

Technical Research on Remote Sensing Monitoring of Green Mine

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Abstract. This paper proposed primary factors for preliminary screening of candidate mines and annual monitoring of green mines based on integrated analysis on green mine construction requirements, assessment indicators, etc.; introduced technical procedure, work content and work method of monitoring through example analysis, and preliminarily built a technology system for preliminary screening of candidate mines and annual monitoring of green mines.

1 Introduction

With continuous advancement of ecological civilization construction, promoting green development of mining industry and accelerating green mine construction have become focuses and difficulties in current mining and utilization of mineral resources. Green mine is to implement scientific and orderly mining, control the disturbance over mining area and surrounding ecological environment within a controllable range, and achieve ecologicalization of mining area environment, scientization of mining mode, high efficiency of resources utilization, standardization of enterprise management and harmonization of mining area community in the entire process of mining mineral resources.^[1-6] This paper discussed content and method of utilizing remote sensing technology and conducting preliminary screening of candidate mines (hereinafter referred to as “candidate mines”), and annual monitoring of green mines (hereinafter referred to as “green mines”), for the purpose of importing advice and suggestions for establishing a remote sensing monitoring technology system of mature green mine as soon as possible.

2 Requirements for green mine construction

According to “The Implementation Opinions of Ministry

of Land and Resources of the P.R.C., Ministry of Finance of the P.R.C., Ministry of Environmental Protection of the P.R.C., General Administration of Quality Supervision, Inspection and Quarantine of the P.R.C., and China Banking Regulatory Commission, China Securities Regulatory Commission on Accelerating Green Mine Construction (Ministry of Land and Resources No. [2017]4)” and the green mine construction specifications issued by Ministry of Natural Resources of the People’s Republic of China, such as “Green Mine Construction Specification of Onshore Petroleum and Natural Gas Mine” (DZ/T0317-2018), “Green Mine Construction Specification of Coal Industry” (DZ/T0315-2018), etc.^[1-6], the assessment indicators for green mine construction include multiple factors, such as environmental features of mines, development and utilization mode, intensive and economical utilization of resources, modernization of mine construction, harmony of mineral estate, corporate cultural image, etc. (Table 1)

Moreover, candidate mines and green mines shall be an independent mine with a valid mining license. In recent three years, the mine has not been subject to administrative penalties by the departments related to natural resources and ecological environment, and the mining right owner has not been included in the anomaly list (Table 1). New mine has normally produced for at least one year. Remaining mining years of productive mine shall be no less than five years, and it operates normally.

Tab.1 Assessment Indicators for Green Mine Construction

Industrie s	Coal	Petroleum and natural gas	Non-ferrous metals	Gold	Metallurgy	Chemicals	Non-metal
Mining area environment	Layout of mining area is reasonable; sign, signboard, etc. are uniform in specifications, clear and handsome; production and living in mining area are orderly and standardized.						
	Totally closed management of production, transportation, storage and ground	Perfect ground engineering system and supporting facilities, flat roads and convenient transportation	Take measures to prevent dust during production, transportation and storage	Take measures to prevent dust during production, transportation and storage	Take measures to prevent dust during production, transportation and storage	Standardized and orderly production, transportation and stock-piling of products and barren rocks	Standardized and orderly production, transportation and stock-piling of ores and barren rocks
	Rain and sewage separation, standardized discharge of "three wastes"	Total recycle and innocent treatment of "three wastes"	Standardized discharge of "three wastes"	Standardized discharge of "three wastes"	Standardized discharge of "three wastes"	Standardized treatment of "three wastes"	Standardized treatment of "three wastes"
	Green coverage ratio, up to 100% of greenable area	Green coverage ratio, up to 80% of greenable area	Green coverage ratio, up to 100% of greenable area	Green coverage ratio, up to 100% of greenable area	Green coverage ratio, up to 100% of greenable area	Green coverage ratio, up to 100% of greenable area	Green coverage ratio, up to 100% of greenable area
Development and utilization mode	Select resource-conserving, environmentally-friendly mining mode	Recovery ratio of oil and gas recovery ratio is not lower than requirements of development planning indicators.	Select resource-conserving, environmentally-friendly mining mode	Select resource-conserving, environmentally-friendly mining mode	Select resource-conserving, environmentally-friendly mining mode	Select resource-conserving, environmentally-friendly mining mode	Select resource-conserving, environmentally-friendly mining mode
	In the central and eastern regions, strip or backfilling mining is in principle adopted, with no need of carrying gangues out of wells.	Leakage prevention shall be conducted during storage and transportation of oil and gas. Leakage prevention and underground water monitoring shall be conducted on development, storage and transportation sites of oil and gas.	Mining mode of underground mine gives priority to backfilling mining technology. Mining mode of open-pit mine shall meet the requirements for ecological construction and environmental protection.	It is suggested to use backfilling mining technology.	Select reasonable advanced mining methods, such as open-pit and underground mining technology, whole tailings backfilling mining technology, etc.	Open-pit mining gives priority to internal discharge mode in priority; underground mining gives priority to backfilling mining method.	Use advanced processing technology, technique and equipment.
	Proper disposal ratio of solid wastes, such as gangue, shall reach 100%.		Proper disposal ratio of solid wastes shall reach 100%; wastewater treatment shall reach the standard.	Proper disposal ratio of solid wastes, such as cyanidation tailings, shall reach 100%; wastewater treatment shall reach the standard.	Proper disposal ratio of solid wastes shall reach 100%;	Proper disposal ratio of solid wastes shall reach 100%; wastewater treatment shall reach the standard.	
	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines	Fulfill obligations in land reclamation, with a reclamation ratio of 100%.	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines	Fulfill obligations in restoration, governance and land reclamation of geological environment of mines

