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^{210}Po and ^{210}Pb Inhalation Dose by Cigarette Smoking in Gansu and Yunnan Provinces, China

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I INTRODUCTION

Nowadays lung cancer is one of the most common kinds of cancer in the world. The first cause of lung cancer is considered as smoking, which accounts for almost 90% of lung cancer deaths[1]. The carcinogenic effect of smoking has been well established by both animal experiments and epidemiological surveys.[2, 3]

Epidemiological studies on underground miners demonstrate that inhaling a large quantity of radon (^{222}Rn) and its progeny also causes lung cancer.[4] However, lung cancer risks associated with exposure to low-level radon remain uncertain. Large-scale epidemiological surveys were carried out in China in order to assess the lung cancer risk associated with residential radon,[5, 6] and with radon in underground tin mines.[7]

However, the surveys carried out at that time are probably open to criticism from the viewpoint of dosimetry. First of all, in the aspect of radiation dose originating from radon, we found that the presence of thoron (^{220}Rn) is not negligible in the area surveyed.[8, 9] In the previous surveys, the detector signal resulted from thoron was considered as the signal resulted from radon, because their radon detectors could not distinguish thoron from radon. It was, therefore, expected that the radon detectors used in their surveys were considerably affected by the presence of thoron. This leads that the radon concentration was significantly overestimated with their radon detectors.

Thus, we started a new survey a few years ago in order to estimate more reliable dose using our radon-thoron discriminative detectors[10] and thoron progeny monitors.[11] In this survey, we have made efforts to re-estimate the doses due to major sources of natural radiation, including radon/thoron progenies and gamma rays.[8, 9] It was also expected that smoking causes significant dose in the studied area, because tobacco smoke contains a significant quantity of naturally occurring radionuclides[12] in addition to a considerable quantity of toxic chemical compound.[13]

In particular, ^{210}Po and its parent nuclide ^{210}Pb can be found in high activity concentration.[14] ^{210}Po and ^{210}Pb are the members of the uranium decay series and relatively long lived radionuclides. The half-life of ^{210}Po is 138 days and that of ^{210}Pb is 22 years. These radionuclides might give a significant dose to humans. Thus, the dose due to inhalation of ^{210}Po and ^{210}Pb in cigarettes has been studied in several countries.[15 ~ 19] The UNSCEAR[20] reports also indicated that ^{210}Po is estimated to cause about 7% of the internal dose from naturally occurring radionuclides.

In this work, the ^{210}Po and ^{210}Pb activity concentrations of different sorts of cigarettes traded in our epidemiological survey area (Gausu and Yunnan provinces, China) were examined as a part of our dose re-estimation study. The annual effective dose was estimated for a regular smoker due to the inhalation of these radionuclides.

II MEASUREMENTS AND METHODS

1. Sampling

In the present study, ^{210}Po and ^{210}Pb concentrations were determined for 7 brands of cigarettes in China (available in Gansu and Yunnan provinces). The locations of the two

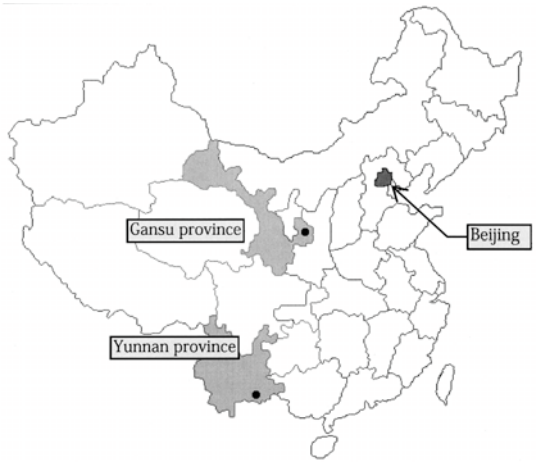

Fig. 1 The location of Gansu and Yunnan provinces.

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provinces are shown in **Fig. 1**. The cities where the tobacco samples were collected are shown as dotted circles. The names of brands collected are: Happiness, Stone forest, Scarlet Camelia, Yun Yan from Yunnan province and Lhan Zhyou (red), Lhan Zhyou (brown), Haiyang from Gansu province. Also, as home-grown tobacco is very popular in these areas, these samples (pouch) were also collected in both provinces.

The samples were purchased in 2006. The data on the cigarette samples including the tar, CO (carbon monoxide) and nicotine concentrations are shown in **Table 1**.

