Green mining policy for environmental protection and sustainable development

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Abstract: Environmental protection is an inevitable choice for the sustainable development of human society. According to EPA data, 21\% of global greenhouse gas emissions come from the industrial areas. The mining is one of the main source of greenhouse gas emissions. To achieve sustainable economic development and ecological environmental protection, the mining industry must be green. The developed countries have taken policies related to green mining since the 1970s and have already achieved great results. At present, the developing countries such as China have also adopted a series of various legal and institutional measures related to the mining, but it is still not perfect compared with the developed countries, and there are still serious environmental pollution problems. Therefore, this paper will discuss the causes of the environmental problems in mining and the green mining policies of some developed countries, and analyze the current situation of China's mining industry. Finally, this paper proposed a green mining policy model for in developing countries such as China for environmental protection and sustainable development.

1. Introduction
Mining is the oldest and the most important, but it is the hardest industry after agriculture in the world. As a result, environmental problems in the mining industry have persisted for 700 years. In the process of ore mining, processing and smelting, a large amount of dust and exhaust gas are generated. These gases contain harmful substances and pollute the atmosphere. The amount of water used in mine production is very large, which means that a large amount of industrial wastewater needs to be discharged and it destroys the groundwater resources. In addition, a vast amount of solid waste and tailings pollute the land and forests.

Due to the extensive human mining activities in the last century, the current crisis of depletion of resources has resulted. In particular the United States, Canada and Australia took the lead in mineral production and consumption.

The purpose of this paper is to present a green mining policy model for environmental protection and sustainable economic development in the developing countries based on the examples of the developed countries in mining.

The following is a brief introduction in the past history of the mining activities of these countries and the environmental damage resulted in.
1.1 The United States of America

American mining industry began to develop in the 1800s and entered a rapid development stage in the 1880s. After the Second World War, the new scientific and technological revolution marked by the development of atomic energy technology, aerospace technology, and computer technology has prospered and it has promoted the further development of the American economy. During this period, these technological developments and social transformations increased the demand for metals and mineral products and also accelerated the development of mining. Below Table 1 shows 15 types of mining output in the United States over the past 20 years.

| Mineral species       | Unit        | 1991 | 1993 | 1995 | 1997 | 1999 | 2001 | 2003 | 2005 | 2007 | 2009 | 2010 |
|-----------------------|-------------|------|------|------|------|------|------|------|------|------|------|------|
| Petroleum             | million tons| 369  | 340  | 326  | 321  | 293  | 355  | 344  | 319  | 315  | 334  | 345  |
| Natural gas           | billion m³  | 501  | 522  | 526  | 535  | 528  | 555  | 541  | 511  | 540  | 593  | 611  |
| Coal (bitumen)        | million tons| 900  | 856  | 932  | 984  | 992  | 102  | 971  | 1025 | 1029 | 973  | 967  |
| Iron steel (pigiron)  | thousand tons| 445  | 486  | 514  | 501  | 479  | 423  | 409  | 372  | 363  | 180  | 268  |
| Aluminum              | thousand tons| 412  | 369  | 337  | 360  | 378  | 264  | 270  | 248  | 255  | 173  | 173  |
| Copper                | thousand tons| 163  | 180  | 185  | 194  | 160  | 134  | 112  | 114  | 117  | 120  | 113  |
| Cadmium               | tons         | 1676 | 1094 | 1266 | 2059 | 1185 | 680  | 670  | 1470 | 735  | 633  | 637  |
| Gold                  | tons         | 294  | 331  | 317  | 362  | 341  | 335  | 277  | 256  | 238  | 223  | 228  |
| Silver                | tons         | 1855 | 1645 | 1564 | 2182 | 1951 | 1740 | 1239 | 1225 | 1281 | 1238 | 1280 |
| Titanium              | thousand tons| 250  | 300  | -    | -    | 400  | 500  | 500  | 500  | 400  | 300  | 200  |
| Lead                  | thousand tons| 476  | 362  | 393  | 458  | 520  | 466  | 460  | 436  | 444  | 405  | 369  |
| Zinc                  | thousand tons| 546  | 513  | 644  | 632  | 843  | 842  | 767  | 747  | 803  | 735  | 748  |
| Molybdenum            | hundreds tons| 534  | 368  | 580  | 601  | 424  | 376  | 335  | 569  | 570  | 478  | 560  |
| Plaster               | hundred thousand tons| 140  | 158  | 166  | 186  | 188  | 163  | 167  | 211  | 179  | 94   | 90   |

(Source: British Geological Survey)

1.2 Canada

It is characterized by a large variety of mineral products and high production output. At present, there are nearly 300 kinds of metal and non-metallic minerals in Canada, of which about 60 kinds have commercial mining value.