Industrie s	Coal	Petroleum and natural gas	Non-ferrous metals	Gold	Metallurgy	Chemicals	Non-metal
Intensive and economical utilization of resources	Conduct integrated assessment of coal and its paragenic/associated resources, and use reasonable utilization mode and disposal technique, thereby guaranteeing integrated utilization of resources	Conduct integrated assessment, development and utilization of associated resources of oil and gas	Conduct integrated assessment of non-ferrous mineral resources and their paragenic/associated resources, use reasonable utilization mode and disposal technique, thereby guaranteeing integrated utilization of resources	Conduct integrated assessment of gold and its paragenic/associated resources, use reasonable utilization mode and disposal technique, thereby guaranteeing integrated utilization of resources	Strengthen reasonable utilization of metallurgical mineral resources and their paragenic/associated useful components, low-grade ore, barren rocks and tailings	Conduct integrated assessment of main mineral varieties and their paragenic/associated resources, and use reasonable technology and technique, thereby guaranteeing integrated recycle of their paragenic/associated resources	Graded utilization, high-quality utilization and integrated utilization of resources
	Classified disposal and reasonable utilization of solid wastes; recycle rate of wastewater up to 85% and above.	Mining water resources based on utilization of oilfield; intensive and economical utilization of land resources.	Classified disposal and reasonable utilization of solid wastes; full utilization of wastewater.	Classified disposal and reasonable utilization of solid wastes; recycle rate of mineral dressing wastewater up to 85% and above.	Classified disposal and reasonable utilization of solid wastes; recycle rate of mineral dressing wastewater up to 85% and above.	Classified disposal and reasonable utilization of solid wastes; recycle rate of mineral dressing wastewater up to 85% and above.	Classified disposal and reasonable utilization of solid wastes; recycle rate of mineral dressing wastewater up to 85% and above.
Digital mine	Modernization of production technology and technical equipment; automation of coal mining; informationization of production management; establishment of industry-university-institute sci-tech innovation platform.	Modernization of technical equipment; digitization of production monitoring; informationization of operating management; establishment of industry-university-institute sci-tech innovation platform.	Modernization of production technology and technical equipment; mechanization of mining, automation of dressing and smelting technique; informationization of production management; establishment of industry-university-institute sci-tech innovation platform.	Modernization of production technology and technical equipment; mechanization of mining, automation of dressing and smelting technique; informationization of production management; establishment of industry-university-institute sci-tech innovation platform.	Modernization of production technology and technical equipment; mechanization of mining, automation of dressing and smelting technique; informationization of production management; establishment of industry-university-institute sci-tech innovation platform.	Modernization of production technology and technical equipment; mechanization of mining, automation of dressing and smelting technique; informationization of production management; integration of industry-university-institute sci-tech innovation.	Modernization of production technology and technical equipment; mechanization of mining, automation of dressing and smelting technique; informationization of production management; establishment of industry-university-institute sci-tech innovation platform.
Enterprise image	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction, no less than 70%, and satisfaction of the masses in mining area, no less than 65%.	Enterprise culture with different regional characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.	Distinctive enterprise culture characteristics; honest operation; good operating benefits; employee satisfaction and satisfaction of the masses in mining area, no less than 70%.
access conditions	Mine shall be an independent mine with a valid mining license. New mine has normally produced for at least one year. Remaining mining years of productive mine shall be no less than five years, and it operates normally.						
	In recent three years, the mine has not been subject to administrative penalties by the departments related to natural resources and ecological environment, and the mining right owner has not been included in the anomaly list.						