2. ^{210}Po and ^{210}Pb concentration measurement

Our measurement procedure, including sample preparation, is similar to that used in previous studies.[15, 19] An outline of the measurement procedure is described below.

(1) Leaching

A known activity of ^{209}Po tracer (17 mBq) was added as an internal tracer to 2 g of air-dry tobacco sample. The samples were dissolved using three portions of 20 – 30 mL concentrated HNO_3. After that, the samples were heated (evaporated) to near dryness. In order to totally digest organic materials, a few drops of concentrated H_2O_2 were carefully added. Afterwards, three portions of 20 – 30 mL concentrated HCl were added and evaporated to near dryness. Finally, 100 mL of 0.5 M HCl stock solution was prepared from the residue.

(2) Source preparation

Polonium was deposited spontaneously onto high nickel-content stainless steel disc for 3 hours at 80 ℃, 100 mg ascorbic acid was added to reduce Fe^{3+}. The deposition efficiency was between 85 – 90%. Two sources were prepared as stock solutions. After drying, the surfaces of the disc were measured in ambient temperature using an alpha spectrometer equipped with a semiconductor silicon detector.

The applied alpha spectrometer was a Canberra Model 7401 type alpha chamber equipped with 19 keV resolution PIPS detector. **Fig. 2** shows an example of alpha spectrum. As can be seen, the peak for ^{210}Po (5.30 MeV) does not overlap with that for ^{209}Po (4.88 MeV). Thus, it was assumed that ^{209}Po has little effects on the ^{210}Po measurement. The minimum detectable activity (95% confidence level) for the spectrometer was estimated to be 0.67 mBq/g with a counting time of 80,000 sec. The mean yield of the measurement was 55% and this is mainly due to the loss generated during the evaporation.

(3) Determination of the ^{210}Pb concentration

Our previous study[19] showed that the ^{210}Po and ^{210}Pb isotopes are in radioactive equilibrium due to the long storage and fermentation period. Therefore, ^{210}Po was assumed to be present in the same concentration as its parent nuclide (^{210}Pb) for the following calculations.

III RESULTS AND DISCUSSION

1. ^{210}Po and ^{210}Pb concentration measurement

Table 1 shows the ^{210}Po (^{210}Pb) activity concentrations of the examined cigarette types. Apparently, the measured ^{210}Po activity concentration values were between 17.4 ± 3.4 and 27.2 ± 3.2 mBq/g.

The activities of the cigarettes from Yunnan Province (Happiness, Stone forest, Scarlet Camelia, Yun Yan) were a little bit higher (30%) than those from Gansu Province. The results of this study were in the range of values reported from

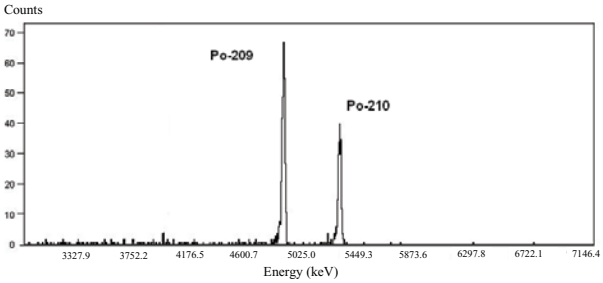

Fig. 2 An example of alpha spectrum obtained from the sample measurement.

Table 1 Activity concentration of ^{210}Po and ^{210}Pb (mBq/cigarette) in cigarette samples

Province	Brand	Nicotine [mg]	Tar[mg]	CO [mBq]	^{210}Po [mBq/g]	^{210}Po [mBq/cigarette]
Gansu	Lhan Zhyou (red)	12	0.8	13	17.6 ± 3.4	11.3 ± 2.2
	Lhan Zhyou (brown)	13	0.9	13	17.4 ± 3.5	11.1 ± 2.3
	Haiyang	13	0.9	13	24.3 ± 3.4	15.5 ± 2.3
	Tobacco-pouch	—	—	—	17.8 ± 4.2	—
Yunnan	Happiness	15	1.2	15	22.8 ± 4.1	14.7 ± 2.3
	Stone forest	14	1.2	15	27.2 ± 3.2	18.3 ± 2.5
	Scarlet Camelia	14	1.3	15	22.9 ± 3.3	14.7 ± 2.2
	Yun Yan	14	1.2	15	26.0 ± 3.5	16.7 ± 2.2
	Tobacco-pouch	—	—	—	18.9 ± 4.1	—

other countries.[15 ~ 19)]

2. Dose estimation

The dose caused by ^{210}Po and ^{210}Pb in cigarette smoke was calculated under the following assumptions. These assumptions were as the same as those in our previous study.[19)] As a daily consumption rate of cigarettes, a value of 20 cigarettes/day was used; this enables us to compare our work with previous works easily. In the case of tobacco pouch (home-grown tobacco), the same consumption rate and an average weight of 0.65 g/cigarette were assumed.

