Investigation of environmental activity levels of bone-coal mining area in five provinces

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Abstrat During 1991-1993, the activity levels of the bone-coal mines were investigated in Zhejiang, Hubei, Hunan, Jiangxi and Anhui Province, respectively, where the reserve of bone-coal is about 90% of our country's total reserve. The average of γ radiation doserate level measured for bone-coal, bone-coal cinder (BCC) and bone-coal cinder brick (BCCB) in these provinces is about 500 nGy/h, 400 nGy/h and 700 nGy/h respectively, while that for fields, roads and houses made of BCCB in corresponding regions of these provinces is about 200 nGy/h, 260 nGy/h and 300 nGy/h respectively. It is shown that the environmental activity level of bone-coal mining area is about 3 times higher than the reference spots.

Key words Bone-coal, Bone-coal cinder brick, Radiation level, Radiation doserate

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1 Introduction

The reserves of bone-coal in five provinces, i.e. Hubei, Hunan, Jiangxi, Zhejiang and Anhui, account for about 90% of the total reserves in China. More than two hundred years ago, local people spontaneously started to mine the bone-coal on a small scale. Instead of charcoal, it was used to make lime and then the lime used to build houses, or to improve the soil. At present, the bone coal is not only used as a kind of fuel for generating electricity or producing cement, but also the bone coal cinder (BCC) is used to produce building materials, such as bone coal cinder bricks (BCCB). The reserve, distribution, mining and utilizing of bone-coal in the five provinces are shown in Table 1, Table 2 and Fig.1.

Table 1 The reserve and distribution of bone-coal in five provinces

Province	Reserve (Gt)	Distribution of bone-coal
Hubei	2.56 (forecast)	Tangxiang, Miaopu, Zhushan, Zhuxi, etc.
Hunan	18.7	Jishou, Changde, Yueyang, Huaihua, etc.
Jiangxi	6.03 (forecast)	Xiushui, Wuning, Dexing, Shangrao, Yushan, etc.
Zhejiang	10.6 (forecast)	Quzhou, Jinhua, Hangzhou, Jiaxing, Shaoxing, etc.
Anhui	7.5	Huangshan, Xuancheng, Chizhou, Chuxian, Lu'an, etc.
Total	45.39 (forecast)	

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Table 2 The situation of mining and utilization of bone-coal in five provinces

Province	Bone-coal mines		Bone-coal cinder brick plants		Refining plants		Bone-coal power stations	
	Quantity	Annual output (Mt)	Quantity	Annual output ($\times 10^6$ps.)	Quantity	Annual output (kt)	Quantity	Annual capacity (GWh)
Hubei	5	0.2		953	3	30	1	9.5
Hunan	407	1.46	27	113			1	33.6
Jiangxi		0.28		4.7				
Zhejiang	200	4.0	40	900	3	796	2	6.26
Anhui	14	0.56	10	80	4	27		
Total	>626	6.5	>77	2051	>10	856	4	49.36

Fig.1 Distribution figure of bone-coal mine in five provinces. ▲ investigated point; ● provincial capital

According to "The national investigation of natural radioactive levels in environment" (abbreviated as "the investigation of levels" below) during 1983-1990, the bone-coal contains richer natural radionuclides ^{238}U and ^{226}Ra. Spontaneously mining and multiple utilization of bone-coal may bring a radioactivite pollution to the bone-coal mine area. This is a man-made radioactivity, which will lead to possible increase of radioactive level of environment and public dose in these regions.

In 1991, a project named "the study of effect of mining and utilizing radioactivity-associated bone-coal on environment" has been granted by the National Environment Protection Agency and the Safety Protection Bureau of the Chinese Nuclear Industry Corporation. The main investigation items include γ radiation doserate in the ambient environment; natural radionuclides in various materials; content of non-radioactive elements in various materials; concentration of ^{222}Rn indoors and outdoors; evaluation and estimation of the collective dose equivalent for the public. The project took more than two years, and was completed in 1993. One of important subprojects is mentioned above.

