Approach to reducing the effect of bone-coal power station on radiation environment

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Abstract The effect of two bone-coal power stations (6 MWe) on environment was investigated within the scope of the dose contribution caused by various radionucildes in different ways. It is found that the best measures to reduce the effect of bone-coal power station on radiation environment include to select a fine boiler system and a comprehensive utilization of the bone-coal cinder (BCC), soot and ash in the catchers.

Keywords Bone-coal, Power station, Radiation environment

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1 INTRODUCTION

Bone-coal is a natural fuel resources in the southern China where raw coal is in a shortage. In this area, mining and utilizing bone-coal has never been interrupted, although bone-coal is low in caloricity, high in ash content, and it contains sulfur and natural radionuclides. It is feasible to make use of the bone-coal to generate electricity. However, the effect of its radiation on environment is a great concern. This paper presents an approach to reducing the effect of bone-coal power station (BCPS) on environment.

2 POLLUTANT ELEMENTS AND PREVENTION MEASURES

A BCPS consists of a boiler system, a steam turbine, an electricity generator, a power distributor, bone-coal storage, bone-coal cinder (BCC) storage, and duster ash storage. The main electrical installation and the technological parameter are listed in Table 1.

As for the effect of the radiation on environment, the following stages of the bone-coal usage in two plants caused us considerable concern: Bone-coal storage→Fluid-bed boiler system→BCC and duster ashes. The resulted pollution includes: (1) the raised dust and the ^{222}Rn released from the bone-coal (bone-coal storage), (2) the soot and ^{222}Rn discharged into the atmosphere from the chimney (boiler system of fluid-bed), and

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(3) the dust and ^{222}Rn released from the BCC and ash in the catchers (BCC and duster ash storage).

Because the BCPS and bone-coal mine are close to each other in a geometric distance, the bone-coal can be easily obtained. As a result, there needs little storage of the coal, and often a supply for five days is required. When an effective measure is adopted, such as using a water sprinkle, the raised dust can be insignificant. The ash is kept in a storage, and the longest storage time does not exceed five days. In addition, measures are taken by providing windbreak, waterproof, and dustproof. The ash can be used as a row material to produce cement. Therefore, the effect of the raised dust and ash on ambient environment is negligible.

Table 1 Main electrical installations and technological parameters of BCPS

Electrical installation	Technological parameter	
	Bone-coal power station A	Bone-coal power station B
BOILER		
Type	Circulating fluid-bed	Composite circulating fluid-bed
Nominal capacity (t/h)	35	35
Final steam pressure (MPa)	3.82	3.82
Final steam temperature (°C)	450	450
STEAM TURBINE		
Rated power (MWe)	6	6
Speed (r/min)	3000	3000
Inlet steam pressure (MPa)	3.43	3.43
Inlet steam temperature (°C)	435	435
GENERATOR		
Rated power (MW)	6	6
Speed (r/min)	3000	3000
Output voltage (kV)	6.3	10.5
Phase	3	3

Based on computer simulations, it is estimated that the public radiation dose caused by the ^{222}Rn released from BCC and ash at the stacking site is only several thousandths of that from the chimney. The effect is also negligible.

BCPS A adopts a circulating fluid-bed boiler with a consumption rate of coal of 20.18 t/h (1.21×10^5 t/a). The efficiency of removing dusts using a whirlwind dust remover and a rotating stream plate desulfurized dust remover is 98%.The ash-laden gases exhaust from chimney which has a height of 80 meters and an internal diameter of two meters at exhaust pass. The amount of soot discharged from the chimney is 44.9 kg/h (269.4 t/a).

The other BCPS uses a composite circulating fluid-bed boiler consisting of three circulating elements. The coal consumption rate is 21.87 t/h (1.31×10^5 t/a). A desulfurized measure is adopted by using burning limestone. The efficiency for removing dusts using a whirlwind separator and electrostatic precipitator is 97.8%. The ash-laden gases exhaust from the chimney which has a height of 80 meters and an internal diameter of two meters at exhaust pass. The amount of soot discharged from the chimney is 19.0 kg/h (114 t/a).

3 ESTIMATION OF PUBLIC RADIATION DOSE

3.1 Radio-nuclides from the bone-coal power station

The concentrations of radio-nuclides in the bone-coal, BCC and ash in the catchers are listed in Table 2.

