Estimation of the resident's additional dose in bone-coal mining areas of the five provinces

JIANG Shan[1], ZHANG Liang[2], YE Ji-Da[3], KONG Ling-Li[4], LI Ying[5], SHI Jin-Hua[4], WU Zong-Mei[3]

([1] *Environmental Radiation Surveillance Station of Anhui Province, Hefei 230061;*

[2] *Environmental Monitoring Center Station of Hunan Province, Changsha 410004;*

[3] *Environmental Radiation Monitoring Station of Zhejiang Province, Hangzhou 310012;*

[4] *Wuhan Academy of Environmental Science, Wuhan 430015;*

[5] *Environmental Monitoring Center Station of Jiangxi Province, Nanchang 330029)*

Abstract This paper introduces the resident's additional dose in bone-coal mining areas. The increase of the annual additional effective doses accepted by the residents living in the carbide-brick houses, the staffs working in the carbide-brick houses and the miners working in the bone-coal mining areas of Hubei, Hunan, Jiangxi, Zhejiang and Anhui Provinces is caused by the rising of environmental radioactive level. The investigation of natural background radiation in the bone-coal mining areas indicated that both mining and utilizing bone-coal cause the rise of environmental radioactive level. The ranges of the annual additional effective dose accepted by the residents, staffs and miners is 1.9—6.8 mSv, 0.5—2.0 mSv and 8.2—71 mSv, and with an average of 3.8 mSv, 1 mSv and 40 mSv, respectively. The annual additional effective doses accepted by part residents and staffs exceed the dose limit of 1 mSv for public exposure, and part miners exceed the dose limit of 20 mSv for occupational exposure. And the contribution of dose caused by inhaled radon to the total additional effective dose is over 76%.

Key words Dose, Bone-coal mines, Dose estimation.

CLC number X837

1 Introduction

In the National Investigation of Natural Radioactive Levels (abbreviated as "investigation of levels" hereinbelow) during 1983 to 1990, it is found that the specific activities of radionuclides in bone-coal are relatively high. The increase of radioactive level in the environment and the rise of the public accepted dose might be caused by some artificial activities, which include mainly mining and utilizing spontaneously bone-coal by local peasants, producing bone-coal cinder brick (commonly abbreviated as BCCB, or called carbide brick) with bone-coal cinder (BCC) on a small scale, and building the dwelling with BCCB. In order to grasp the state of exposure dose accepted by the special crowd living in the high radiation level areas, to work out "actuation level" for the indoor radon concentration to accord with our national conditions and to provide scientific basis and basic data for taking the preventive measures, the State Environment Protection Bureau and Chinese Nuclear Industry Corporation decided to carry out a project of "the study of effect of mining and utilizing radioactivity-associated bone-coal mines on environment". The main investigation items include: γ-rays doserate in field, specific activities of natural radioactive radionuclides and content of non-radioactive elements in various environmental media, indoor and outdoor radon concentration and dose estimation etc.. The project took more than two years, and was completed in 1993. One of the important subprojects is the estimation of the additional effective dose for the residents living in the bone-coal mining areas of the five provinces. The estimation results of annual additional effective dose for

Supported by State Envivonment Protection Bureau and Chinese Nuclear Industry Corporation (Project No.90201001)

Received date: 2004-11-01

the residents are given in the paper.

2 Selection of investigated sites

As the monitoring sites, two or three bone-coal mines were selected for every province of five provinces (Hubei, Hunan, Jiangxi, Zhejiang and Anhui), and thirty rooms of BCCB house and ten rooms of ordinary red-brick (ORB) houses were selected in every mining area, respectively, according to factors such as geographical distribution, bone-coal reserves, its multiple utilization, and bone-coal power station.

The monitoring sites of γ radiation level include fields and roads in mining areas and in reference spots, and opencast localities and shaft of mines, as well as inside and outside of the houses. The monitoring sites of radon concentration include main inside and outside of the house, and mining localities of bone-coal. The measurement period of radon concentration is three or six months.

The SG-102 X-γ doserate meters produced by Institute of Laoshan Electronic Instrument and the CSR solid state nuclear track detector[1] prepared by Shanghai Institute of Radiation Medicine were used for the purpose.