2 Surveyed item and instrument

The investigated sites include fields and roads of the bone-coal mining area and reference spots, opencast mining localities and shafts of bone-coal mine, plants of producing building materials with bone coal cinder, places of bone-coal multiple utilizing, inside and outside of houses made with bone-coal cinder brick (BCCB) and of houses made with ordinary red brick (ORB). There are 93 measurement spots for fields, 87 for roads, more than 34 for opencast mining localities, 37 for shafts, 95 for bone-coal pile sites, 93 for bone-coal cinder (BCC) pile sites, 23 for BCCB pile sites, 326 and 102 for the indoor and outdoor of BCCB houses, respectively, and 122 for the indoor of ORB houses.

The investigation was carried out strictly according to the Regulation of Environmental Activity Level Investigation. The measured values can be traced to national metrology standard. The surveyed item is γ-ray air absorbed doserate. The SG-102 X-γ doserate meters, made in Laoshan Electronic Instrument Research Institute and calibrated by a high pressure ionization chamber, were used for the purpose.

3 Results

3.1 Indoor condition

The indoor γ radiation doserate levels in BCCB houses at the bone-coal mine area and in ORB houses at the reference spots in five provinces are shown in

Table 3 Indoor γ-radiation doserate levels in bone-coal mining areas and in reference points (nGy/h)

Province	Location of mines	BCCB houses				ORB houses				Reference values[2)]
		n[1)]	Doserate	Mean	SD	*n*	Doserate	Mean	SD	
Hubei	Miaopu	35	118～370	223	77	23	72.7～173	110[3)]	20	
	Zuantanyan					36	54.6～152	87.1	27	
	Tangxiang	31	150～576	341	97	23	72.7～173	110	20	
	Average	2		282	83	3		102	13	93.2
Hunan	Nijiangkou	16	158～232	192		12	82～115	98.5		
	Ningxiang	7	490～515	504	26	22	80～131	92		
	Sangzhi			369				104[2)]		
	Average	3		355	156	3		98.2	6.0	104
Jiangxi	Yushan	19	189～754	335	193	3	101～254	178	76	
	Shangrao	5	312～391	341	39	8	80.6～163	122	41	
	Xiushui	14	106～165	129	16	3	79.0～104	91.7	127	
	Average	3		268	121	3		131	131	107
Zhejiang	Anren	21	167～327	212	22	6	91～131	105	13	
	Zhuge	32	551～737	637	51	5	177～200	191	9.0	
	Shuangpai	18	363～517	435	39	4	160～231	206	27	
	Average	3		428	212	3		167	55	124
Anhui	Jixi	69	152～335	217	49			95.9[2)]		
	Yixian	59	141～269	199	37			95.9[2)]		
	Average	2	199～217	208	13	2		95.9		95.9
Average of five provinces		5	208～428	308	85	5	95.9～167	119		105

Notes: 1) *n* =number of samples; 2) The average values quoted from Refs. [1-5]; 3) Assuming the same with that of ORB houses of Tangxiang.

with an average of 308 nGy/h. It was 2.6 times higher than that in the ORB houses at the reference spots in five provinces, and was 2.9 times of reference value of "the investigation of levels ". The highest value of the γ radiation doserate level in the BCCB houses was 428 nGy/h, which was measured in Zhejiang Province, and was twice as high as that in Anhui Province.

3.2 Bone-coal mining area

The outdoor γ radiation doserate levels in bone-coal mining area and the reference spots of five provinces are shown in Table 4. The outdoor γ radiation doserate levels in the BCCB houses range from 138 to 278 nGy/h, with an average of 197 nGy/h. The average value of γ radiation doserates measured from fields and roads at the bone-coal mining areas is 201 nGy/h and 256 nGy/h, respectively, and is 2.9 and 2.7 times, respectively, as high as that measured from fields and roads at the reference spots.

The γ radiation doserate measured from fields of the bone-coal mining areas in Hubei, Hunan, Zhejiang and Anhui Province is 73.1, 90, 377 and 265 nGy/h, respectively, and is 1.2, 1.3, 4.4 and 4.7 times, respectively, as high as that measured from fields at the reference spots. The γ radiation doserate measured from roads of the bone-coal mining areas in Hubei, Hunan and Zhejiang Provinces is 198, 161 and 409 nGy/h, respectively, and is 3.6, 2.3 and 2.6 times, respectively, as high as that measured from roads at the reference spots.

