Radiological monitoring results of the ambient environment around Qinshan Nuclear Power Plant

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Abstract A plan of surveillance monitoring Qinshan Nuclear Power Plant (QNPP) has been implemented since 1992, the objective of which is to establish the database of environmental radiation information around QNPP, and to detect any unplanned discharge of radioactive materials from QNPP. This paper presents the monitoring results for radionuclide concentrations in the environmental matrices before and after QNPP operation. The radionuclide concentrations in vegetation, food, atmosphere, soil and littoral soil samples have been determined. After operation of QNPP, the mean values of ^{137}Cs, ^{90}Sr and ^{3}H in water are 0.6, 4.9 mBq/L and 1.7 Bq/L, respectively; the mean values of ^{137}Cs in soil and littoral soil are 3.5 and 2.7 Bq/kg, respectively; the mean values of ^{137}Cs in rice, green cabbage, meat, mullet, milk and tea are 0.033, 0.039, 0.081, 0.069, 0.018 and 0.62 Bq/kg, respectively; the mean values of ^{90}Sr in rice, green cabbage and tea are 0.081, 0.315 and 4.1 Bq/kg, respectively; gross β activity in fallout is 0.9 Bq·m^{-2}·d^{-1}. Compared with the data before QNPP's operation, no significant difference has heen observed in the radioactivity of ^{137}Cs, ^{90}Sr, ^{3}H and the gross β activity in ambient environmental matrices from 1992 to 2001, and there are only some fluctuations within the range of background.

Keywords Qinshan Nuclear Power Plant, Environmental radiation monitoring, Radionuclides
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1 Introduction

Qinshan Nuclear Power Plant (QNPP), a 300 MW pressurized-water reactor, was built in 1983, and put into operation in December 1991. In order to estimate the impact QNPP exerted on the ambient environment and the radiation dose the public received, the lab monitoring system and instantaneous land gamma radiation dose-rate monitoring system were established in 1985, and worked from 1988. This paper provides the part results of the lab monitoring system.

2 Monitoring program

2.1 Materials and methods

Before operation (1988~1991) the scope of sampling collections is about 50 km, while after that the scope of surveillance monitoring is about within 10 km. Samples are collected from the selected locations of the Qinshan Region (Fig.1), including five spots for littoral area soil samples, five places (Qianshanzhen, Qinlian, Wuyan, Tongfeng, Zhongjiaqiao) for fallout, vegetation, animal and fresh water samples, and A,B,C for sea water samples.

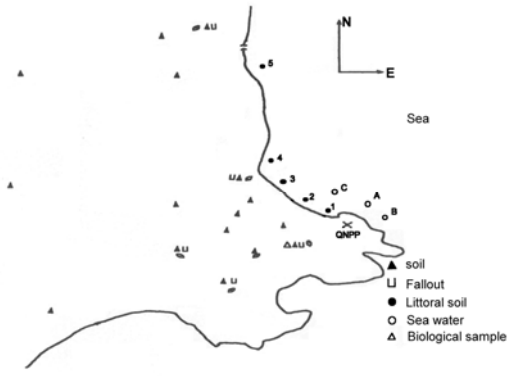

Fig.1 Map of Qinshan Region, indicating various sampling spots.

It is reported[1] that (^{131}I + ^{137}Cs) in vegetation, (^{137,134}Cs + ^{60}Co) in seabeach deposition and ^{133,135}Xe in atmosphere are important for absorbed dose assessment of the key resident group.

Since ^{131}I concentration has never been detected

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out, i.e. the ^{131}I activity is less than the minimum detection level, it has not been listed it in Tables 1 and 2.

2.2 Sample processing

Samples were collected and prepared in accordance with the procedure of IAEA Technical Reports Series No.295[2] and a guidebook on radiation environmental monitoring.[3]

2.2.1 Soil and littoral area soil

Samples were taken at the depth of 0~10 cm and dried at 105 °C. After removing extraneous materials such as pieces of stones and shellfishes, the samples were ground into particles with a size of <200 μm, weighted, and sealed in (ϕ 7.5 cm×5 cm) plastic vials for determination.