After one hundred years of development, the number of mineral products produced in Canada increased from 25 in 1867 to 65 in 1966, and Canadian mining output increased from 502.7 million US dollars in 1946 to 8466 million US dollars in 1973. The output of oil, natural gas, iron ore, lead, zinc, nickel, potassium salts, and gypsum has basically continued to increase.
| Mineral species     | Unit            | 1991 | 1993 | 1995 | 1997 | 1999 | 2001 | 2003 | 2005 | 2007 | 2009 | 2010 |
|--------------------|-----------------|------|------|------|------|------|------|------|------|------|------|------|
| Petroleum          | million tons    | 82   | 88   | 96   | 103  | 102  | 112  | 125  | 127  | 136  | 134  | 141  |
| Natural gas        | Billion m$^3$   | 129  | 155  | 176  | 184  | 194  | 205  | 200  | 176  | 174  | 156  | 151  |
| Coal (bitumen)     | million tons    | 399  | 353  | 386  | 412  | 365  | 341  | 266  | 307  | 323  | 277  | 337  |
| Iron steel (pig iron) | hundred thousand tons | 827 | 863 | 846 | 867 | 886 | 830 | 906 | 886 | 949 | 556 | 827 |
| Aluminum           | thousand tons   | 182  | 231  | 217  | 233  | 239  | 258  | 279  | 289  | 308  | 303  | 296  |
| Copper             | thousand tons   | 811  | 733  | 726  | 656  | 614  | 633  | 557  | 595  | 596  | 494  | 525  |
| Cadmium            | thousand tons   | 1829 | 1888 | 2349 | 2260 | 2091 | 1493 | 1759 | 1727 | 1388 | 1299 | 1357 |
| Gold               | thousand tons   | 176  | 153  | 152  | 171  | 159  | 160  | 141  | 120  | 102  | 97   | 98   |
| Silver             | thousand tons   | 1339 | 896  | 1284 | 1224 | 1231 | 1320 | 1310 | 1124 | 860  | 631  | 596  |
| Titanium           | thousand tons   | 200  | 210  | 220  | 240  | 250  | 230  | 190  | 210  | 250  | 200  | 240  |
| Lead               | thousand tons   | 276  | 213  | 210  | 186  | 161  | 154  | 81   | 79   | 75   | 69   | 65   |
| Zinc               | thousand tons   | 116  | 100  | 112  | 107  | 101  | 106  | 729  | 67   | 63   | 70   | 65   |
| Molybdenum         | hundred thousand tons | 192 | 188 | 182 | 190 | 186 | 194 | 163 | 199 | 255 | 137 | 158 |
| Plaster            | hundred thousand tons | 670 | 771 | 825 | 894 | 931 | 833 | 892 | 827 | 764 | 354 | 272 |

(Source: British Geological Survey)

1.3 Australia

Mining is an important part of the Australian national economy and accounts for about 7% of the gross domestic product (GDP). Mining development process of Australia can be divided in four stages. The first stage is from the settlement to the mid-20th century, summarized the early history of the mining industry. The second stage is from the 1950s to the 1970s, during which time a world-scale mining industry emerged in Australia. The third stage is the integration and growth process of the mining industry in the 1980s. The fourth stage is the most detailed stage in the 1990s, during which "globalization" has played a major influence.

| Mineral species     | Unit            | 1991 | 1993 | 1995 | 1997 | 1999 | 2001 | 2003 | 2005 | 2007 | 2009 | 2010 |
|--------------------|-----------------|------|------|------|------|------|------|------|------|------|------|------|
| Petroleum          | million tons    | 288  | 263  | 270  | 300  | 270  | 340  | 270  | 214  | 215  | 215  | 248  |
| Natural gas        | Billion m$^3$   | 217  | 244  | 298  | 299  | 307  | 325  | 332  | 371  | 399  | 423  | 450  |
| Coal (bitumen)     | million tons    | 165  | 180  | 193  | 217  | 234  | 267  | 281  | 308  | 325  | 347  | 356  |
| Iron steel (pig iron) | hundred thousand tons | 565 | 677 | 786 | 788 | 747 | 730 | 800 | 621 | 635 | 437 | 600 |
2. Impact of mining development on the natural environment and Sustainable development of the economy

There is no doubt that the mining activities at that time fully supplied the resources necessary for regional economic development and contributed decisively to creating a high-tech world like today. But at the same time, it also brought a series of environmental problems and the risk of resource depletion, which not only caused serious impacts and damages to the local natural environment, but also increasingly severe impacts on the ecological environment.

In the past, mining development has resulted in the deterioration of the natural environment in the vast majority of mines due to its rough operation, institutional backwardness, short-term profit pursuits, and neglect of sustainable development.

