complete land reclamation at mine sites. Small amounts of money were used for water and soil pollution. Since 2009, the central and local governments are increasing the funds on yearly bases. In 2009, the fund from central finance was RMB 3.6 billion, and in 2010 it was RMB 5.7 billion. At the same time, the funds from provincial budgets and companies also increased rapidly.

3.2.4 Technologies of mine closure and reclamation

In the last twenty years, with the development of the Chinese mining industry, tremendous progress has been made on mining technologies for various types of mines. But the progress of closure technologies is only manifested in the treatment of physical stability problems and land remediation. The technologies for revegetation and restoration for mine sites are developing. Some technologies of soil and groundwater restoration for polluted sites are still in the pilot phases.

The primary closure approaches are used in the following: (1) in the control of physical stability problems, such as landslides, debris flows, fissures, land subsidence, etc. (2) for land restoration, including placement of soil covers, soil amelioration, reforestation and revegetation with grass, etc. (3) for waste re-utilisation,

and (4) for construction of mine parks in some mining cities. Among these approaches, physical stability was the focus for the past five years. Land reclamation and water restoration will receive the major focus in the next few years.

3.3 National Mining Parks of China

The establishment of National Mining Parks is a new concept that has happened in the last 10 years. For the purpose of mine reclamation, ecological restoration and local economic development, the Ministry of Land and Resources issued the National Mining Park (No. 2004-256) notice to the provinces (including direct-controlled municipal and autonomous regional authorities) in November of 2004. So far 28 National Mining Parks have been approved for construction in 2005, and 33 more were approved in 2010. There are now 61 National Mining Parks in China, among them, 17 National Mining Parks have been opened to the public. According to mineral type, there are 18 coal mines, 11 gold mines, 7 copper mines, 5 iron mines, 4 construction stones; plus others including an oilfield, gypsum mine, salt mine, diamond mine, nickel mine, muscovite mine, and mercury mine, etc.

Among the mining parks that are now open, the economic benefits of the Suichang Gold Mine National Mining Park in Zhejiang province is the best example of regeneration to date. The construction on this park started in July of 2006 and it opened on December 18, 2007. The total area of the park is 33.6 km², and within that 6.3 km² is core scenic area. The total investment to establish this park is RMB 65.18 million (equivalent to US\$ 9.728 million). According to company claims, they have recovered the investment by now through admission fees; the number of visitors reached 200,000 at the end of 2010.

3.4 The provisions for mine closure and reclamation in China's "Twelfth Five-Year Plan"

In the "Twelfth Five-Year Plan" (2011–2015) published on March 16, 2011, China has set the target for environmental protection and economic development. That is "green development—accelerating a resource-conserving, environmentally-friendly society".

In section 4 of chapter 22, section 1 of chapter 23, chapter 24 and section 3 of chapter 25, there are many detailed plans for mine closure and reclamation. These include: (1) Developing green mining; strengthening the conservation and comprehensive utilisation of mineral resources. The recovery rate of exploitation and mineral processing, the comprehensive utilisation rate will be constantly improved through advanced technologies. (2) Strengthening mine geo-environmental recovery and land reclamation; improving the financial assurance system for restoration and treatment of mining environment. Law enforcement and supervision of geological environments will be strengthened. (3) Strengthening the comprehensive management of heavy metal pollution. Some selected rehabilitation pilot projects will be developed to improve the situ remediation technology. (4) Improving the laws, regulations and standards of environmental protection; strengthening environmental monitoring, the capacity of early warning and emergency response. (5) According to the principle of "developer is the protector, benefiter is the compensator", accelerating the establishment of ecological compensation mechanism. The reserve fund system of sustainable development will be promoted for resource enterprises.

4 Recommendations and the future of mine closure

4.1 Opinions and recommendations

Environmental controls of mine closure are presently receiving considerable attention in China. However, like any developing economy, there may often be a lag in development and implementation. Also, China cannot copy all the experiences and lessons from other developed countries. The following are high priorities in the opinions of the authors:

1. More practical laws and regulations should be developed and implemented to improve mine closure practice. At the same time, strengthening of enforcement is particularly important for future mine closure and reclamation.

China has many laws and regulations focused on mining and environment protection, so the focus in regulatory updates is to improve their applicability and implementation. For instance, the Environmental

Protection Law of the P.R. China (1989) should be amended. Mine environment should be highlighted in many sections to indicate its importance. Management responsibilities for the mining environment should be distinguished clearly among MLR, MEP and other ministries or departments. The Mineral Resources Law of P.R. China (1996) should also be amended. The substantive content of mining environmental protection should be expanded into this law and set up as a separate chapter.

The main responsibility for enforcement lies with the government; the different levels of government should strengthen their own management as well as that of government owned companies. The elimination and prosecution of corruption is more important than anything else. For example, according to the Provisions on the Protection of the Geologic Environment of Mines (2009), three reports should be submitted before operations of a mine: mineral exploitation programme, environmental impact assessment and a programme of mining geo-environmental protection and reclamation/ rehabilitation. If one of these three reports cannot pass the regulatory review, the mining activities should not be developed. But in fact, some mines usually operate without these reports or provide them after the start of operations. This happens mainly because of lax supervision and corruption.

