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Research on radioactive environment of gypsum mine in Yanchi county, Ningxia

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Abstract. Yanchi County is rich in reserve of gypsum mines, and is one of the important producing areas of gypsum mine in Ningxia, its gypsum product accounts for a certain scale in national market, and is an important production base of gypsum, however, Yanchi County is also an important metallogenic region of uranium resources, therefore, it is an important measure for guaranteeing long-term healthy development of gypsum mine in this region to carry out radiation research on gypsum mines. Based on this, in this paper, field test of radioactive environment of 7 gypsum mines within this county was performed, and the current radioactive environment situation of each mine was evaluated, for reference purpose.

Keywords. Yanchi County; gypsum mine; radioactive

Yanchi County is located in the east of Ningxia Hui Autonomous Region, and the southwest edge of Mu Us Desert, with rich nonmetallic mineral resources, where, its gypsum reserve ranks the first in Ningxia. Gypsum mines are of large scale of exploration and utilization, and provides a strong and powerful support for economic and social development of Yanchi County, and the output building gypsum and high-strength gypsum power and gypsum power for mold purpose, etc. Account for a certain scale in national market. Main producing area of gypsum mine is located in the middle of southwest edge of Ordos Basin, and is an important metallogenic region of uranium resources in China [1], therefore, carrying out preliminary research on radiation of gypsum mine in this region is an important measure for guaranteeing radiation safety of mine workers, local residents and product users, and is of great significance to promoting realization of green development of economy in this county.

1. Metallogenic characteristics of gypsum mines in Yanchi County

Gypsum mines in Yanchi County are mainly distributed in Qingshan Township, Mahuangshan Township and other places, and the reserve of gypsum mine resources all over the county is up to 600 million tons, accounting for above 36% of that in the whole region. Gypsum mines mainly occurs in Qingshuiying Formation of Tertiary Oligocene, covered by the thrusting base of the Quaternary Pleistocene above, and they are formed under stable hydrodynamic and hydro-chemical conditions, relatively low intensity and low frequency of tectonic activity, and slow subsidence of inland lakes and basins.

1.1. Mineral components

In accordance with survey results of Ningxia Corps of China National Geological Exploration Center of Building Materials Industry, main mineral components of gypsum mines within Yanchi County are gypsum + anhydrite, followed by clay minerals and small amount of silica and calcium and so on, where, the silica is mainly distributed on the surface of large-flake gypsum, while the calcium is filled in the cracks or pores of the lamellar aggregate gypsum.

1.2. Ore type

In accordance with exploration and prospecting results of gypsum mines in Yanchi County, and in combination with the mineral components and structure construction, it can be known that, gypsum mines are mainly divided into two natural types: lumpy gypsum and muddy gypsum. Content of lumpy gypsum is generally above 80%, with few clay mineral and other impurities, and occasionally a small amount of calcium and silicon components; content of muddy gypsum is generally above 55%, filled with clay minerals in clump or thin-layer form [2].

2. Current radiation level of gypsum mines

2.1. Research object

This research carried out field test of radioactive environment of 7 gypsum mine enterprises within Yanchi County. These 7 gypsums mine enterprises have relatively big production scale, broad application scope of product, cover the main producing areas of gypsum mines in Yanchi County, and are all in normal production, thus being convenient to carry out field research.

2.2. Air absorbed dose rate level of gamma radiation

In accordance with predecessors' survey results of radioactive environmental background in Yanchi County, the background level of air absorbed dose rate level of radiation on the earth surface within the county was 0.08μGy/h. Air absorbed dose rate level of gamma radiation within mines mainly comes from γ nuclide in gypsum mine and soil, and in various living area, mining pit, processing area, stock ground and other different places of gypsum mines, FD-3013H air absorbed dose rate meter of gamma radiation for environmental monitoring was used to measure the test objects such as ground soil, gypsum mine and waste slags, etc., and the tested points covered all elements of the mines basically, the test results of which are as shown in Table 1.

