Resources Policy 48 (2016) 112–116

Contents lists available at ScienceDirect

Resources Policy

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

The impact of unregulated ionic clay rare earth mining in China

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ARTICLE INFO

Article history:
Received 15 January 2016
Received in revised form
14 March 2016
Accepted 14 March 2016

Keywords:
Illegal Mining
Market Impacts
Rare Earths
Ionic Clays
Environment

ABSTRACT

The ionic clay rare earth resources in China are the cheapest and most accessible source of heavy rare earths. They are also the most valuable. The Chinese rare earth market has an uncontrolled illegal market segment that represents approximately 40% of the domestic market, which translates to 30% of the global market. This sector of the market pays little or no attention to the environmental damage of their mining and processing actions and, through their unregulated supply, depresses the market price such that external (and in some cases, internal) producers are having difficulties making or maintaining profit margins. It creates significant negative externalities that adversely affects the native environment and the international rare earth market.

1. Introduction

The rare earths consist of the 15 lanthanide elements – lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium (Gschneidner, 1964). Researchers commonly add scandium and yttrium for a total of 17. Rare earths are desirable because they bestow enhanced properties of magnetism, strength and luminescence. Rare earths are gaining in importance in the world economy because of their usefulness in technologically advanced products (e.g. hybrid electric vehicle motors, LEDs, mobile phones, mag-lev trains and lasers) and renewable energy technologies (e.g. wind turbines), national security systems, military and defence applications (Campbell, 2014; Gholz, 2014).

There are four principle rare earth ores that have been successfully processed. These are monazite, bastnasite, xenotime and ionic clays. The only developed ionic clay deposits reside in China. The chemical processing that is associated with non-ionic rare earth ores involves multiple steps and processes, some involving radioactive elements (Hurst, 2010). Extraction and primary processing can be time consuming, contain an element of danger due to the flammability of the chemicals employed, and are costly. Ion-adsorbed rare earths ores occur in a cationic state that are adsorbed into clays. They are not associated with radioactive elements. In 1991, the Chinese government designated ionic clay based rare earth elements as a "special resource for protected extraction" (Wubbeke, 2013)

The rare earth element distribution is different between non-ionic rare earth ores and the ionic clay deposits. This is illustrated in Table 1 where the ionic clay mines are denoted by IAC (Chen, 2014). Table 1 illustrates that in IAC there are higher occurrence of the heavier rare earth elements (from Terbium oxide (Tb_4O_7) to Lutetium oxide (Lu_2O_3), including yttrium oxide (Y_2O_3). This is significant because the heavier rare earths also are the higher valued rare earths. This is illustrated by Fig. 1 (Chen, 2014).

Fig. 1 shows the weighted average value per tonne of separated rare earth oxide of the selected mines output (Chen, 2014). This creates a favourable situation for the extraction of rare earths from ionic clays. They are easier to process, do not have associated radioactive elements, and are more valuable. These three factors contribute to the unregulated (illegal) rare earth mining of ionic clays in China. The Chinese refer to ionic clay miners in three ways: white, grey and black. White miners are fully regulated by the Chinese government. They follow governmental environmental guidelines for the extraction and processing of ionic clays and are not the subject of this paper. It is the grey and black miners that lay outside government management. The grey and black miners are the unregulated (illegal) miners and are the subject of this paper.

2. Illegal miners

Potential profits for unregulated mining can be significant. According to InvestorIntel (2012), the low price for the heavy rare earth concentrate (a mix of rare earths) is 20,000 Yuan to 30,000 Yuan per tonne. The illegal miners pay no mining licence fees or royalties, i.e. essentially they are taken for free, with little or no

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http://dx.doi.org/10.1016/j.resourpol.2016.03.003
0301-4207/

Table 1
Rare earth concentrations of selected minerals across the major producing mines.

REO	Mountain Pass, USA	Mount Weld, Australia	Bayan Obo, China	MaoNiuPing, China	Weishan, China	IAC,China
La_2O_3	33.20%	23.88%	25.00%	31.49%	32.90%	27.56%
CeO_2	49.10%	47.55%	50.72%	47.67%	48.65%	3.23%
Pr_6O_{11}	4.30%	5.16%	5.10%	4.11%	4.39%	5.62%
Nd_2O_3	12.00%	18.12%	16.60%	12.96%	12.70%	17.55%
Sm_2O_3	0.80%	2.44%	1.20%	1.47%	0.73%	4.54%
Eu_2O_3	0.10%	0.53%	0.18%	0.26%	0.10%	0.93%
Gd_2O_3	0.20%	1.09%	0.70%	0.66%	0.10%	5.96%
Tb_4O_7	0.06%	0.09%	0.01%	0.08%	0.10%	0.68%
Dy_2O_3	0.05%	0.25%	0.01%	0.22%	0.10%	3.71%
Ho_2O_3	0.02%	0.03%	0.01%	0.04%	0.12%	0.74%
Er_2O_3	0.02%	0.06%	0.01%	0.06%	0	2.48%
Tm_2O_3	0.02%	0.01%	0.01%	0.02%	0	0.27%
Yb_2O_3	0.02%	0.03%	0.01%	0.05%	0.11%	1.13%
Lu_2O_3	0.01%	0	0.01%	0	0	0.21%
Y_2O_3	0.10%	0.76%	0.43%	0.00%	0.00%	24.26%