According to Bureau's research, more than 30 states in the United States mine coal and operate a basic economy, causing damage to 7 million acres of land[1]. Although it has not yet collapsed but the sunk danger area is about 5.2 million acres. Of these, 500,000 acres are located in densely populated urban areas, so it’s more dangerous. For example, the Illinois Geological Survey has published about 330 million homes in this area are all in danger of collapsing. According to the American Research Conference Ground Failure Hazard, at least 75 billion U.S. dollars were lost in debris flows and collapses caused by mining operations between 1925 and 1975. The cost of collapse losses is three times higher than the combined cost of floods, hurricanes, tornadoes and earthquakes.

It is reported that as of 2002, there were more than 3,500 dams caused by mining waste in the world. These dams often collapse, leading to the outflow of many harmful substances and causing environmental damage. For example, Canadian mining produces approximately 650 million tons of waste annually. A dam collapsed in April 1998, a huge outflow of harmful substances, including 528 million gallons of pyrite tailings and one billion gallons containing heavy metals flowed into the river. Many areas around the river were polluted, more than 7,000 acres were damaged and the total loss was $ 225 million[2].

If underground mining is not operated properly, it may also change the storage structure of groundwater sources and cause destructive effects on groundwater systems. In addition, various harmful substances such as cyan are used in the smelting process and the waste causes environmental pollution. In fact, environmental damage from the mining development is a serious problem.

| Aluminum       | Ten thousand tons | 123 | 138 | 130 | 149 | 172 | 180 | 186 | 190 | 196 | 194 | 193 |
|----------------|-------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Copper         | Thousand tons     | 320 | 411 | 379 | 558 | 711 | 896 | 830 | 935 | 871 | 854 | 870 |
| Cadmium        | Thousand tons     | 1076| 951 | 838 | 632 | 462 | 416 | 673 | 358 | 351 | 370 | 350 |
| Gold           | Tons              | 242 | 243 | 253 | 313 | 299 | 280 | 282 | 263 | 247 | 222 | 260 |
| Silver         | Tons              | 1180| 1092| 939 | 1106| 1720| 1970| 1868| 2417| 1880| 1633| 1880|
| Titanium       | Thousand tons     | 148 | 180 | 198 | 223 | 198 | 202 | 201 | 203 | 234 | 145 | 131 |
| Lead           | Thousand tons     | 579 | 535 | 455 | 531 | 681 | 759 | 688 | 767 | 641 | 566 | 712 |
| Zinc           | Thousand tons     | 102 | 103 | 94  | 103 | 116 | 152 | 148 | 137 | 151 | 129 | 148 |
| Molybdenum     | Hundred tons      | 68  | 72  | 103 | 123 | 125 | 205 | 191 | 189 | 184 | 166 | 170 |
| Plaster        | Hundred thousand tons | 181 | 209 | 184 | 189 | 380 | 322 | 366 | 388 | 389 | 343 | 327 |

(Source: British Geological Survey)
3. Green mining policies of some developed countries

Due to the recent increased interest in the quality of the environment in American society for decades, the government has adopted regulations concerned with the environmental protection. It is stipulated that the original levels of land, air and water must be maintained during mine production, and the mines shall remain in their original state after the pit is closed. From the strict demands on environmental protection, the US mining industry spends billions of dollars a year to comply with standard ecological environmental recovery rules such as improving air and water quality and restoring land[3][4].

The Canadian mining administration is divided into federal and provincial levels. There is a division of labor and collaboration between the two levels. Except for issues related to the public interest or inter-provincial coordination such as the environment and mine reclamation, they perform their duties in accordance with their respective legislative authority.

In the environmental management of the mining, the federal government is responsible for environmental science and technology, environmental protection, health issues, information and statistics on national mining activities.

The functions of the local mining management department include the entire process of mineral resource exploration, development, mining and construction management, purification and mine closure.

The specific details of the Canadian government's implementation of green mining policies include mining area restoration and mine environmental evaluation systems, reducing pollutant emissions, innovation and continuous improvement in waste management, ecosystem risk management, and mine closures, etc.

Australian mining companies are required by law to develop a mine environmental protection and closure plan when developing mines and it must be approved by the government. Australia has also set up a "Mine Closing Fund", which is mainly funded by the payment of mining enterprises for ecological restoration, facility demolition, and industrial transformation after the mine is closed. If the enterprise completes the related work of closing the pit in accordance with the standards, the paid funds will be returned[5][7].

