

## Cancer Mortality in Low Radon Spa Area

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Recently lower mortality for cancers of all sites was reported among inhabitants in the Misasa spa area, where there is a high radon background. To clarify the effects of radon exposure on cancer mortality, the effects of a hot spring itself on cancer mortality was investigated in the Beppu spa area, which has only a low radon background, and adjacent control areas. For females, the mortalities for cancers of all sites, liver and lung were higher in Beppu than those for all Japan on the basis of the standardized mortality ratio (SMR), while the SMR for all cancers was lower in adjacent areas. For the male inhabitants in both areas the cancer mortalities of all sites were not significantly different from those of all Japan. When we directly compared the most typical spa areas in Beppu and an adjacent control area, a Poisson regression analysis did not show that the relative risk of dying from cancer of all sites was decreased in the spa areas. These results are thus consistent with the view that the lower cancer mortality in the Misasa spa area might be related to exposure to low levels of radon.

Key words: Cancer mortality — Radon — Spa area — Standardized mortality ratio — Relative risk

Radon is a naturally occurring radioactive gas, which is inhaled by humans. Epidemiological studies have demonstrated an excess risk of lung cancer for miners who experienced high radon exposures in Colorado<sup>1)</sup> and Czechoslovakia.<sup>2)</sup> Recently, Pershagen *et al.* concluded that residential exposure to radon is also an important cause of lung cancer in Sweden.<sup>3)</sup>

On the other hand, hot springs which contain radioactive substances such as Rn, Ra, Th, and U have been thought to be good for health since the early 1900s in Europe and thus have been used for medical treatment. Recently, Cohen<sup>4)</sup> tested the linear-no threshold theory of radiation carcinogenesis and found no correlation between the average radon exposure in various countries and their lung cancer mortality rates. Mifune *et al.*<sup>5)</sup> also investigated the effect of low-dose radon exposure in the Misasa spa area in Japan, utilizing the mortality records of inhabitants. The Misasa spa provides a large quantity of hot spring water with radon. A Poisson regression analysis showed that the relative risks among the inhabitants of Misasa were significantly lower than in the control area for deaths from cancers of all sites and stomach cancer. These results may mean that exposure to low levels of radon reduces deaths from cancer. However, they could not rule out an effect of the hot-spring itself on cancer.

In this study, we investigated the mortality rates of cancer in the Beppu spa area, to clarify the effect of the hot spring itself on cancer. Beppu is located in Oita Prefecture on Kyushu Island in Japan, and is a famous spa resort with about 2,700 hot spring sources, yielding a total volume of spring water of some  $13 \times 10^7$  liters/day. To our knowledge, no previous data on radon concentrations of spas in Beppu are available, although Beppu has been thought to be a low radon spa area. We measured the radon concentration in five hot springs using the method of Saito and Takata,<sup>6)</sup> while the concentration in the air was measured by the method of Matsuoka *et al.*<sup>7)</sup> The radon concentrations in the spa areas were found to be low at the hot springs as well as in the air (Table I).

First, we calculated the standardized mortality ratio (SMR) for cancers of several sites in the years 1989–1991 among the inhabitants of Beppu city and of five adjacent cities (Nakatsu, Kitsuki, Usuki, Tsukumi and Saeki) (Fig. 1). These cities all face the sea, as does Beppu, but have few spas. The observed number of deaths due to cancer in each area from 1989 to 1991 was obtained from Oita Prefectural Office. The expected number of deaths was then calculated by applying the age-specific death rate of cancer for all of Japan in the years 1989–1991<sup>8–10)</sup> to the corresponding populations of each area in 1990.<sup>11)</sup> The ratio of observed deaths to the expected number was then multiplied by 100, and a 95% confidence interval of the SMR was computed on the assumption that the occurrence of observed deaths follows a Poisson distribution.<sup>12)</sup>

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Secondly, cancer mortalities in Kamegawa and Kannawa, both typical spa areas in Beppu city, were directly compared to those in Kitsuki using a Poisson regression analysis.<sup>13)</sup> We scrutinized copies of the death certificates from 1989 to 1991 of the inhabitants in both areas at the Beppu and Hiji health centers and arranged them according to 10-year age groups as well as according to the causes of death. Due to the small number of cancer deaths in younger people, the analysis was limited to subjects 40 years old or above. Four age groups were established, i.e., 40–49, 50–59, 60–69 and 70+. After adjustment for sex and age, the relative risks (RR) of dying from cancers for inhabitants in the spa area were calculated and compared to those in Kitsuki. We also calculated the RRs of dying from all causes, cardiovascular diseases and cerebrovascular diseases to clarify the issues brought up in this study. The RR and the 95% confidence interval were derived from the regression

coefficient and standard error. Computations were done by using the Statistical Analysis System (SAS).<sup>14)</sup>

As shown in Table II, the total cancer mortality for women in Beppu was significantly higher than that for all Japan ( $P < 0.05$ ). In addition, the liver and lung cancer mortalities were also higher in Beppu. On the other hand,

Table I. Radon Concentrations at Spa Areas in Beppu

Sample	Temperature (°C)	Radon concentration (Bq/liter)
Hot spring		
Kamegawa A	54	8.010
Kamegawa B	58	0.782
Kannawa A	44	0.031
Kannawa B	70	not detectable
Kannawa C	45	4.468
Air		
Kannawa B indoor	24	not detectable
outdoor	17	not detectable