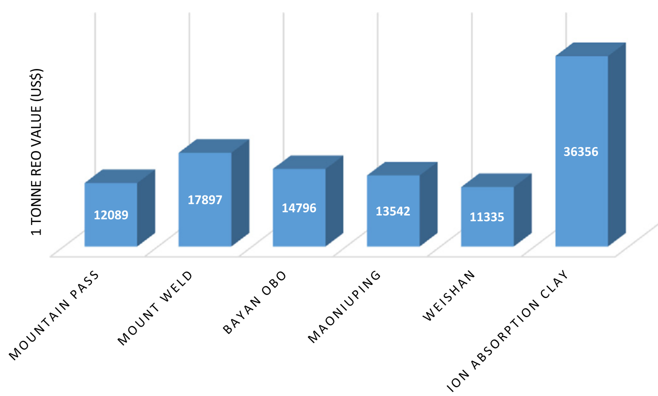

Fig. 1. Weighted average value of major rare earth mines – US$/Tonne REO contained.

regard to the environmental impact. Workers are often employed to work at night (7 pm to 7 am) and the salary paid is approximately 300 Yuan per day. The cost of illegal mining in China is relatively low. The difference between revenues and costs can be substantial. Illegal miners often have agreements with local officials. These agreements are seen as beneficial to the local authorities because the associated value-add activities increase taxes and employment (Wubbeke, 2013). The exact number of tonnes involve in illegal rare earth extraction is unknown. One way to estimate the amount of illegal material is by using evidence from missing exports (Vezina, 2015). As early as 2006 to 2008, there was a discrepancy between Chinese export statistics and corresponding foreign import statistics in the range of 20,000 to 30,000 t annually (Wubbeke, 2013). The most recent and frequently quoted estimates are around 40.000 t (Ebner, 2014; IntevestorIntel, 2012; Stanway, 2015).

Market power discussions have centred on China's external competitors (Golev et al., 2014). The largest being Lynas and, until recently when the Mountain Pass operations were placed on care and maintenance, Molycorp. The production of unregulated mining is greater than the combined production of China's two biggest competitors Lynas and Molycorp, (Roskill Information Services Ltd, 2015). Moreover, if we examine the world market in 2014, the illegal market share is larger than the total external market. Table 2 presents the estimated legal mine production for the world in 2014 (U.S. Geological Survey, 2015).

China currently has an annual rare earth output of around 150,000 t. Approximately 40 percent of the output was produced

Table 2
Country comparisons (2014) Rare earths.

Country	Mine production (tons)	Percentage
China	95,000	86.3%
United States of America	7000	6.3%
Australia	2500	2.2%
India	3000	2.7%
Russia	2500	2.2%
Thailand	1100	1.0%
Vietnam	220	0.2%
Malaysia	200	0.2%
Total	110,000	
Total percentage external to China		13.7%

by illegal mining. It is extensive. For example, in the mountain near Dachong village, 75 km away from the city of Guiping in south China's Guangxi Zhuang Autonomous Region, is a place considered rich in rare earth deposits. On the mountain of about 6.7 ha, there are thousands of holes dug by illegal miners to access the rare earths (China Central Television (CCT), 2015). Unregulated mining in China is the regulated Chinese mining largest competitor.

3. Environment

Unlike the complicated chemical processing that is associated with non-ionic rare earth ores involving multiple steps and processes, some involving radioactive elements (Packey, 2013), the ionic-adsorbed clays are highly weathered ores within which the rare earths have been adsorbed. These rare earth oxides are illegally extracted from the clays by two ways; traditional surface/hill top mining and in-situ leaching.

Surface hill top mining is followed by tank or heap leaching. Usually sodium chloride or ammonium sulphate are employed to take the rare earths into solution. The production of one ton of rare earth oxide from ionic-adsorbed clays, requires 300 m^2 of ground cover and soil to be removed; 2000 t of tailing to be created and 1000 t of wastewater containing heavy metals and concentrated leaching solution to be released into the environment (Su, 2009).

The resultant damage from ionic clay surface mining includes severe erosion, air pollution, biodiversity loss and health problems (China Development, 2011). In the Ganzhou region in 2020 alone, the impact was the destruction of 153 square kilometres of forests, the abandonment of 302 mines and the deposition 191 million tons of tailings (Guo, 2012). Estimates of reclamation costs are at 38 billion RMB. To put this into context, the total sales income for rare earths from that area is 32.9 billion RMB (Xinhua, 2012). Thus, the negative externalities of illegal mining outweigh the local revenues from the sale of rare earths. In 2011, the Chinese government placed a ban on surface/hill top mining. But this activity is still used by illegal miners (State Council, 2011).

The second technique is called in-situ leaching. A series of leaching holes, each 0.8 m in diameter and 1.5–3 m in depth are drilled into the rare earth rich clays. The holes are placed 2–3 m apart, with about one third of the ground surrounding the site cleared. The leaching solution of 3–5% ammonium sulphate is sprayed over the surface. The leaching solution travels through the soil, extracts the rare earths, and fills the leaching holes (Zhao, 2000). The mixed rare earth oxide solution is then collected from the leaching holes.

In-situ leaching can cause serious environmental degradation including soil contamination, water (above and underground) contamination, elevated PH values, mine collapses and landslides. More than 100 landslides were reported in Ganzhou region. These