3 Dose estimation

The estimation of annual additional effective doses includes internal radiation caused by inhalation and ingestion of radioactive materials and external radiation caused by γ-rays. The internal radiation dose comes from inhalation of radon and/or radon daughter, ingestion of foods and immersion inhalation of air near the ground. The last two parts are not included in the dose estimation because of their contributions to total dose are only 0.1% and 3%,[2] respectively.

3.1 External radiation dose

The formula used for estimating the dose caused by γ-ray external radiation is as follows:[3]

$$H_{\mathrm{E.r}} = [D_{\mathrm{r.out}}\times(1-q)+D_{\mathrm{r.in}}\times \mathrm{q}]\times 8760\times 0.7\times 10^{-6} \quad (1)$$

where $H_{\mathrm{E.\gamma}}$ is annual effective dose caused by γ-ray external radiation (mSv/a); $D_{\gamma.\mathrm{out}}$ is γ-ray doserate outdoor (nGy·h^{-1}); $D_{\gamma.\mathrm{in}}$ is γ ray doserate indoor (nGy·h^{-1}); q is residential factor of residents (0.8 according to Ref.[3]); 8760: number of hours per year; 0.7: conversion factor of effective doses according to Ref.[3] (Sv/Gy); 10^{-6}: unit conversion factor of γ-ray doserate (mGy/nGy).

3.2 Internal radiation dose

The formula used for estimating the dose caused by inhalation of internal radiation of radon is as follows:[4]

$$H_{\mathrm{E.Rn}}=[C_{\mathrm{Rn.out}}\times(1-q)\times f_1+C_{\mathrm{Rn.in}}\times q\times f_2]\times 8760\times A\times 10^{-6} \quad (2)$$

where $H_{\mathrm{E.Rn}}$ is annual effective dose caused by inhalation of internal radiation of radon (mSv/a); $C_{\mathrm{Rn.out}}$ is average outdoor radon concentration (Bq·m^{-3}); $C_{\mathrm{Rn.in}}$ is average indoor radon concentration (Bq·m^{-3}); f_1: outdoor radon equilibrium factor (0.8 according to Ref.[4]); f_2: indoor or pits radon equilibrium factor (0.4 according to Ref.[4]); A: dose conversion factor of equilibrium equivalent concentration (EEC) of radon [9 nSv·h^{-1}/(Bq·m^{-3}) according to Ref.[4]].

The other signs are the same as those in Eq. (1).

The residential factor to estimate the dose is set at 0.8 for the residents living in BCCB houses, and the monthly work time of 170 hours[5] is taken for the staffs working in BCCB house and the miners working in the bone-coal mines.

4 Results

Table 1 shows the estimate results of individual annual additional effective dose caused by the external radiation of γ-rays and the internal radiation of inhaled radon and/or its daughter for the residents living in BCCB houses, the staffs working in BCCB houses, and the miners working in opencasts or in pits.

4.1 Resident living in mining areas

Table 1 shows that the range of the average annual additional effective doses caused by external radiation and internal radiation for the residents living in BCCB houses in bone-coal mining areas is from 1.9 mSv to 6.8 mSv, with an average of 3.8 mSv. While the doses caused by γ-ray external exposure are from 0.66 mSv to 1.3 mSv, with an average of 1.0 mSv, the doses caused by inhalation of radon and/or radon daughter internal exposure are from 1.0 mSv to 5.5 mSv, with an average of 2.8 mSv. Except the residents living in BCCB houses of Xiushui mine areas of Jiangxi Province, the total annual additional effective doses accepted by residents living in BCCB houses in other mining areas may exceed the dose limit of 1 mSv for public exposure which was stipulated in Ref.[6].

Table 1 The individual annual additional effective dose caused by internal and external radiation for four kinds of persons living or working in the mining areas of the five provinces (mSv/a)