Table 1. Test results of gamma radiation dose rate of various gypsum mines

Mine name	Type	Number of tested points	Air absorbed dose rate of gamma radiation/ ($\mu Gy\cdot h^{-1}$)		
			Minimum	Maximum	Average
Yulian Gypsum Mine	Gypsum mine	22	0.04	0.42	0.11
Qianyuan Mining	Gypsum mine	17	0.05	0.33	0.13
Jiahe Mining	Gypsum mine	16	0.04	0.11	0.07
Tianshi Mining	Gypsum mine	19	0.05	0.14	0.09
Yindong Mining	Gypsum mine	20	0.04	0.17	0.07
Wangjigou Gypsum Mine	Gypsum mine	17	0.04	0.10	0.07
Zhigang Welfare Building Materials Factory	Gypsum mine	17	0.04	0.09	0.07

It can be seen from analysis of the test results that, total four mines showed its maximum air absorbed dose rate of gamma radiation being 0.05μGy/h higher than the local environmental background level (after deducting the environmental background 0.08μGy/h from test result of each mine), besides, in reference to relevant regulations in *Requirements for Geological Radiation Environmental Impact Assessment of Uranium Mine*s (EJ/T977-95), Yulian Gypsum Mine and Qianyuan Mining also showed its air absorbed dose rate of gamma radiation being 0.17μGy/h higher than the environmental background level, which were beyond the requirements of the standard for management of radioactive wastes, therefore, these mines belonged to key object of supervision of survey and detailed survey of associated radioactive mines.

2.3. Radon concentration level in soil

Areas whose surface can be drilled were selected in the mining area, and then drilled at the depth of 50-80cm using special steel chisel, a special sampler with a hole in the head was used to (the hold on lower end walls of the sampler shall be checked before use, to guarantee them from being blocked by mud) insert into the hole, and then top ground surface part of the sampler was tightly sealed with soil, so as to prevent air from entering the hole at the time of pumping. These tested holes shall basically cover the production area, living area and place of intensive personnel activity in the factory, and the number of tested points shall be determined depending on practical geological of the mines. Upon filed test of these mines, test results of radon concentration in soil and air of various gypsum mines were as shown in Table 2.

In accordance with *Code for Indoor Environmental Pollution Control of Civil Building Engineering (2013 Edition)* (GB50325—2010), different countermeasures shall be taken when the radon concentration in soil reaches different contents. It can be seen from the test results that, 3 mines showed an average radon concentration in soil exceeding 50000Bq/m3 within its range, thus being the areas of key control, so when constructing dwelling houses for employees and other buildings within these 3 mines, multiple anti-radon measures shall be taken to guarantee personal health of the employees; the remaining 4 gypsum mines showed an average radon concentration in soil below 20000Bq/m3, which was basically at a safe level.

2.4. Radon concentration level in air

Radon concentration in air was tested regarding both indoor and outdoor open environment of the ground buildings in the mines, and during the test process, it was required by the standard for testing indoor radon concentration in air that the buildings must be sealed for over 24h, however, in practice, the mines were in normal production, and failed to meet the requirement of sealing the indoor environment for over 24h. Ground buildings of these mines were all simple slab houses or bungalows, with serious air leakage and good cross ventilation, and had the doors frequently opened and closed during the test process, thus having a relatively good air ventilation, therefore, test result of indoor radon concentration in air was basically the same with that in outdoor open environment. It can be seen from the test results that, the radon concentration in air was at a safe level on the whole, without any abnormalities.

2.5. Annual effective dose of gamma radiation

In accordance with national investigation of natural penetrating radiation level in environment (1983-1990), environmental exposure to ionizing radiation could affect human health, and the annual effective dose (AED) equivalent was an important indicator for evaluating environmental radiation level of radioactive nuclide [3]. In accordance with *Norm for the Measurement of Environmental Terrestrial Gamma-Radiation Dose Rate* (GB/T 14583—93), environmental terrestrial gamma-radiation dose rate can be used to estimate the annual effective dose equivalent of environmental radioactive radiation level toward local residents, and the calculation formula is as follows:

$$H_e = D_\gamma \times K \times t \times 10^{-6} \quad (1)$$

Where: H_e refers to effective dose equivalent, mSv; D_γ refers to environmental terrestrial gamma-radiation dose rate, nGy/h; K refers to the ratio between the effective dose equivalent rate and the air absorbed dose rate, and 0.7Sv/Gy is adopted in the standard; t refers to stay duration of the personnel in environment, h.