According to recent publications,[15, 17)] 70% of the polonium in a cigarette was assumed to be transferred into the cigarette smoke. Although the transfer factor might be different from cigarette to cigarette, it was assumed to be the same for all brands of cigarettes. For the dose calculation, the ratio of inhaled smoke to totally produced smoke is needed. The ratio was assumed to be 50% on the basis of recent references[15, 17)]. As for the dose conversion factors for adults[20)], 3.3×10^{-6} Sv/Bq and 1.1×10^{-6} Sv/Bq were used for the inhalation of ^{210}Po and ^{210}Pb, respectively.

Considering the above assumptions, the annual effective dose (Sv) due to the inhalation of ^{210}Po or ^{210}Pb by smoking (E) can be calculated with the following formula.

$$E = F_1F_2KGCT \quad (1)$$

where F_1 is the average transfer factor from tobacco to smoke (0.7), F_2 is the ratio of inhaled smoke to totally produced smoke (0.5), K is the dose conversion factor for ^{210}Po or ^{210}Pb (Sv/Bq), G is the number of cigarettes smoked (20 cigarettes/day), C is the concentration of ^{210}Po or ^{210}Pb (Bq/cigarette), and T is the duration of dose calculation (365 days).

Table 2 shows the annual effective dose due to ^{210}Po and ^{210}Pb inhalation via smoking (20 cigarette/day). The average annual effective dose was estimated to be 123.2 ± 22.3 μSv/y and 41.1 ± 7.4 μSv/y for ^{210}Po and ^{210}Pb, respectively.

The range of estimated dose was 93.5 – 154.3 μSv/y for ^{210}Po and 31.2 – 51.4 μSv/y for ^{210}Pb. The average dose originating from the two isotopes was 164.3 ± 23.5 μSv/y.

IV CONCLUSION

In the present study, the ^{210}Po and ^{210}Pb activity concentrations in Chinese cigarettes were investigated for 7 brands available in the market and for 2 samples of home-grown tobacco. The ^{210}Po activities of cigarettes were between 11.1 ± 2.2 and 18.3 ± 2.5 mBq/cigarette. As we expected, these values were comparable to the range reported in previous literatures.[15 ~ 19)]

The activity values of cigarette samples originating from Yunnan province were approximately 30% higher, which enhances radiation dose received due to smoking. The annual effective dose originating from ^{210}Po in cigarettes was within a range of 93.5 – 154.3 μSv/y and that from ^{210}Pb was within a range of 31.2 – 51.4 μSv/y, in the case of smoking one pack of cigarettes (20 cigarettes) a day.

The radiation dose received during smoking was considered to be of a small scale, compared with the dose from radon/thoron and their progenies. However, it is desirable for our epidemiological study to consider doses from major sources of natural radiation. In this point of view, the estimation of dose due to smoking was significant. In the future, by the measurement of samples of cigarettes available in the market, we would like to get a rather comprehensive picture on the radiation dose during smoking for the people living in these two provinces.

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Table 2 The annual committed effective dose due to ^{210}Po and ^{210}Pb inhalation via smoking (20 cigarettes per day)

Province	Brand	effective dose (μSv/y) from ^{210}Po	effective dose (μSv/y) from ^{210}Pb
Gansu	Lhan Zhyou (red)	95.4	31.8
	Lhan Zhyou (brown)	93.5	31.2
	Haiyang	131.1	43.7
	Tobacco pouch (Gansu)	97.6	32.5
Yunnan	Happiness	123.8	41.3
	Stone forest	154.3	51.4
	Scarlet Camelia	123.6	41.2
	Yun Yan	140.7	46.9
	Tobacco pouch (Yunnan)	103.8	34.6
	Mean value ± σ	123.2 ± 22.3	41.1 ± 7.4
	Minimum value	93.5	31.2
	Maximum value	154.3	51.4

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