2. Consistent application of the “polluter pays principle” should be adopted. This also agrees with the principle of “developer is the protector, benefiter is the compensator” which is mentioned in the “Twelfth Five-Year Plan” (2011–2015).

Legislation should adopt the “polluter pays principle” to address and make provisions for mitigation and compensation of ecological damage (loss of habitat or biodiversity). If the company fails to comply with the regulatory requirements and does not undertake the mitigation measures despite a legal notice, one or more of the following actions can be taken: a) order the cessation of mining activities, b) use the financial assurance deposit in part or full to complete the work deemed necessary after cessation of activities, and c) terminate the license to operate.

In recent years, financial assurance deposits for restoration and reclamation has been established in some provinces, but it is still not completely developed to deal with mining environmental issues. The reasons are related to the inaccurate estimates for obtaining the value of the financial assurance (Liu and Zheng, 2004). The true costs of closure and reclamation should be assessed through further research and application, and the calculation procedures should be confirmed in legislation and regulations.

3. An interagency report review board should be established to provide a comprehensive review mechanisms; this board should be governed by MLR. The main responsibility should be the approval of reports of mining geo-environmental protection and reclamation as well as training the professionals who are engaged in mining environmental protection.

Currently the department of geo-environment of MLR is responsible for approving the reports on mining geo-environmental protection and reclamation. This is done as an additional service as it is not the main focus of this department. In some cases when some important mines submit their reports of mining geo-environmental protection and reclamation, this department will organise an appraisal meeting with report review by outside experts. This is a difficult task for the organiser and experts and has led to many abuses. Doing this review as a part time assignment does not work and it is necessary to appoint full-time specialists and coordinating staff.

The preparation and review of the reports of mining geo-environmental protection and reclamation/ rehabilitation is a new requirement. MLR should strengthen the training of technicians and develop strict approval procedures. This should be an important priority for the government.

4. Research should be conducted on new mining and processing technologies for the mining industry as well as reclamation technologies for mine closure projects. The best way to accomplish this is to combine imported technologies with local practices.

China has few advanced technologies in underground mining and mineral processing specifically focused on environmental protection. It is important to strengthen technology innovation such that production costs can be reduced and environmental damage prevented. The technology innovation includes mining technologies, mineral processing technologies and mining environmental management technologies. Research should also be conducted in mining environmental protection. New technologies related to land reclamation and ecological restoration should be imported and further developed. Some of these technologies include

bioremediation, wetland treatment systems, cover technologies and geochemical engineering remediation technology.

Pilot projects for closure and reclamation should be carried out in different climates and at different types of impacted mine sites. If possible, a database of all mines should be established to effectively guide the work related to protection of the mining environment.

5. Companies should establish special management units and monitoring systems to deal with mining environmental protection. Internal audits and other procedural steps must become an important part of mining environmental protection for all mining companies. It's also an important manifestation of corporate social responsibility.

The government should emphasise the importance of mining environmental protection in the form of legislation. For mining companies the importance of environmental protection should be the same as that of mining and mineral processing. The responsibilities of the mining environmental sector include environmental monitoring, closure planning, sewage treatment, environmental research, land reclamation, ecological restoration, soil amelioration, revegetation, environmental emergency planning and implementation, etc.

Mine closure planning and implementation are a major task for the environmental departments in mining companies as the implemented closure should be robust in the long term. Mine closure has not been done well in China in the past and it should be the focus of government supervision in the future.

6. Community committees should be formed in all the mining regions to facilitate participation of civil society in the decision making processes. Most disputes can be resolved through consultation between the community committees and mining companies without depending on government mediation.

In the past ten years, with the development of mining industry, more and more conflicts and petitions originated in many mining areas. Some people even died as a result of these incidents; such conflicts have become a major issue of mining development in China. One of the main reasons for these conflicts is the lack of formal engagement in many local communities that prevented the discussion of the controversial issues with mining enterprises and governments (Song and Zhou, 2006).

Therefore it is essential that community committees be formed in all the mining regions, this should also be confirmed in the form of legislation. The community committees should be given legal rights and status to obtain practical benefits for the local residents. In doing this, there will be a higher probability that the mining environment will be protected and restored.

4.2 The future of mine closure

Obviously, mine closure is not only controlling physical stability problems and land remediation as the Chinese government has done in the past 10 years. China has a long way to go in full implementation of mine closure and reclamation and there are also many detailed activities that should be undertaken in the future.

Based on the above analyses the most important issues for mine closure and reclamation in China are strong management commitment and enforcement of legislation and regulations. It is expected that in the next 10 years, if the Chinese government can effectively strengthen the implementation of mining environmental practices, the mining environmental quality will reverse from the present deteriorating conditions and will achieve fundamental improvement. Otherwise, if this is not accomplished then the results will be disastrous.

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