Province	Mine's name	Residents living in BCCB houses						Staffs working in BCCB houses					
		External radiation		Internal radiation		Sum		External radiation		Internal radiation		Sum	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hubei	Miaopu	0.70	0.09	1.5	0.29	2.2	0.30	0.16	0.02	0.43	0.06	0.59	0.06
	Zuantanyan	0.38	0.08	2.2	0.36	2.6	0.37	0.08	0.01	0.67	0.07	0.75	0.07
	Tangxiang	1.4	0.11	3.1	0.37	4.5	0.39	0.33	0.02	0.93	0.08	1.3	0.09
	Average	0.83	0.43	2.3	0.65	3.1	1.0	0.19	0.10	0.68	0.20	0.87	0.30
Hunan	Nijiangkou	0.61	0.09	1.0	0.59	1.6	0.60	0.13	0.01	0.22	0.04	0.35	0.04
	Ningxiang	2.0	0.12	2.8	0.62	5.0	0.63	0.59	0.03	0.71	0.07	1.3	0.07
	Average	1.3	0.70	1.9	0.90	3.2	1.7	0.36	0.23	0.47	0.25	0.83	0.48
Jiangxi	Yushan	1.1	0.11	1.0	0.36	2.1	0.38	0.25	0.02	0.29	0.05	0.54	0.05
	Shangrao	1.2	0.11	1.8	0.38	3.1	0.40	0.31	0.02	0.53	0.06	0.84	0.07
	Xiushui	0.31	0.07	0.20	0.32	0.51	0.37	0.06	0.01	0.06	0.02	0.12	0.02
	Average	0.87	0.04	1.0	0.65	1.9	1.1	0.21	0.21	0.29	0.19	0.50	0.03
Zhejiang	Anren	0.49	0.09	1.1	0.53	1.6	0.54	0.15	0.01	0.32	0.05	0.47	0.05
	Zhuge	2.1	0.14	4.8	0.75	6.9	0.76	0.64	0.03	1.3	0.10	1.97	0.10
	Shuangpai	1.2	0.13	10.7	0.66	11.9	0.67	0.33	0.02	3.2	0.15	3.54	0.16
	Average	1.3	0.66	5.5	4.0	6.8	0.42	0.37	0.20	1.6	1.2	2.0	1.3
Anhui	Jixi	0.66	0.10	1.7	0.74	2.4	0.75	0.17	0.02	0.44	0.01	0.61	0.06
	Yixian	0.66	0.09	5.0	1.3	5.7	1.3	0.15	0.01	1.26	0.10	1.41	0.10
	Average	0.66	0.13	3.3	1.7	4.0	1.7	0.16	0.01	0.85	0.41	1.0	0.40
Average of the five provinces		1.0	0.26	2.8	1.5	3.8	1.6	0.26	0.09	0.78	0.45	1.0	0.51

Province	Mine's name	Miners working in opencasts						Miners working in bone-coal pits					
		External radiation		Internal radiation		Sum		External radiation		Internal radiation		Sum	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Hubei	Miaopu	0.11	0.01			0.11	0.01						
	Zuantanyan							0.99	0.04	70	0.71	71	0.72
	Tangxiang	0.28	0.02			0.28	0.02						
	Average	0.20	0.09	0.0		0.20	0.09	0.99	0.04	70	0.71	71	0.72
Hunan	Nijiangkou	0.18	0.02	0.34	0.08	0.52	0.08						
	Ningxiang	0.18	0.02	0.42	0.12	0.60	0.12						
	Average	0.18	0.03	0.38	0.04	0.56	0.04						
Jiangxi	Yushan	0.32	0.02			0.32	0.02						
	Shangrao	0.30	0.02			0.30	0.02						
	Xiushui	0.13	0.04			0.13	0.04						
	Average	0.25	0.09	0.0		0.25	0.09						
Zhejiang	Anren	0.61	0.03	0.03	0.02	0.64	0.04						
	Zhuge							1.7	0.05	6.5	0.22	8.2	0.23
	Shuangpai							2.3	0.06	6.5	0.22	8.8	0.23
	Average	0.61	0.03	0.03	0.02	0.64	0.04	2.0	0.30	6.5	0.31	8.5	0.30
Anhui	Jixi	0.36	0.04	0.32	0.08	0.68	0.08						
	Yixian	0.69	0.02	0.97	0.12	1.7	0.12						
	Average	0.53	0.17	0.64	0.32	1.2	0.51						
Average of the five provinces		0.35	0.18	0.21	0.26	0.57	0.36	1.5	0.51	38	32	39.5	40

4.2 Staffs working in BCCB houses

Table 1 shows that the range of the average annual additional effective dose caused by γ-ray external radiation and by the inhalation of radon and/or its daughter internal exposure for the staffs working in BCCB houses in the mining areas is from 0.50 mSv to 2.0 mSv, with an average of 1.0 mSv. It means that the annual additional effective dose accepted by partial staffs may exceed the dose limit of 1.0 mSv for public exposure.[6]