Table 2 Concentration of radionuclides in bone-coal, BCC and ash in the catchers (Bq/kg)

Radionuclide	^{238}U	^{232}Th	^{226}Ra	^{40}K
Ordinary coal	55	30	34	
BCPS A				
Bone-coal	580	32	590	890
Duster ashes	1200	54	1100	1100
Bone-coal cinder	600	41	520	1200
BCPS B				
Bone-coal	1300	33	100	520
Duster ashes	2690	56	1860	640
Bone-coal cinder	1350	33	880	700

For the estimation of the public radiation dose, the radio-nuclides such as ^{238}U, ^{234}U, ^{232}Th, ^{222}Rn, ^{210}Pb and ^{210}Po are concerned.

Based on the results from literature,[1] during the burning process of coal, radionuclides are concentrated in the soot from the chimney, ash in the catchers and bone-coal cinder, especially in the soot. It is therefore assumed that the concentration of ^{210}Pb and ^{210}Po in the soot is two times as long as that in ash in the catchers. Due to the property of the ^{222}Rn gas, it is further assumed that all the ^{222}Rn is released with smoke into the ambient environment.

Table 3 lists the radioactive source items obtained from the chimneys according to the consumed bone-coal and soot for the two BCPS under general operation.

Table 3 Gaseous radiation effluents of BCPS ($\times 10^8$ Bq/a)

Radionuclide		^{238}U	^{234}U	^{232}Th	^{226}Ra	^{222}Rn	^{210}Pb	^{210}Po
Discharged	BCPS A	3.24	3.24	3.24	2.96	7.14	5.92	5.92
amount	BCPS B	3.07	3.07	3.07	2.12	1310	4.24	4.24

3.2 Results

The computer program, YEAR3O (revised edition), was used to estimate the dose.

Because BCPS A is not far away from BCPS B, parameters related to meteorology, living custom, and resident recipes were assumed to be identical for the two BCPSs. And the condition is roughly same about the two BCPSs in the estimation of doses. The maximum public individual annual effective dose equivalents are shown in Table 4.

Table 4 The public annual effective dose equivalent at the leeward (mSv/a)

Position	Age group	BCPS A		BCPS B	
		0.2 km	0.4 km	0.2 km	0.4 km
	Infant	0.134	0.072	0.144	0.116
SW	Child	0.076	0.044	0.027	0.023
	Adult	0.084	0.048	0.019	0.017
	Infant	0.194	0.101	0.208	0.179
WSW	Child	0.115	0.061	0.039	0.036
	Adult	0.123	0.072	0.028	0.027
	Infant	0.114	0.061	0.127	0.118
W	Child	0.066	0.039	0.024	0.024
	Adult	0.073	0.042	0.017	0.018

As shown in Table 4, the infant group has a maximum dose in WSW at the 200 meter from the BCPS, the doses are approximately 0.194 mSv/a and 0.208 mSv/a, respectively, with a manageable public radiation dose being 0.25 mSv/a[2], the public doses of both BCPSs are within the acceptable level.

The dose contributions caused by various radionuclides and radiations from gaseous effluents are shown in Table 5. As shown in the table (for BCPS B), the key radionuclide is ^{210}Po and the primary channel into human body is the ingested agricultural products. The dose contribution from ^{210}Po is 59.6% of the total. The dose caused by ^{222}Rn in the inhaled air is only 2.76×10^{-6} mSv/a, a very low quantity compared with the total dose of 0.208 mSv/a. Clearly, the dose caused by ^{222}Rn is negligible.

4 MEASURES TO REDUCE RADIATION DOSE

It was estimated that the public maximum individual annual effective dose is equivalent to 0.208 mSv/a. It is lower than the manageable objective value (0.25 mSv/a), but still higher than the corresponding radiation level caused by ordinary nuclear power plant. It is necessary to take appropriate measures to reduce the radiation dose from the BCPS.

4.1 Increasing height of a chimney

In general, increasing height of the chimney is a way to reduce the radiation dose from the BCPS. It is estimated that if the height of the BCPS's chimney is increased from

80 m to 100 m or 120 m, the maximum doses equivalent in the infant group at WSW-0.2 km are 0.389 mSv/a, 0.388 mSv/a, and 0.388 mSv/a respectively. The change of the maximum doses equivalent in the infant group is minimal. Therefore, to increase height of the chimney will not be effective to reduce the radiation level.

