Resources, Conservation and Recycling 83 (2014) 24–33

Contents lists available at ScienceDirect

Resources, Conservation and Recycling

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

Full length Article

Reduction and utilization of coal mine waste rock in China: A case study in Tiefa coalfield

Gangwei Fan[a,*], Dongsheng Zhang[a,b], Xufeng Wang[a]

[a] School of Mines, Key Laboratory of Deep Coal Resource Mining, Ministry of Education of China, China University of Mining & Technology, Xuzhou 221116, China
[b] College of Geology and Mineral Engineering, Xinjiang University, Urumchi 830046, China

ARTICLE INFO

Article history:
Received 1 April 2013
Received in revised form
27 November 2013
Accepted 2 December 2013

Keywords:
Coal mine
Waste rock
Mine design
Backfill

ABSTRACT

In China, coal mine waste rock (CMWR) produced during coal mining and processing is still increasing significantly as a result of coal production which has huge environmental impact. CMWR reduction and utilization is a major issue for coal enterprises and government to reduce the surface footprint and the public environmental impact. Tiefa coalfield, an old coalfield with 60 years of coal exploitation, was selected as a case to study the methods to minimize the environmental impacts of CMWR piles in a short period. We argue that a systematic design on CMWR utilization is needed on the basis of a usage evaluation which takes consideration of CMWR source, compositions, and proximate analysis. Mine design is crucial and the base for reducing the CMWR generation at the headstream. Placing roadway into coal seam rather than rock, panel optimization, and parametric analysis for mining technique were conducted in Tiefa coalfield. A promising technology of CMWR backfill under the ground was employed with a resultant increase of coal recovery rate. The surface CMWR recycling depends on brick making, electricity generating, and rehabilitation of subsided land. The practice of the presented methods indicates that the CMWR piles on Tiefa coalfield may disappear in 3 years, which could significantly reduce the environmental impacts of CMWR dumps. The technologies conducted in Tiefa coalfield developed a model of CMWR reduction and utilization for Chinese coal mines.

1. Introduction

In China, coal mine waste rock (CMWR) produced in coal mining and processing is the greatest source of industrial solid waste in terms of production, accumulation volume, and occupied area. There are about 4.5 billion tons of CMWR stockpiled into more than 1700 waste dumps which occupied 150 $km^2$of land (Bian et al., 2009; Zhao et al., 2008). Furthermore, it is estimated that the annual production of CMWR is more than 315 million tons for underground coal mining (Liu and Liu, 2010). The traditional CMWR management by dumping in cone-shaped heaps may leave environmental, social and economic impact for thousands of years (Bell et al., 2000; Franks et al., 2011; Glauser et al., 2005; Szczepanska, 1999). The CMWR dumps may cause environmental problems in many different ways, such as poison releasing into soil, groundwater, or surface water, poisonous gas emitting after the spontaneous combustion, or nuclear pollution (Hao et al., 2009; Lambert et al., 2004; Liu and Liu, 2010; Martinez et al., 2007; Meck et al., 2006; Querol et al., 2008; Ribeiro et al., 2010; Tiwary, 2001). More seriously, landslides or even explosions sometimes occur in the dumps, which may directly injure or kill people. Fig. 1 shows an explosion accident occurred in a CMWR dump in China in 2005 with 8 persons dead and 122 persons injured (Wang et al., 2008).

Tiefa coalfield was selected as a case to study the CMWR reduction and utilization in China. Tiefa coalfield is an old mining area with over 60 years of coal exploitation. In 2008, 16 CMWR stockpiles stood in 8 coal mines and about 1.23 km^2 of land were resultantly occupied. The CMWR inventory had been up to 31.76 Mm^3 by 2006 with an average increase of 5.50 million m^3 per year. A new stockpile will appear in 8–10 years and 20 million Yuan (about 6.13 Yuan per US dollar) will be spent. The local residents had suffered the environmental impacts of CMWR in a long term. Therefore, a systematic study on how to reduce the CMWR generation and dispose the accumulated stockpiles should be conducted to avoid underground CMWR discharged to surface dumps or new ones.

CMWR reduction and utilization is a systematic engineering, which should take the local conditions into consideration. Basically, in the mine design stage, reducing the CMWR generation should be considered. CMWR reduction from the source is the base of the system for reducing and utilizing CMWR. The CMWR produced

* Corresponding author at: School of Mines, China University of Mining and Technology, Xuzhou, Jiangsu 221116, China. Tel.: +86 516 83103893.
E-mail address: fangw@cumt.edu.cn (G. Fan).

0921-3449/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.resconrec.2013.12.001

Fig. 1. An explosion accident occurred in a CMWR dump.

from underground or ground surface should be disposed in the subsequent processing. Many approaches had been practiced to reuse the CMWR in recent years, for instance, high carbon CMWR was used for power generation, for building material, and so on (Canibano, 1995; Kwolek, 1999; Liu and Liu, 2010; Lottermoser, 2003). However, not every approach can be used to dispose all kinds of CMWR. Most of the existing papers focused on a specific technology or a certain coal mine. Seldom research made a design for a large whole coalfield for CMWR deduction and treatment. Besides the technologies evaluation on the basis of proximate analysis, the locations, the CMWR source, the market, the policy, and the environment effect should be taken into considerations. Reusing so many CMWR piles and avoiding the continuous generation in a time period of 3–5 years is still a great challenge, which should be systematically designed on the basis of a scientific evaluation.