3 Contents of remote sensing monitoring

According to national relevant notifications and specifications [1-6], green mines shall be some industrial leaders in six sectors, such as mining area environment, resources development mode, integrated utilization of resources, energy conservation and emission reduction, sci-tech innovation and informationization, enterprise management and enterprise image. By comparing

construction requirements for different types of green mines, according to application status of remote sensing technology in natural resources survey monitoring work, it is recommended to carry out remote sensing survey and monitoring of selection conditions and qualified conditions of green mines in such sectors as access conditions, appearances and features of mine, ecological environmental protection, energy conservation and emission reduction, harmony of mineral estate, etc., which can provide technical support for selection and supervision of green mines (Table 2).

Tab.2 Primary Factors for Preliminary Screening of Candidate Mines and Annual Monitoring of Green Mines

Type of factor	Name of factor	Standard requirements	Monitoring focuses
Access conditions	Independent mine	With a valid mining license	With a license, within a valid period
	Normal production time	One year	One-year mining duration
	Illegal mining	Hasn't mined within three years	Whether there existed illegal mining within three years
	Nature reserve	Mining area is not within nature reserve.	There is no crossover between mining right boundary and nature reserve boundary.
Appearances and features of mine	Functional partition of mining area	Various areas, such as production area, management area, living area, ecological preservation area, etc. are clearly defined.	Functional partitions are obvious; there is no solid waste within management area and living area.
	Construction without permission	No temporary building	No metal building and temporary plant building
	Mining area greening	Green coverage ratio 100%	Greenable areas in the mining area have been greened.
Ecological environmental protection	Roads in the mining area	Hardening of drainage ditch in the inner side, planting of border trees in the outer side	Hardening of inner side of roads, planting of border trees in the outer side
	Solid wastes	Implement land reclamation, greening or beautification	Restoration and governance measures
	Restoration and governance of illegal lands in previous years	Restoration and governance of previous illegal lands	Whether lands destroyed by the mine beyond range of mining right have been restored governance.
Energy conservation and emission reduction	Wastewater	Standardized discharge	No water pollution
	Barren rocks	Resource utilization	Secondary processing evidence beside barren rock pile
Harmony of mineral estate	Goaf collapse area	Can't endanger basic farmland, building construction and important transportation facilities	No basic farmland, building construction and important transportation facilities are destroyed.
	Water pollution within residential area	No pollution	Whether water color and water quality in river and pit-pond nearby residential area are abnormal.

4 Remote sensing monitoring method

At present, because microwave remote sensing technology and hyperspectral remote sensing technology have not yet formed an application technology system, they didn't meet the actual needs in the mine monitoring work. So we use home-made high resolution (spatial resolution above 2.5m) remote sensing data as main data source, supplemented by UAV remote sensing data, conducting visual interpretation and human-computer interactive interpretation This is still a common method for preliminary screening of candidate mines and annual monitoring of green mines. As shown in Figure 1, relevant

technical procedures, according to experimental research in some mines in Jiangxi Province, Hunan Province, Fujian Province, etc., can be divided into three stages: preparation of remote sensing data, comparison of monitoring factors, online validation and review application of data.