Table 1 Monitoring items and methods

Nuclides	Matrices	Methods	Instruments
^{137}Cs	Water, vegetation	AMP-$Cs_3Bi_2I_9$ precipitation	LB4100 low background counter
	Soil	γ ray spectrometry	ORTEC-ADCAM-100 spectrometer system
^{90}Sr	Water, vegetation	Extraction chromatography by HDEHP-kel-F	LB4100 low background counter
^{3}H	Water, vegetation	Internal standard method	Quantulus-1220 low level liquid scintillation spectrometer
Gross β	Fallout	Evaporation-β measurement	LB4100 low background counter
	Aerosol	Ashed-β measurement	LB4100 low background counter

Table 2 Monitoring program

Matrices		Nuclides	Frequency (a^{-1})	Sampling sites
Atmosphere	Fallout	Gross β	4	Qianshanzhen, Zhongjiaqiao, Wuyan, Qinlian, Tongfeng
	Aerosol	Gross β		
Water	Sea	^{137}Cs, ^{90}Sr, ^{3}H	1	Spots A, B, C (<3km[a)])
	Well	^{137}Cs, ^{90}Sr, ^{3}H	2	Zhongjiaqiao
	Pool	^{137}Cs, ^{90}Sr, ^{3}H	2	Zhongjiaqiao
Vegetation	Rice	^{137}Cs, ^{90}Sr	2	Wuyan, Qinlian, Tongfeng, Zhongjiaqiao
	Green cabbage	^{137}Cs, ^{90}Sr	2	Wuyan, Qinlian, Tongfeng, Zhongjiaqiao
	Tea	^{137}Cs, ^{90}Sr	2	Zhongjiaqiao
	Pine needle	^{137}Cs, ^{90}Sr	1	Zhongjiaqiao
Animal	Mullet	^{137}Cs	1	Qianshanzhen
	Milk	^{137}Cs	2	Huangshan dairy farm
	Meat	^{137}Cs	1	Qinlian
Soil	Littoral area soil	γ-emitting nuclide	2	Spots No. 1~5 [<5km[a)]]
	Soil	γ-emitting nuclide	2	15 spots

a) The distance from the total drain exit of QNPP

2.2.2 Vegetation

Vegetation samples were dried at low temperature (50 °C). After dried, the samples were charred at 300 °C and burnt at 450 °C to white ashes, which then were poured into a glass bottle for ^{137}Cs and ^{90}Sr analysis.

2.2.3 Fish and meat

The edible portion of fish and meat was taken for determination. Before ashed at 450 °C, animal oil in the sample had to be evaporated at 200 °C for 3~4 days. When ashing the sample, the temperature should rise slowly to avoid sample splashing out of the vessel.

2.2.4 Water

After water sample (excluding ^{3}H sample) was collected, hydrochloric acid (12 mol/L) was added at the rate of 10 mL per liter of sample to vessel to avoid adsorption of radionuclide on the wall of the sample container.

2.2.5 Fallout sample

The rain and dust in the fallout collector were poured into a beaker and evaporated till dryness, then the sample was transferred to a porcelain basin and ashed completely in a muffle furnace at 450 °C. The ashed sample was weighed and preserved for gross β measurement.

2.3 Result and discussion

2.3.1 ^{137}Cs, ^{90}Sr, ^{3}H in water

The ^{137}Cs, ^{90}Sr, ^{3}H concentrations in sea water, well water and pool water were measured. The results are listed in Table 3, which shows that the values fluctuated nearby the background level, and even a little less than the background level. It indicates that the radionuclide activities in environmental materials have not changed at a pace of QNPP operation. We regard two facts as the reason of this phenomenon. On one hand, though the atmospheric nuclear tests were forbidden many years ago, some quantities of artificial radionuclides in atmosphere have still fallen continuously; on the other hand, the sampling capacity is not enough, especially the number of background samples. In addition, we have measured the water samples of total drainageway (i.e. those of the third circuit cooling water of QNPP), the results are listed in Table 4. We have studied the values in Table 3 and Table 4 and found the correlation between ^{90}Sr in sea water

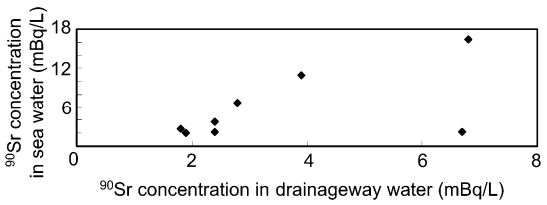

Fig.2 The ^{90}Sr concentration correlation between sea water and drainageway water.