2. CMWR usage evaluations

2.1. CMWR piles distribution in Tiefa coalfield

In 2008, 12 CMWR piles were still growing and the other 4 piles were abandoned. The abandoned piles, 8.03 Mm^3 accumulated in total were Daming No. 2 Pile, Xiaoming No. 1 Pile, Xiaonan No. 1 Pile, and Daxing No. 1 Pile. The total CMWR accumulation in Tiefa coalfield is listed in Table 1. Fig. 2 shows the locations for all the coal mines in Tiefa coalfield.

Table 1
The CMWR piles in Tiefa coalfield.

Coal mine	No.	Occupied area (km^2)	Height/m	Accumulated volume (Mm^3)
Daming(DM)	1	0.09	98	2.88
	2	0.02	42.5	0.425
	3	0.01	40.5	0.1817
Xiaoming(XM)	1	0.11	116.7	4.16
	2	0.02	44.2	0.2358
Dalong(DL)	1	0.12	103.8	4.255
	2	0.13	101.8	4.339
Xiaonan(XN)	1	0.07	55.1	1.362
	2	0.07	97.8	2.233
Xiaoqing(XQ)	1	0.16	85	1.74
	2		83. 4	1.668
Daxing(DX)	1	0.15	85.2	2.018
	2	0.11	98.31	3.348
	3	0.07	52.8	0.528
Xiaokang(XK)	1	0.06	81	1.652
Daping(DP)	1	0.04	65.5	0.737
Total	16	1.23	–	31.7625

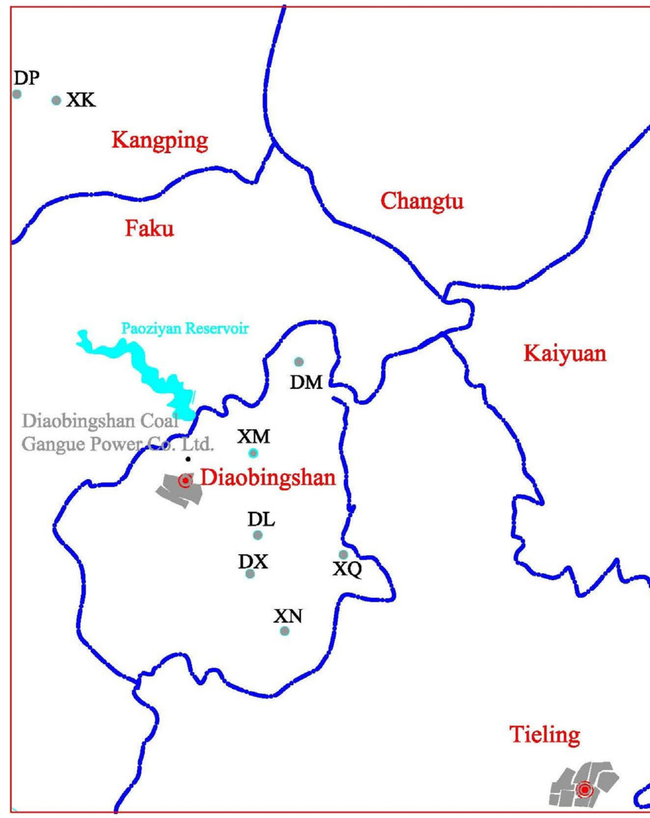

Fig. 2. Locations for all the mines in Tiefa coalfield.

The CMWR is produced by the following three ways: underground roadway driving, underground roadway maintenance, and surface coal washing. The sources of CMWR in Tiefa coalfield in 2009 are shown in Table 2. The CMWR discharged from coal washing took about 80% of the total, which is a great challenge for disposal.

2.2. CMWR compositions and proximate analysis

CMWR is a mixture of many kinds of rock. Generally, CMWR is comprised of inorganic matter and little organic matter. The inorganic matter mainly contains SiO_2, Al_2O_3, Fe_2O_3, and some impurities (see Table 3). The result of proximate analysis for CMWRs from different coal mines is shown in Table 4, which is the basic data for CMWR usage evaluation (Li and Han, 2006).

2.3. CMWR usage evaluation

Researchers present many methods for classifying CMWR usage. In China, CMWR is commonly classified into four sorts by their sources, coal roadway driving, rock roadway driving, coal washing, and post-self-combusted (Wang and Sun, 2004). However, the common classification system, which ignores the essential factor of composition, is still over-simplified and insufficient for usage evaluation. The criterions for CMWR usages based on the compositions are drawn in Table 5, which can be used for evaluating the potential usages of CMWR (Li and Han, 2006).

Based on Tables 3–5, the potential approaches to utilize the CMWR from different coal mines of Tiefa coalfield could be determined as Table 6 shows.