Table 5 The dose contribution caused by various radionuclides and ways (SWS 0.2 km) (Sv/a)

Radionuclide	Group	Immersion radiation	Ground radiation	Inhaled air	Ingestion		Sum
					Agricultural products	Animal products	
^{226}Ra	Infant	7.94E-13	1.47E-07	6.69E-09	1.30E-05	6.03E-09	1.31E-05
	Child	7.94E-13	1.47E-07	8.59E-09	3.11E-06	1.57E-09	3.27E-06
	Adult	7.94E-13	1.47E-07	8.92E-09	1.79E-06	2.58E-10	1.95E-06
^{230}Th	Infant	4.16E-15	1.30E-10	4.97E-08	1.57E-05	7.44E-08	1.58E-05
	Child	4.16E-15	1.30E-10	1.09E-07	1.29E-06	6.62E-09	1.41E-06
	Adult	4.16E-15	1.30E-10	1.55E-07	1.85E-06	2.72E-09	2.1E-06
^{210}Pb	Infant	2.96E-15	3.06E-10	4.37E-09	5.17E-05	2.47E-08	5.17E-05
	Child	2.96E-15	3.06E-10	5.11E-09	1.65E-05	8.32E-09	1.65E-05
	Adult	2.96E-15	3.06E-10	4.78E-09	9.79E-06	1.41E-09	9.80E-06
^{210}Po	Infant	8.90E-18	5.94E-13	6.88E-09	1.24E-04	3.47E-08	1.24E-04
	Child	8.90E-18	5.94E-13	4.75E-09	1.73E-05	5.14E-09	1.73E-05
	Adult	8.90E-18	5.94E-13	3.24E-09	1.32E-05	1.10E-09	1.32E-05
^{234}U	Infant	3.96E-16	1.21E-10	2.13E-08	1.42E-06	1.11E-08	1.45E-06
	Child	3.96E-16	1.21E-10	3.04E-08	3.96E-07	1.70E-09	4.30E-07
	Adult	3.96E-16	1.21E-10	3.47E-08	4.32E-07	2.82E-10	4.67E-07
^{238}U	Infant	2.58E-14	5.84E-09	1.87E-08	1.30E-06	1.02E-08	1.33E-06
	Child	2.58E-14	5.84E-09	2.54E-08	3.66E-07	1.57E-09	3.99E-07
	Adult	2.58E-14	5.84E-09	2.95E-08	3.97E-07	2.59E-10	4.32E-07
^{222}Rn	Infant	0.0	0.0	2.76E-09	0.0	0.0	2.76E-09
	Child	0.0	0.0	2.76E-09	0.0	0.0	2.76E-09
	Adult	0.0	0.0	2.76E-09	0.0	0.0	2.76E-09
Sum	Infant	8.72E-13	1.53E-07	1.10E-07	2.07E-04	1.61E-07	2.08E-04
	Child	8.72E-13	1.53E-07	1.86E-07	3.91E-05	2.49E-08	3.94E-05
	Adult	8.72E-13	1.53E-07	2.39E-07	2.74E-05	6.03E-09	2.78E-05

4.2 Selection of boiler system

The composite circulating fluid-bed boiler used in BCPS B, has advantages of low pollution and higher dust-removing efficiency. In addition, its discharged amount of soot is only 42.3% of that of BCPS A. As a result, if BCPS A had a composite circulating fluid-bed boiler, its discharged amount of soot might be decreased to 50%, and the corresponding public maximum radiation dose would be also reduced by about half.

4.3 Utilization of cinder and ash in catcher

BCPS A produces 37600 t of BCC and 56900 t of ash in catcher every year. The effect of such a large amount of BCC and ash from the catcher in the stacked sites on ambient environment is significant. To make use of the waste to produce useful products is an effective way to prevent pollution. There are matured ways to utilize the BCC and ash from the catcher as raw materials to produce cement. This will also protect environment from radioactive contamination. Because the BCC and ash from the catcher have concentrated natural radionuclides, the production of cement using these materials should follow the corresponding codes.[3] According to estimation, the BCC should not exceed 30% and the maximum ash content from the catcher is 15%. When mixed at a (BCC/ash) ratio of 1:1.15, the total content of the mixture should not exceed 20% of the total raw materials in weight.

5 CONCLUSIONS

Small-scale BCPS($6\,MW_e$) may give public individual maximum annual effective dose equivalents less than the annual manageable objective level. However, it is necessary and possible to further reduce the radioactive level caused by BCPS. An effective measure is to select a good boiler system with a rational structure that produces small amount of soot. An integrated utilization of the BCC and ash from the catcher is also an effective way to reduce radiation.

References

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