Table 5 shows that the γ radiation doserates measured from various functional areas of bone-coal mines were different at Jixi and Yixian County in Anhui Province. For example, the γ radiation doserate measured from mining areas of the bone-coal at Jixi County and Yixian County is 306 nGy/h and 543 nGy/h, respectively, which is higher than 147 nGy/h and 210 nGy/h measured from the processing areas and is much higher than 147 nGy/h and 155 nGy/h measured from living areas. In addition, the average

Table 4 Outdoor γ-radiation doserate levels in bone-coal mining areas and in reference spots (nGy/h)

Province	Location of mines	Bone-coal mining area									Reference spot	
		Outdoor of BCCB house			Fields			Roads			Fields	Roads
		n	Doserate	Mean	*n*	Doserate	Mean	*n*	Doserate	Mean	Mean	Mean
Hubei	Miaopu	11	118～182	141	2	47.1～50.2	48.6	5	118～182	148		
	Zuantanyan	6	120～189	155	2	74.7～120	97.6	10	94.3～248	209		
	Tangxiang	11	147～351	254				8	160～351	237		
	Average	3	141～254	183	2	48.6～97.6	73.1	3	148～237	198	60.9[1)]	55.3[1)]
Hunan	Nijiangkou	4	176～209	195	8		90	12		161	71.1[2)]	70.5[2)]
Jiangxi	Yushan	12	70.3～595	375								
	Shangrao	10	89.0～596	298								
	Xiushui	5	61.5～393	162								
	Average	3	162～375	278								
Zhejiang	Anren	4	85～100	92.0	23	165～505	289	21	158～439	285	97	
	Zhuge	5	106～152	130	6	259～671	493	22	302～666	473	104	
	Shuangpai	3	174～210	192	8	192～632	348	9	284～806	469	57	
	Average	3	92.0～192	138	3	289～493	377	3	285～473	409	86	155
Anhui	Jixi	13	81.5～206	151	25	70.8～388	226					
	Yixian	18	181～345	230	19	91.9～721	303					
	Average	2	151～230	190	2	226～303	265				56.7[3)]	
Average of five provinces		5	138～278	197	5	73.1～377	201	3	161～409	256	68.7	93.6

Note: 1-3) Quoted from Ref. [1], [2], [5], respectively.

Table 5 The γ-radiation doserate levels of different functional area in bone-coal mines at two counties of Anhui Province (nGy/h)

Location of mines	Mining area			Processing area			Living area			Fields of reference spots
	n	Doserate	Mean	*n*	Doserate	Mean	*n*	Doserate	Mean	
Jixi	5	201～388	306	25	70.8～248	147	25	70.8～248	147[1)]	
Yixian	7	351～721	543	19	91.9～254	210	7	104～184	155	
Average	2	306～543	424	2	147～210	178	2	147～155	151	56.7[2)]

Notes: 1) Supposing the γ-radiation doserate of the processing area is identical with that of the living area because the two areas are mixedly distributed; 2) Quoted from Ref. [5].

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of γ radiation doserates measured from the mining areas, processing areas and living areas of the bone-coal mines in the two counties is 7.5, 3.1 and 2.7 times, respectively, as high as that measured from fields of the reference spots.

It is shown that the γ radiation doserates measured from fields, roads and BCCB houses in the bone-coal mine areas of five provinces have obviously risen, which can be attributed to the mining and utilizing of bone-coal with high radioactive content, including using BBC with more radionuclides to make BCCB, to pave the road or fill the house bases, and the scattering of bone-coal and BCC during transportation.

3.3 Bone-coal mine areas

The γ radiation doserates of the opencast mining localities and shafts in Hubei, Zhejiang and Anhui Provinces are shown in Table 6. The γ radiation doserate of opencast mining localities is 439, 544 and 425 nGy/h in Hubei, Zhejiang and Anhui Province, respectively, and is 7.2, 1.9 and 1.6 times as high as that of fields in bone-coal mine areas (in the parentheses), respectively. The γ radiation doserate of shafts is 8.2 and 3.7 times higher than that of fields, respectively, in the bone-coal mine areas of Hubei and

Table 6 The γ-radiation doserate levels of opencast mining localities and shafts in bone-coal mine areas (nGy/h)

