RADON-222 CONCENTRATION IN WATER AND THE EXPOSURE OF THE PUBLIC,

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INTRODUCTION

Radon and its short-lived decay products are greatly concerned by the world scientific community since such exposure constitutes nearly 50% of the effective dose received by the public in countries with temperate climates(UN93). Vigorous researches have been conducted to investigate many aspects of the indoor ^{222}Rn problem. The predominant source of indoor ^{222}Rn in China genera lly appears to be the soil adjacent to the foundation. The other major sources, potable water and building materials, occasionally contribute significantly to indoor radon concentrations, and may be the dominant source in some cases. Several investigations in the past decade were conducted to measure ^{222}Rn concentrations in public water supplies, in wells, thermal springs and underground thermal water in China. Radon concentrations in drinking water have been observed to range over an extremely large range. The highest ^{222}Rn concentration recorded so far is 11 MBq m^{-3} in a private well of Guo Village, Jiangxi province(Li81). The ^{222}Rn concentrations in domestic water from public water supplies of the Chinese major cities are depends on the types of water supplies. The purpose of this paper is to summaries the results of ^{222}Rn concentrations in public water supplies of Chinese major cities, each with population larger than one million, and to estimate the contributions of waterborne radon to indoor air radon concentration as well as the related doses received by the residents from waterborne radon.

METHODOLOGY

The investigation was conducted in nearly 100 Chinese cities, which either are the capital cities of each province, municipal city directly under the Central Government, or are cities with population larger than 0.4 million. Several sites were selected in each city, and at each site, two representative tap water samples were sampled from water tap with radon bubblers after allowing about 10 minutes water flow. Each sample, with a volume of 50 cm^3 water, was collected into 100 cm^3 radon bubbler. High pure nitrogen gas was used to degassing Rn dissolved in water and drove it from bubbler into scintillation flask for measurement in laboratories.

RESULTS

1. Radon Concentrations in Different Types of Water

Radon concentrations in different types of water have been observed to range over an extremely large range, as listed in Table 1. The average concentrations in 138 thermal springs, most of them are famous in China, and 93 underground thermal water wells are 118.2 and 36.3 kBq m^{-3}, respectively, The highest concentration found is 11 MBq m^{-3}, in a private well, Guo Village, Jiangxi Province. The ^{222}Rn concentrations in domestic water from public water supplies of about 100 Chinese cities are ranging from 0.035 kBq m^{-3}, in

Fuzhou, to 101.3 kBq m^{-3}, in Shenyang, with average of 7.82 kBq m^{-3}.

Table 1. Radon concentrations in different types of water (KBq m^{-3})*

Water Type	No. of samples	range	Mean+-1SD
Surface	6	0.035- 2.98	0.27+- 0.28
Wells	9	0.68 -11000	20.5 +- 14.8
Thermal spring	138	0.3 -2720	118.2 +-266.3
Underground thermal water	93	0.3 - 259	36.3 +- 29.0
Tap water		0.053-101.3	9.5 +- 13.1

* Data from Ch93, Ch84, Ch87, Fa93, Ji89, Li81, Wa91,Zh87, Zh89.

2. Radon Concentration in Public Water Supplies

Table 2 shows the ^{222}Rn concentrations measured in the public water supplies of 24 Chinese major cities, each with population larger than one million. The average ^{222}Rn concentrations in domestic water from public water supplies of the Chinese major cities, are in the range from average of the 24 major cities is 8.61 $\pm$ 13.3 kBq m^{-3}, For those cities with Surface public water supplies systems, for example, Shanghai, Tianjin, Guangzhou et al., the average radon concentration is 0.27 $\pm$ 0.28 kBq m^{-3}, ranging from 0.05 to 7 kBq m^{-3}. In some cities, the main sources of thier public water supplies are from well or underground water, the waterborne ^{222}Rn concentration are much higher, with average value of 20.5 $\pm$ 14.8 kBq m^{-3}, ranging from 0.68 to 101.3 kBq m^{-3}.

Table 2 Radon concentration in public water supplies(kBq m^{-3})*

City	Mean+-1SD	City	Mean+-1SD
Beijing	14.8 +- 2.2	Zhengzhou	1.22+- 0.09
Haerbing	5.02+- 0.26	Xian	7.98+- 0.53
Changchun	0.96+- 0.18	Nanjing	2.13+- 0.05
Wulumuqi	21.2 +-22	Wuhan	0.33+- 0.06
Anshan	34.8 +- 3.6	Shanghai	2.46+- 1.87
Shenyang	54.7	Chengdu	9.6 +-10.5
Sijiazhuang	18.0 +- 2.1	Hangzhou	1.39
Tianjin	0.27+- 0.11	Chongqing	0.44+- 0.17
Lanzhou	26.4 +- 3.2	Changsha	0.45+- 0.04
Dalian	0.73+- 0.09	Kungming	0.98+- 0.20
Taiyuan	12.3 +- 0.7	Nanchang	6.44+- 0.01
Jinan	5.26+- 0.34	Guangzhou	0.85+- 0.43
Aggregate water supplies			9.5+-13.1
Surface water supplies			1.0+-0.7
Underground water supplies			20.5+-14.2

* Some data from Reference Ch93.

3. Transfer Factor of ^{222}Rn from water to Indoor Air
An important question in assessing the impact of waterborne ^{222}Rn on indoor exposure is to know the transfer factor, f, of ^{222}Rn from water to indoor air. Transfer factor can be expressed as f= Ca/Cw, Ca and Cw are ^{222}Rn concentrations in air and in water, respectively. Several measurements on the values of f were made. One study measured indoor air ^{222}Rn concentrations in real conditions in bathrooms using underground thermal water by dual filter grab sampling method. The values of f were in the range of 2 10^{-3} to 26 10^{-3} and average and standard deviation were 7.2 10^{-3} +- 7.1 10^{-3}(Ch84). In another study, ^{222}Rn concentrations were measured in a room with volume of 15 m^3 by grab sampling. The average f values were 2.4 10^{-4} and 3.2 10^{-3} under window open and close conditions(Ch93).

4. Increment of ^{222}Rn Concentrations in Indoor Air Due to Water Use
We take 2 10^{-4} as typical value of the ratio of airborne to waterborne ^{222}Rn concentrations. The increments of radon concentrations in indoor air are 0.2, 4.1 and 1.9 Bq m^{-3} for the three different types of public water supplies listed in Table 2. These increments equivalent to 0.8%, 17% and 8% of the nation-wide average of indoor radon concentration, respectively. This suggest that the reference concentration, 10 kBq m^{-3}, adopted by UNSCEAR in its 1993 Report is reasonable. The estimated annual effective doses to the sesidents, are 2.3,177 and 734.3 10-6 Sv, respectively, by inhalation pathway, including doses from inhaled radon that becomes dissolved in tissues.

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