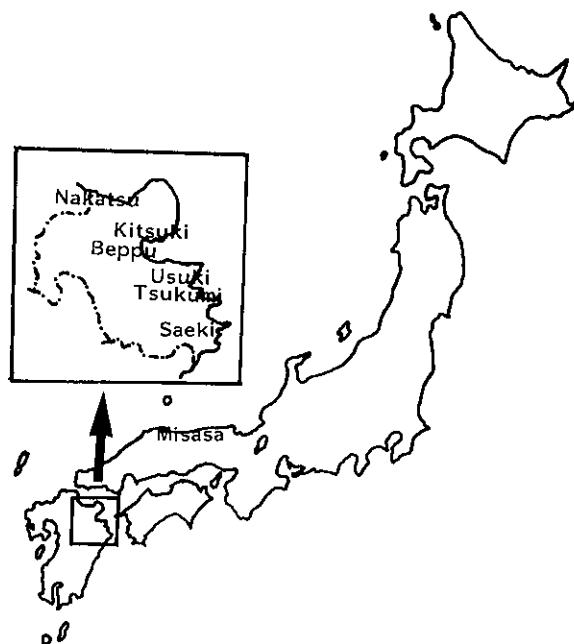


Fig. 1. Map of Japan with an enlargement of Beppu and the 5 control cities in Oita Prefecture.

Table II. Standardized Mortality Ratios (SMRs) of Cancers in Beppu and Adjacent Cities (1989–1991)

Sites of cancer	Beppu			Adjacent cities		
	O	E	SMR	O	E	SMR
<b>Men</b>						
All sites	499	471.8	105.8	801	790.6	101.3
Stomach	85	109.2	77.8 *	194	183.0	106.0
Rectum	27	19.8	136.4	32	33.1	96.8
Liver	97	62.5	155.1 *	139	104.4	133.1 *
Lung	97	99.2	97.8	157	167.0	94.0
<b>Women</b>						
All sites	404	356.7	113.3 *	499	558.0	89.4 *
Stomach	63	72.2	87.2	102	113.3	90.0
Rectum	16	15.3	104.6	23	23.8	96.5
Liver	40	27.2	147.3 *	42	42.5	98.7
Lung	61	40.6	150.1 *	65	64.1	101.4

O: Observed number of cancer deaths.

E: Expected number of cancer deaths.

\*  $P < 0.05$ .

Table III. Relative Risks of Dying from Cancers, Cardiovascular and Cerebrovascular Diseases for the Inhabitants of the Beppu Spa Area versus Those of Kitsuki as Estimated by a Poisson Regression Analysis<sup>a)</sup>

Cause of death	Relative risk <sup>b)</sup>	95% Confidence interval
All deaths	1.05	0.94–1.17
Cancers	1.10	0.89–1.35
Stomach	0.50	0.30–0.83
Colon, Rectum	1.09	0.61–1.96
Liver	1.54	0.86–2.76
Lung	1.50	0.93–2.42
Cardiovascular diseases	1.27	1.01–1.61
Cerebrovascular diseases	1.00	0.75–1.32

a) Variables for sex and age (40–49, 50–59, 60–69, 70+) were also included as independent variables.

b) The relative risk for inhabitants of the Beppu spa area as compared to that of Kitsuki.

the total cancer mortality for men in Beppu was not different from that for all Japan. The liver cancer mortality for men in both Beppu city and the adjacent areas was higher and only stomach cancer mortality in Beppu was lower. The results obtained from an analysis limited to Kamegawa and Kannawa were almost the same as those above (data not shown).

When directly compared to the control area, the RRs of dying from cancers of all sites in typical spa areas were not reduced while the RR of lung cancer was increased, but not significantly ( $P=0.09$ ). The RR for stomach cancer was, however, significantly reduced in the Beppu spa area. The relative risk from dying of cardiovascular diseases for inhabitants in the Beppu spa area was increased compared to that in Kitsuki (Table III).

In this study we analyzed the cancer mortality in the Beppu spa area with a low radon concentration by employing the same methods as previously used in a study of the Misasa spa area with a high radon concentration. If we observed a decreased risk of cancer death in Beppu, the reduction in cancer risk in the Misasa spa area might be attributed to other factors than a low-dose radiation exposure. However, this was not the case.

Among all cancers, stomach cancer behaved differently. It is possible that the diets might be different between Beppu, which is an urbanized city, and the less urbanized Kitsuki. This finding was common to the two spa areas and the reason for it remains to be found.

There are some differences other than in radon concentrations between Beppu spas and Misasa spas. The hot spring water in Beppu contains very small amounts of heavy metals such as Cd, Ge and so on, but that in Misasa does not. The role, if any, of these metals in cancer mortality has not been clarified yet. As Beppu faces the sea and Misasa is located at an inland area, the diets and other life-style factors of inhabitants in the two areas might be different. The inhabitants of both areas do not traditionally drink water from the springs.

Because we had no data on smoking, alcohol use and other life-style factors of the individuals, and because the mortality data were limited to only the past three years, the findings of this study need to be cautiously interpreted.

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