Table 3 Radionuclide concentrations in water samples (^{90}Sr, ^{137}Cs: mBq/L; ^{3}H: Bq/L)

Samples	Nuclides	Background (1988~1991)		1992~2001	
		Number	Range (mean)	Number	Range (mean)
Sea water	^{90}Sr	10	1.6~11.5 (6.0)	30	0.5-16.5 (6.0)
	^{137}Cs	8	0.5~1.5 (1.0)	30	ND-1.4 (0.7)
	^{3}H	8	1.2~5.2 (3.0)	26	ND-2.7 (1.3)
Well water	^{90}Sr	3	2.7~6.9 (4.5)	10	1.4-13.8 (3.4)
	^{137}Cs	3	0.5~0.8 (0.6)	10	ND-1.4 (0.6)
	^{3}H	2	3.8~5.1 (4.5)	10	ND-2.4 (1.5)
Pool water	^{90}Sr	2	13~19 (16)	10	0.5-8.4 (5.2)
	^{137}Cs	---	---	10	ND-1.9 (0.6)
	^{3}H	1	5.1	10	ND-4.6 (2.2)

Table 4 Radionuclide concentrations in the drainageway water (^{90}Sr, ^{137}Cs: mBq/L; ^{3}H: Bq/L)

Year	^{90}Sr	^{137}Cs	^{3}H
1993	6.7±4.9	----	2.6±1.7
1994	6.7±4.2	1.1±0.7	----
1995	3.9±4.4	1.0±0.4	1.4±1.1
1996	6.8±6.7	1.0±0.8	1.8±1.9
1997	2.4±1.2	0.8±0.2	2.3±1.2
1998	1.8±0.7	0.6±0.2	1.5±0.7
1999	2.8±1.7	0.8±0.4	----
2000	1.9±0.9	0.8±0.2	3.4±5.4
2001	2.4±1.4	0.7±0.4	<1.4
Mean	3.9±2.2	0.9±0.2	2.0±0.9

and ^{90}Sr in drainageway water is weak (with a correlation coefficient of 0.29, see Fig.2. Similarly, the correlation coefficients for ^{137}Cs and ^{3}H are found to be 0.1 and 0.39 respectively. The poor correlations of radionuclides indicate that the individual radionuclide content in one kind of sample in each pair is not, therefore, a good predictor of the radionuclide content in the other kind of sample.

2.3.2 ^{137}Cs and ^{90}Sr in biological samples

The analytical results are listed in Table 5. There are no significant difference between before and after QNPP operation. Under normal operation condition, the main radioactive materials released by QNPP are inert gases, so the dust particles ^{90}Sr and ^{137}Cs attached are with exceedingly minor quantities. As a result, the adsorbed and accumulated quantities in vegetation are difficult to detect out. We can get a conclusion that the change of environmental radiation level around QNPP is not observable. Chen Guo-Pei[4] investigated the 1983~1988 ^{137}Cs content in rice, cabbage, meat and mullet in the same region, and obtained the mean values of 29, 38, 55 and 106 mBq/kg respectively, which also corresponded with our analytical results.

2.3.3 ^{137}Cs in soil and littoral soil samples

As the ^{134}Cs and ^{60}Co activities are less than the minimum detection level, we only list ^{137}Cs values in Table 6. Since a little island is near the second spot, radionuclides released from QNPP liquid effluents seem easier to deposit at this spot. But the ^{137}Cs activity in the spot did not show an increasing tendency

Table 5 ^{90}Sr and ^{137}Cs concentrations in biological samples (Dried tea, pine needle: Bq/kg; others: mBq/kg)

Sample	Nuclide	Background (1988~1991)		1992~2001	
		Number	Range (mean)	Number	Range (mean)
Rice	^{90}Sr	15	26~160 (68)	30	43~190 (81)
	^{137}Cs	14	12~61 (30)	27	25~45 (33)
Green cabbage	^{90}Sr	11	210~1000 (490)	30	55~1197 (315)
	^{137}Cs	9	17~156 (75)	30	20~182 (50)
Meat	^{137}Cs	6	23~140 (81)	10	34~120 (81)
Mullet	^{137}Cs	1	63	8	19~140 (69)
Spiral shell	^{137}Cs	---	---	5	1.0~2.7 (2.0)
Milk	^{137}Cs	3	17~21 (18)	10	6~33 (18)
Dried tea	^{90}Sr	2	19.1~26.0 (22.6)	10	1.0~11.2 (4.1)
	^{137}Cs	3	0.56~0.76 (0.59)	10	0.46~0.80 (0.62)
Pine needle	^{90}Sr	---	---	10	2.7~24.3 (10.2)
	^{137}Cs	2	0.06~0.13 (0.10)	10	0.05~0.13 (0.08)