4.3 Miners working in opencast localities

Table 1 shows that the range of the average annual additional effective dose of internal and external exposure accepted by miners working in opencast localities of bone-coal mines in the five province is from 0.20 mSv to 1.2 mSv, with an average of 0.57 mSv. The average annual additional effective dose accepted by miners does not exceed the dose limit of 1 mSv of public exposure and is much lower than the dose limit of 20 mSv for occupational exposure.[6]

4.4 Miners working in bone-coal pits

Table 1 shows that the average annual additional effective dose accepted by miners working in bone-coal pits in Zhuge and Shuangpai of Zhejiang Province is 8.2 mSv and 8.8 mSv, respectively, with an average of 8.5 mSv. And in Zuantanyan of Hubei Province, the average annual additional effective dose accepted by miners working in bone-coal pits is 71 mSv, which is 3.6 times the dose limit of 20 mSv for occupational exposure.[6] And the average annual additional effective dose caused by inhalation of radon and/or its daughter is 70 mSv, which is 98.6% of the total dose.

The total annual additional effective doses for the four kinds of personnel are shown in Fig.1.

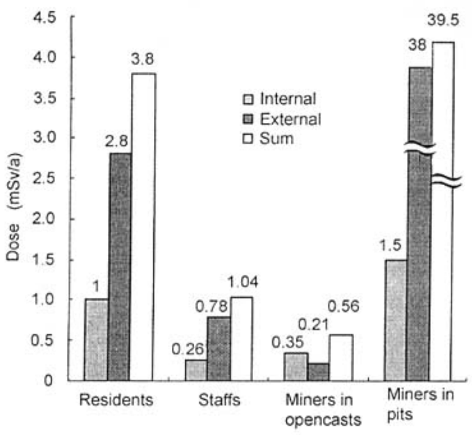

Fig.1 Annual additional effective doses for various kinds of personnel.

The contribution of radon inhalation to total dose is prevailing for the residents and staffs living and working in BCCB houses. As for the miners working in the bone-coal pits, the dose caused by inhalation of radon and/or its daughter is more than 76% of the total dose. It is emphasized that the main point of radiation protection should be effectively decreasing the radon concentration in working environment.

5 Summary

The annual additional effective dose accepted by the residents living in BCCB houses (except Xiushui mine area of Jiangxi Province) and by the staffs working in BCCB houses is 1.6—11.9 mSv and 1.3—3.5 mSv, respectively. It is noticed that partial residents and staffs living and working in BCCB houses might accept an annual additional effective dose which exceeds the dose limit of 1 mSv for public exposure stipulated in GB 18871-2002.[6]

The annual additional effective dose accepted by miners working in bone-coal pits (Zuantanyan mine of Hubei Province) is 71 mSv, being 3.6 times the dose limit of 20 mSv for occupational exposure.

The project team proposes that some effective safety measures should be taken to protect environment and public health. For example, BCCB house's doors and window should be often opening, the ventilation in bone-coal pits should be enhanced and the working condition should be improved. For the miners working in pits, working time should be decreased properly. In addition, if the equilibrated equivalent concentration of radon in BCCB houses is over 400 Bq/m^3,[7] the house cannot be used as dwelling house.

Acknowledgement

We would like to express gratitude to Prof. Pan Zi-Qiang, Chen Zhu-Zhou, Hu Feng-Quan, He Zhen-Yun and Zhang Wei-Ming for their technical guidance in this investigation.

References

1 Pang Deling, Ma Guocai. Nucl Tech (in Chinese), 1991, **14**(7): 391

2 Ye Jida, Kong Lingli, Li Yong, *et al.* Radiat Prot (in Chinese), 2004, **24**(1): 1

3 UNSCEAR Report of 1982

4 UNSCEAR Report of 1993

5 ICRP publication 65 (1993)

6 The State Standard of PRC: Basic standards for protection against ionizing radiation and for the safety of radiation sources (GB 18871-2002) (in Chinese)

7 The State Standard of PRC: Code for indoor environmental pollution control of civil building engineering (GBA50325-2001) (in Chinese)