In this research, external radiation mainly took gamma radiation caused by the mines into account, the limit for its occupational exposure dose equivalent was 20mSv/a, and if applying internationally recommended annual working hours (2000h/a), the public exposure was 1mSv/a, and the public exposure adopted the annual exposure hours of 8760h, and took the outdoor detention factor of 0.2, then calculation result of the population exposure dose equivalent was as shown in Table 3.

It is stipulated in *Basic Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (GB18871—2002) that, estimated average dose to which the members of relevant key populations in the public is exposed shall not exceed 1mSv/a, and its dose constraint value shall be within 10%-30% of the limit for public exposure dose (i.e. 0.1-0.3mSv/a). For test results of this research, annual effective dose of gamma radiation of the workers in these 7 mines did not exceed the occupational exposure dose, while for annual effective dose of gamma radiation of the public, 2 mines (Qianyuan Mining and Yulian Gypsum Mine) exceeded the upper limit for the public constraint dose 0.3mSv/a, which showed that there was still a certain risk of radiation hazard in these two mines [4].

Table 2. Test results of radon concentration in soil and air within various gypsum mines

Mine name	Number of tested points	Radon concentration in air/($Bq \cdot m^{-3}$)			Radon concentration in soil/($Bq \cdot m^{-3}$)		
		Minimum	Maximum	Average	Minimum	Maximum	Average
Yulian Gypsum Mine	3	7.18	10.92	8.66	11533.83	24176.63	18391.59
Qianyuan Mining	5	5.42	16.40	7.54	1530.70	5276.40	3075.70
Jiahe Mining	5	5.42	5.46	5.45	6754.27	88406.87	59891.48
Tianshi Mining	5	7.27	12.73	10.74	4675.50	104291.20	55841.38
Yindong Mining	6	5.46	12.57	9.05	11106.00	150255.00	56366.44
Wangjigou Gypsum Mine	4	7.28	20.00	13.01	4496.53	8497.87	6083.79
Zhigang Welfare Building Materials Factory	4	5.47	18.19	10.57	9977.93	22092.73	15729.34

Table 3. Calculated results of population exposure dose equivalent Unit: mSv/a

Name	Occupational exposure			Public exposure			Remark
	Minimum	Maximum	Average	Minimum	Maximum	Average	
Yulian Gypsum Mine	0.06	0.59	0.15	0.05	0.52	0.13	Public constraint dose was exceeded
Qianyuan Mining	0.07	0.46	0.18	0.06	0.40	0.16	Public constraint dose was exceeded
Jiahe Mining	0.06	0.15	0.10	0.05	0.13	0.09	
Tianshi Mining	0.07	0.20	0.12	0.06	0.17	0.11	
Yindong Mining	0.06	0.24	0.10	0.05	0.21	0.09	
Wangjigou Gypsum Mine	0.06	0.14	0.10	0.05	0.12	0.09	
Zhigang Welfare Building Materials Factory	0.06	0.13	0.09	0.05	0.11	0.08	
Public constraint dose	0.3						

3. Conclusion

It was discovered from research on radiation level of gypsum mines in Yanchi County that, air absorbed dose rate of gamma radiation in the producing areas and the produced slags within Qianyuan Mining and Yulian Gypsum Mine exceeded the national management limit, thus belonging to the category of national associated radioactive ore difference, and its annual effective dose also exceeded the upper limit for public constraint dose, thus having a certain risk of radiation hazard, however, air absorbed dose rate of gamma radiation of the environment, products and slags, etc. of the remaining gypsum mines was equivalent to the local environmental background. As for radon concentration in soil tested within Tainshi Mine, Yindong Mining and Jiahe Mining, it has exceeded 50000Bq/m^3 in multiple tested points, therefore, it needs to take comprehensive anti-radon measures to guarantee personal health of the workers when constructing buildings within the mines.

Fund project

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Biography

Tian Shaochong, male, master, engineer, with research orientation of Environmental Geology, and Engineering Geology.