4. Current status of China's mining industry

China is richer in mineral types and larger in volume than other countries. It has already discovered 171 types of minerals and identified 158 reserves. At present, China's primary energy and the major minerals consumptions such as iron, copper, and aluminum accounts for about 20% and 40% of the world, respectively. In 2016, the total amount of ore mined exceeded 30 billion tons. Compared with 2011, the output of coal and iron ore decreased and increased in the output of natural gas, bauxite, and gold. The production of petroleum, nickel, titanium was basically flat.

| No | Mineral type | unit | 2011 production | 2016 production | No | Mineral type | unit | 2011 production | 2016 production |
|----|--------------|------|-----------------|-----------------|----|--------------|------|-----------------|-----------------|
| 1  | Coal         | Hundred million t | 37.6 | 34.1 | 11 | Molybdenum | Metal tens of thousands t | 8.7 | 9.1 |
| 2  | Petroleum    | Hundred million t | 2.0  | 2.0  | 12 | Antimony    | Metal tens of thousands t | 12.4 | 10.8 |
| 3  | Natural gas  | Hundred million m³ | 1053.4 | 1368.3 | 13 | Gold        | Metal t | 302.0 | 394.9 |
| 4  | Iron         | Hundred million t | 13.3 | 12.8 | 14 | Fluorite    | Ten thousands t | 655.0 | 370.0 |
| 5  | Copper       | Metal t | 126.7 | 185.1 | 15 | Phosphate   | P₂O₅30% | 0.8  | 1.4  |
Since China needs to proceed with industrialization based on the development and utilization of material resources, it is still necessary to consume a lot of mineral resources in order to maintain sustainable and stable growth of the national economy.

Due to the mining development started late relatively, China is experiencing the pain of environmental destruction only today which already experienced in the mining developed countries.

Statistic data shows that the area of land collapsed by mining in China has reached 2 million hectares, and it is still increasing at a rate of 25,000 hectares every year[6]. There are 40 cities were damaged by mining collapse and 25 of them were severely. The amount of waste rocks and tailings is 300 million tons per year, and the land which directly destroyed and deposited is 140,000km²–200,000 km², which is increased by 200km² every year. A total of 1.4 billion tons of mining wastewater and waste liquid were discharged into the rivers, causing serious pollution. Tailings emissions from copper, lead, tin, zinc and other mining companies in 2001 reached 31 million tons in Yunnan province. And it is increasing at an annual rate of 12%, resulting in the destruction of forests and vegetation, loss of topsoil, frequent debris flow, river siltation, and environmental degradation. In Shandong province, the total of the mining area is 8050km², the ground subsidence of the mined area is 332km² and the destroyed area by open-pit mining area is 205km². In addition, in Hebei and Shanxi provinces, the waste-rock and tailings due to the mining development has been destroyed vast area of the natural environment seriously.

5. Suggestions for Green mining policymodel
Mineral resources are the foundation and basic driving force for economic development. It never imagine that economic development without resources. Although the developing countries such as China have been enacting a series of legislation and policies on green mining, but as shown in Table 4, there is no basic decay trend of the mineral production. If it continue to the current state of mineral production, the resources of China will be depleted in decades. This will have a serious impact on sustainable economic development. From that, we proposes the green mining policy suggestions and a model to protecting the natural environment and ensuring sustainable economic development.
Fig. 1 is the schematic diagram of the green mining policy model proposed in this paper. The main actors of the green mining policy model are government and mining enterprises. The government also includes relevant departments related to mining such as the ministry of agriculture and forestry (Government and Association in Fig.1). When a company applies for mining development, it reviews and ratifies whether the development plan satisfies all the requirements including the environmental protection act. The government also monitors and controls the company's production activities in accordance with the environmental protection act and the sustainable development principles. In addition, the government should enact a certain incentive system (Encourage in Fig.1) to provide financial support to companies, and at the same time, admire outstanding companies to raise public attention. The government must prohibit ratification or strict penalties for companies that violate the standard requirements in the mine development or operation process that do not meet the requirements of the Environmental Protection Act and the sustainable economic development.

The enterprise must submit a development application when a company proceeds with mining development detailing the environmental damage caused by the development, its countermeasures, and the restoration plan after the operation is completed. The application for development should be made in consideration of the requirements of the Environmental Protection Act as well as the requests of the government and the relevant departments. The application must also be revised and reconfirmed with the comments of the local population. Companies should apply scientific operating methods to their operations to maximize resource utilization and recycling rates and must ensure clean production. Thus, it must be secured to minimize environmental damage and ensure sustainable development (Scientific operation, High efficiency and Clean production in Fig.1).

It is necessary to use resources highly and many types of minerals must be secured in order to develop to the developed countries. The rapid economic growth of China is mainly based on the proliferation in the supply of mineral resources. Therefore, resource management strategies should be rationalized and green mining policies must actively implemented to ensure material foundation to ensure sustainable development.

6. Summary
In this paper, we have described the history of mining activities in the last century and the environmental problems, the crisis of resource depletion resulted from it in some countries. In addition, we have listed the green mining policies in these countries for environmental protection and sustainable economic development. This paper has proposed a green mining policy model to be taken in the developing countries for environmental protection and sustainable economic development.
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