Table 6 Average ^{137}Cs concentrations in soil and littoral area soil (Bq/kg)

Year	No. of sampling spot for littoral area soil					Soil
	1	2	3	4	5	
	200 m[a)]	500 m	1 km	1.5 km	4 km	
Background	3.3	---				
1992	4.1	---				
1993	2.8	3.0	2.6	1.6	3.1	4.2±2.4
1994	2.4	3.4	3.6	2.9	3.2	4.4±2.1
1995	2.4	2.6	3.0	2.5	2.4	2.8±1.9
1996	2.7	3.0	3.2	3.4	2.5	4.1±2.2
1997	2.3	2.8	2.3	3.7	3.8	4.1±2.2
1998	2.2	2.6	2.4	2.4	2.3	3.8±2.3
1999	1.8	2.4	2.7	2.4	2.2	2.7±1.8
2000	2.4	3.6	2.8	3.8	2.9	2.9±1.8
2001	2.0	0.9	<0.8	2.2	2.5	2.8±1.6
Mean	2.5±0.6	2.7±0.8	2.6±0.9	2.8±0.7	2.8±0.5	3.5±0.7

a) The distance from the total drain exit

Table 7 Gross β in fallout
($Bq \cdot m^{-2} \cdot d^{-1}$)

Year	Wuyan	Zhongjiaqia	Qinlian	Qianshanzhen	Tongfeng	Mean
	8 km[a)];15 m[b)]	1 km; 6 m	2 km; 9 m	2 km; 15 m	3 km; 10 m	
1992	0.57±0.10					
1993	0.57±0.14	0.86±0.23	0.82±0.15	0.77±0.12	0.70±0.10	0.74±0.11
1994	0.59±0.13	0.80±0.18	0.88±0.37	0.69±0.14	0.58±0.20	0.71±0.13
1995	0.52±0.19	0.80±0.18	1.00±0.33	0.80±0.16	0.86±0.11	0.80±0.17
1996	0.72±0.09	0.95±0.31	1.03±0.26	0.86±0.36	0.73±0.20	0.86±0.14
1997	0.69±0.19	0.89±0.27	0.97±0.39	1.23±0.42	1.32±0.87	1.02±0.26
1998	0.77±0.45	1.00±0.67	0.90±0.43	0.90±0.56	0.88±0.68	0.89±0.08
1999	0.96±0.70	1.49±1.86	1.53±1.14	1.25±0.65	1.57±0.86	1.36±0.26
2000	0.73±0.18	0.99±0.65	1.25±0.64	1.40±1.24	0.69±0.40	1.01±0.31
2001	0.54±0.28	0.91±0.42	0.76±0.08	0.91±0.13	0.67±0.25	0.76±0.16

a) The distance from the gaseous effluents vent of QNPP; b) The height of the collector

when the time passed. It fluctuated near the mean value and was not statistically higher than the activities of samples from other 4 spots. ^{137}Cs concentrations in littoral area soil are commensurate with the

average ^{137}Cs concentration (3.5±0.7 Bq/kg) in the soil of Qinshan Region.

2.3.4 Gross β activity in fallout and aerosol

Gross β activities in five fallout collecting places are presented in Table 7. It seems that there are an increasing trend of gross β year after year. We regard the reason as the human being action rather than QNPP effect. There are several quarries around QNPP, annual outputs of which have been increasing as the economical construction has been developing rapidly in past years. In addition, the densities of population and automobiles have been increasing, so the dust quantities in air are continuously increasing. All of these results in the gross β activities in fallout raising.

In 1993, we collected three atmosphere samples above QNPP at the height of 200, 500 and 1000 m, respectively, while QNPP was running. The gas volume was some 2000 liters. Four days later, the samples were measured. The gross β activities of the samples were found to be less than LLD (7.1×10^{-6} Bq/L). We can therefore get a conclusion that with the disposal system of gaseous effluent working efficiently, QNPP has not affected the environmental radiation level.

3 Conclusion

Compared to the background level, it is evident that the activity of ^{137}Cs, ^{90}Sr and ^{3}H in environmental materials are not significantly increasing, and the radionuclide contents in the main metrices of ambient environment of QNPP fluctuate around the local environment background level. Human's activities cause a slight increase of the gross β activity only in fallout samples.

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