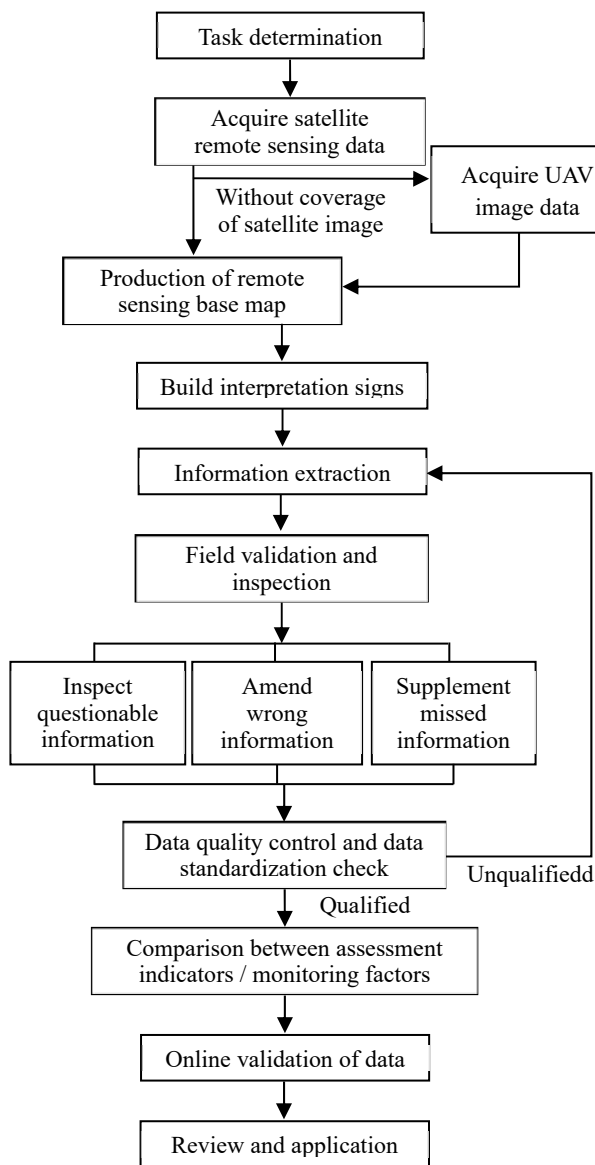


Fig.1 Remote Sensing Workflow for Preliminary Screening of Candidate Mines and Annual Monitoring of Green Mines

4.1 Data preparation

The data preparation stage includes the following steps: production of remote sensing base map, information extraction, field validation, quality check of interpretation data, etc.

The remote sensing base map is a foundation for preliminary screening of candidate mines and annual monitoring of green mines. Appropriate data shall be selected to conduct production of remote sensing base

map. Selection and monitoring of open-pit mining mines can use remote sensing data with a spatial resolution above 2.5m, because mine ground objects have total area of more than 100 m². Selection and monitoring of underground mining mines shall use remote sensing data with a spatial resolution above 1.0m, because it needs to recognize ground objects, such as well-head, adit collar, etc. (total area is in general 16 m² or so.) Plane-coordinate system of remote sensing base map shall use the 2000 Chinese Geodetic Coordinate System; Height system uses the 1985 National Height Datum; Gauss-Kruger projection mode (3° zone) can be adopted. Image shall maintain optimal resolution of raw image data.

Information extraction, field validation and quality check of interpretation data work shall be executed according to Regulation on Remote Sensing Monitoring of Mining Exploration (DZ/T0266) [7]. Information that is clearly marked and recognized on the image need no field validation.

4.2 Comparison between assessment indicators / monitoring factors

With ArcGIS software as basis, a “Green Mine Remote Sensing Monitoring Information System” is built to conduct a unified management over survey monitoring information and relevant management information (such as mining right information, nature reserve information, etc.) from remote sensing base map of candidate mines and green mines. On this basis, preliminary comparison or recognition of assessment indicators of candidate mines and green mines (or called monitoring factors) is carried out.

4.2.1. Comparison between access condition factors

Access conditions can be monitored whether independent mine is valid, whether mine produces normally, and whether there were illegal mining actions within three years. Taking a tungsten ore mine in Fujian Province shown in Figure 2A as an example, open mining pits are uniformly distributed within range of mining right, mine mining site, refuse dump, mine construction, etc. are complete, mining pit road and refuse dump in its north side are in use; therefore, the mine can meet conditions for access and annual inspection of green mine. Taking a non-metal mine in Jiangxi Province shown in Figure 2B as an example, periphery of open-pit stope, especially of the east and west sides, is beyond range of mining right, and illegal parts have not yet been restored governance; therefore, the mine can meet access conditions of green mine.