Type	Province	Location of mine	Bone-coal mining areas				Fields of bone-coal mine areas			
			n	Doserate	Mean	SD	*n*	Doserate	Mean	SD
Opencast mine localities	Hubei	Miaopu	4	279～698	430	185	2	47.1～50.2	48.6	
		Tangxiang	10	302～635	448	196			73.1 [1)]	
		Average	2	430～448	439(7.2)[2)]	12.7	2		60.8	
	Zhejiang	Anren	20	295～805	544(1.9)	166	23	165～505	289	97
	Anhui	Jixi			306	76.4	25	70.8～388	226	
		Yixian			543	110	19	91.9～721	303	
		Average	2	306～543	425(1.6)	168	2		265	
	Average of three provinces		3	425～544	469(2.3)	65.0	3		205	125
Shafts	Hubei	Zuantanyan	16	402～1396	796(8.2)	344	2	74.7～120	97.6	10
		Zhuge	15	738～2212	1338	451	6	259～671	493	158
	Zhejiang	Shuangpai	6	1289～2244	1806	433	8	192～632	348	134
		Average	2	1338～1806	1572(3.7)	331	2		420	
	Average of two provinces		2	796～1572	1184(4.6)	549	2		259	

Notes: 1) Average value of mine areas fields in Miaopu and Zuantanyan from Table 4; 2) The value in parentheses is a ratio of γ-radiation doserate of bone-coal mining areas to that of fields of bone-coal mine areas.

3.4 Solid materials

The γ radiation doserates of bone-coal, BCC and BCCB measured in Hubei, Hunan and Zhejiang Provinces are shown in Table 7. The γ radiation doserate of bone-coal is 400, 707 and 409 nGy/h, respectively, in Hubei, Zhejiang and Hunan Province. The doserate of BCC is 347, 399 and 389 nGy/h, respectively, in three provinces. And doserate of BCCB is 708 nGy/h in Zhejiang Province.

In addition, the ratio of γ radiation dose rate of BCC to bone-coal is 1.2 and 1.4, respectively, at Zuantanyan in Hubei and at Maitianxiang in Hunan. But the ratio is only 0.6, 0.7and 0.5, respectively, at Anren, Zhuge and Shuangpai in Zhejiang because the BCC there contains considerable amount of broken limestones and some lower radioactive materials.

Table 7 The γ-radiation doserate levels of bone-coal BCC and BCCB in bone-coal mine areas of five provinces (nGy/h)

Province	Location of mines	Bone-coal			BCC			BCCB			Fields of reference spot
		n	Doserate	Mean	*n*	Doserate	Mean	*n*	Doserate	Mean	
Hubei	Miaopu				7	136～184	158				
	Zuantanyan	5	370～442	400	5	447～513	493				
	Tangxiang				11	192～576	390				
	Average			400	3	158～493	347				60.9[1)]
Zhejiang	Anren	59	263～646	466	33	212～355	272				97
	Zhuge	18	514～880	736	21	280～789	480	15	614～821	698	104
	Shuangpai	18	579～1140	920	14	295～594	444	8	568～822	717	57
	Average	3	466～920	707	3	272～480	399	2	698～717	708	86
Hunan	Nijiangkou				1		188				
	Maitianxiang	2	288～529	409	1		589				
	Average	1		409	2	188～589	389				71.1[2)]
Average of three provinces		3	400～707	505	3	347～399	378	1		708	72.6

Notes: 1) and 2) is quoted from Ref. [1] and [2], respectively.

4 Conclusions

From this investigation, we can conclude that:

(1) The γ radiation doserate level of the BCCB houses, fields and roads in the bone-coal mine areas in five provinces is about 3 times as high as that specified in "the investigation of levels".

(2) The mean γ radiation doserates of the opencast mining areas in Hubei, Zhejiang and Anhui Provinces are 7 times as high as that of fields of three provinces according to "the investigation of levels", and that of shafts in Hubei and Zhejiang are 18 times as high as that of fields of two provinces according to "the investigation of level". The γ radiation doserate of shafts measured in Zhejiang Province is twice as high as that of shafts in Hubei Province.

The investigation has manifested that the γ radiation doserates levels of the fields, roads and BCCB houses in bone-coal mining area have been increased obviously, because the BCCB are produced using bone-coal cinder with high radioactive content, the roads are paved or the bases of house are filled with the bone-coal cinder, the bone-coal and bone-coal cinder are scattered during transportation, and the house are build by the BCCB with higher radioactivity.

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