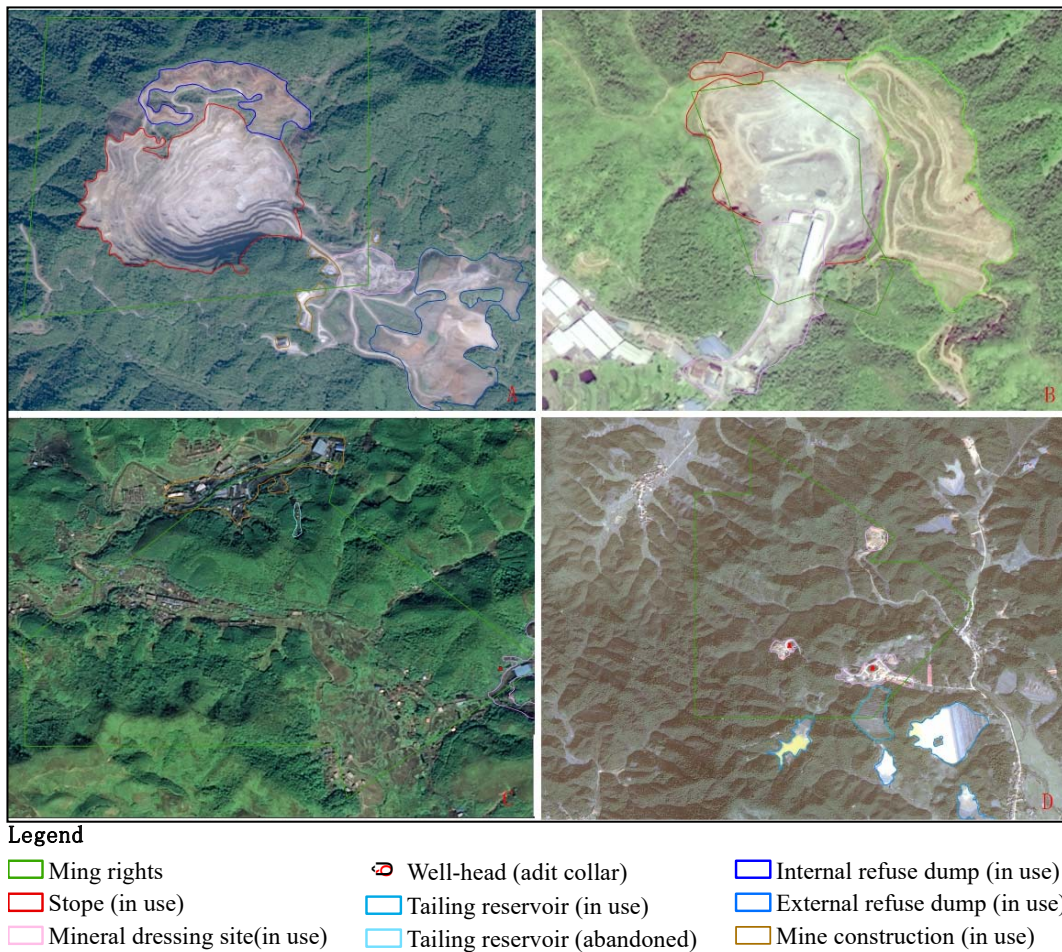


Fig.2 An Example for Comparison between Monitoring Factors

4.2.2. Comparison between appearances and features factors of mine

In terms of appearances and features of mine, monitor whether functional partitions of mining area are defined, whether there is construction without permission, and whether greenable area is greened. Taking a coal mine in Hunan Province shown in Figure 2C as an example, production well / adit collar, coal dressing site and gangue pile are orderly stacked, functional partitions of mining area are defined; coal mining collapse area has been or is being restored governance; therefore, the coal meets conditions for selection or annual inspection of appearances and features of green mine. Taking a gold mine in Jiangxi Province shown in Figure 2D as an example, images in the vicinity of production well /adit collar, mineral dressing site, etc. are chaotic, and solid wastes are stacked downslope disorderly; therefore, the mine can't meet conditions for appearances and features of green mine.

4.2.3. Comparison between ecological environmental protection factors

Ecological environmental protection can be monitored whether inner side of the roads in the mining area can be hardened, and outer side can be planted with border trees, whether solid wastes have measures of restoring governance, and whether previous illegal lands have been restored governance. Taking a lead zinc mine in Hunan Province shown in Figure 3 as an example, the tailing reservoir of the mine has been covered with soil and restored the green, and vegetation growth is basically coordinated with the surrounding environment; the solid waste pile has been partially covered with soil and grass on the top, and partially restored on the edge; inside of road to the mine has been hardened by field verification, which basically has met conditions for ecological environmental protection of green mine.

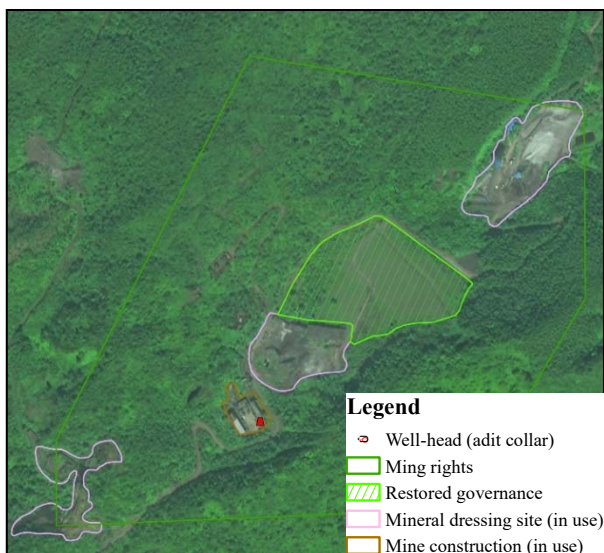


Fig.3 An Example for Comparison between Ecological Environmental Protection Factors

4.2.4. Comparison between energy conservation and emission reduction factors

Energy conservation and emission reduction can be monitored whether mine wastewater reaches discharge standard (the water body around the mining area is not polluted.), and whether the barren rocks are utilized. Taking a gold mine in Jiangxi shown in Figure 2D, the accumulation of wastewater in the tailing reservoir is normal, there is no abnormal water flow on the surface, there is no abnormal vegetation in the low-lying areas, there is no leakage at the lower reach of tailing reservoir on the surface, and there is no anomaly in the discharge of mining wastewater; therefore, the mine can meet conditions for energy conservation and emission reduction of mines.

4.2.5. Comparison between mineral estate harmony factors

Harmony of mineral estate can be monitored whether mine geological disasters endanger basic farmland, building construction and important transportation facilities, whether water body in residential area is abnormal in water color, water quality, etc. Taking a coal mine in Hunan Province shown in Figure 2C an example, the goaf collapse area in the Northwest, where vegetation has been restored after years of governance, has basically no impact on building construction and important transportation facilities in the mining area; the water color of the water system flowing through the mining area has not changed; therefore, the mine can basically meet conditions for harmony of mineral estate of green mine.

4.3 Online validation and review application of data

Through online validation function of information system, remote sensing monitoring result can be interchanged with review department and mine enterprises; through the work

process including inspection, feedback / amendment, re-inspection, re-feedback / re-amendment and other, monitoring organization and review department, mine enterprise, etc. jointly validate remote sensing monitoring result; full flow record of validation and amendment process can ensure the traceability of result formation process and responsibility. Validated result data shall be reviewed by competent authority, and directly submitted for application.

5 Conclusions

Constructing green mine is an effective approach to advance intensive and economical utilization of natural resources. Through integrated analysis on construction requirements and assessment indicators of green mines, main content of remote sensing monitoring of green mines shall include the following indicators: whether the mine continues to be mined in the current year, whether the mine had any illegal mining action in recent years, whether the mine environment is clean, whether the solid wastes are properly disposed, whether the wastewater is discharged in accordance with the standard, whether the mine area which shall be restored governance has been governed, and whether the barren rocks have achieved resource utilization.

The monitoring test results of some mines in Hunan Province, Jiangxi Province and Fujian Province show that not all the assessment indicator values can be obtained through remote sensing; however, remote sensing technology can be used in monitoring selection conditions and qualified conditions of green mine in such sectors as access conditions, appearances and features of mine, ecological environmental protection, energy conservation and emission reduction and harmony of mineral estate, which will provide technical support for selection and supervision of green mine.

It is suggested to increase the application of microwave remote sensing technology and hyperspectral remote sensing technology in the green mine monitoring work, in order to further determine goaf subsidence range and environment pollution area, which can provide the solid technical support for annual assessment of green mines.

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References

1. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Onshore Petroleum and Natural Gas Mine, Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)

2. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Coal Industry, Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)
3. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Metallurgical Industry, Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)
4. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Non-ferrous Industry, Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)
5. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Gold Industry, Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)
6. Ministry of Natural Resources of the People's Republic of China, Green Mine Construction Specification of Non-metallic Minerals Industry , Beijing: Ministry of Natural Resources of the People's Republic of China, (2018)
7. Ministry of Land and Resources of the People's Republic of China, Green Mine Construction Specification of Non-metallic Minerals Industry , Beijing: Ministry of Land and Resources of the People's Republic of China, (2014)