INDOOR RADON SURVEY IN JAPAN

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INTRODUCTION

Radon and its progeny are the major source of exposure to the general public. Large scale radon surveys have been performed in many countries with various passive radon detectors. Our group in National Institute of Radiological Sciences has also conducted a nation-wide radon survey in Japan using passive radon detectors which were originally developed at Karlsruhe Nuclear Research Center in Germany. The main purpose of our survey is to obtain annual average indoor radon concentration and to estimate dose due to radon progeny as well as to find out high radon areas in Japan.

METHOD

The survey was planed to cover more than 7,000 houses throughout Japan which corresponds to 0.017% of the total houses in Japan. The number of sampling houses in each prefecture was selected in principle in proportion with the total number of houses in prefecture in order to obtain radon concentration profile of the present stock of houses. The results are also expected to reveal the approximate population averaged radon concentration in each prefecture as well as the whole nation. Each house is measured in two places namely a living room and bed room for two successive periods of six months for the estimation of annual average radon concentrations. After six months of exposure in a house, the dosimeters were returned to our institute, NIRS by mail for the further processing. New detector foils (polycarbonate) were placed in the dosimeter housings and were sent again to the same house for the second six months measurements. These two sets of successive six months measurements provide annual average radon concentration in the selected houses. As a total more than 30,000 detector foils were used for the survey. The detector foils which were retrieved from the selected houses, were subjected to a combined chemical and electrochemical etching processes to develop etch pits due to alpha particles from radon and its progeny. The number of etch pits was then counted either automatically by an image counter or manually depending on the number of etch pits developed in the unit area (1cm^2) in the center of the foil. The etch pits were read manually when track density was more than 300 tracks/cm^2 since the machine could not distinguish overlapping etch pits. The overlapping correction for the counting by the machine were executed by an equation determined from the correlation between automatic and manual counting (1).

Self-background of 26 etch pits per cm^2 during the six months exposure as well as inherent background for each batch of foils were then subtracted from the measured track density (2) and the net counts were converted to average radon concentrations during the measurements. The conversion factor of 21.8 tracks/cm^2 per kBq/m^3 day was used to obtain radon concentration. The conversion factor was estimated by a series of calibration exercises which were made available by the Australian Radiation Laboratory, Melbourne, Australia and the Environmental Measurement Laboratory, New York, U.S.A.

The results obtained from more than 7,000 houses were carefully checked to identify abnormal conditions during the measurements. All the data measured not in a living room or bed room were eliminated. The results obtained from the house with no answer to the questionnaire were not included in the final results. Only the results with at least one set of successive six months measurements were used for the estimation of the annual average radon concentration. Total number of houses where the annual radon concentration could be obtained was reduced to 6,645 houses.

Additional measurements were conducted in Hokkaido, Hiroshima and Kochi Prefectures to clarify the thoron contribution to the first measurement undertaken throughout Japan. Two sets of passive detectors were installed in two places (living room and bed room) in each house. One passive detector was the same as the original detector used in the first survey. The other passive detector used plastic foil as a filter to prevent thoron entry into the housing of the detector. The air exchange rates of the original and modified passive detector were estimated to be 27.7, 1.79 h^{-1} by the experiment using SF_6 gas. The original passive detector measures radon plus thoron and the modified passive detector measures mainly radon since the modified detector is expected to show one tenth of the response of the original detector to thoron due to the slower air exchange rate.

RESULTS AND DISCUSSION

The indoor radon concentrations obtained by the survey shows roughly a log-normal distribution as shown in Fig. 1. The estimated arithmetic mean of the radon concentrations in 6,645 houses is 21.3 Bq/m^3 (S.D. 18.8 Bq/m^3), and the geometric mean and its standard deviation are 17.3 Bq/m^3 and 1.83, respectively. The median of the concentration is 16.4 Bq/m^3. The number of houses having a concentration of ten times higher than the geometric mean is only 17 in 6,645 houses, i.e., 0.26% of the measured houses. Ninety percent of the houses are less than 38 Bq/m^3, 97.5% less than 68 Bq/m^3, 99% less than 96 Bq/m^3. Only 27 houses are over the action level set by EPA in the U.S.A. These high radon concentration houses are distributed in the western part of Japan except one house found in Niigata Prefecture. However, no radon prone area is found, although Hiroshima Prefecture has 6 high radon houses out of total 27 houses. All these high radon concentration houses are wooden houses except two concrete houses in Okinawa Prefecture. The average radon concentrations in each municipality (city, town, village) are shown in Fig. 2. Many higher radon concentrations are found in Chubu, Kinki, Chugoku and Shikoku districts, where winter is relatively mild and the air exchange rate of the houses in these regions is not low, the concentrations seems to have a relationship with the geology as found by the measurements of exposure rates due to terrestrial gamma rays (3). These areas are typical granite region in Japan. The areas covered with volcanic ash, in Kanto District around Tokyo and Kagoshima Prefecture in Kyushu district shows lower concentrations.

The results of the additional measurements carried out in Hokkaido, Hiroshima and Kochi Prefectures shows three different profiles of the correlation between radon and thoron concentrations. In Hokkaido Prefecture no significant thoron contribution was found in the indoor radon measurements. The arithmetic, geometric mean and median for radon plus thoron concentration (27.4, 21.6, 21.4 Bq/m^3) measured by original detectors are very close to the corresponding values for radon (26.3, 20.4, 19.9 Bq/m^3) measured by modified detectors. In Kochi Prefecture the difference is somewhat larger, i.e., the arithmetic, geometric mean and median for radon plus thoron concentrations are 20.4, 16.3, 15.4 Bq/m^3, while the corresponding values for radon are 14.3, 12.9, 11.9 Bq/m^3. The difference is much significant in Hiroshima Prefecture. These values are 49.9, 36.3, 32.0 Bq/m^3 for radon plus thoron, and 27.8, 24.5, 24.3 Bq/m^3 for radon. No indication of large contribution of thoron is available from the values, such as mean, standard deviation, percentile. Most high thoron concentrations were found in traditional wooden houses where they have walls made of clay and straw. The straw is used for adhesive material to keep clay in the wall. Thoron might pass through the air space in the straw and reach indoor air without much delay usually confronted during the diffusion in the normal wall. It infers that thoron concentration may have high values in wooden houses. However, other type of houses may sometimes have high thoron contribution as found in Austria with the same way of measurements by the authors in collaboration with Dr. M. Tschurlovits in Atom Institute of Austrian University.

CONCLUSION

The arithmetic mean radon concentration was estimated to be 21.3 Bq/m^3 (S.D. 18.8 Bq/m^3) by a nation-wide survey in Japan. The geometric mean was found to be 17.3 Bq/m^3. Ninety nine percent of the measured houses are less than 96 Bq/m^3. No radon prone area was found, although a little elevation of radon concentration was found in the western part of Japan due to granite formation. Our detectors have a disadvantage of detection of thoron since the air filtration rate of the detector is very high. The estimated radon concentration based on the first survey of indoor radon might have been overestimated due to thoron contribution to the radon measurements. In the additional survey one prefecture showed no thoron contribution while the other two prefectures showed significant thoron contribution in the radon measurements. No clear-cut indication of high thoron houses has not been obtained.

REFERENCES

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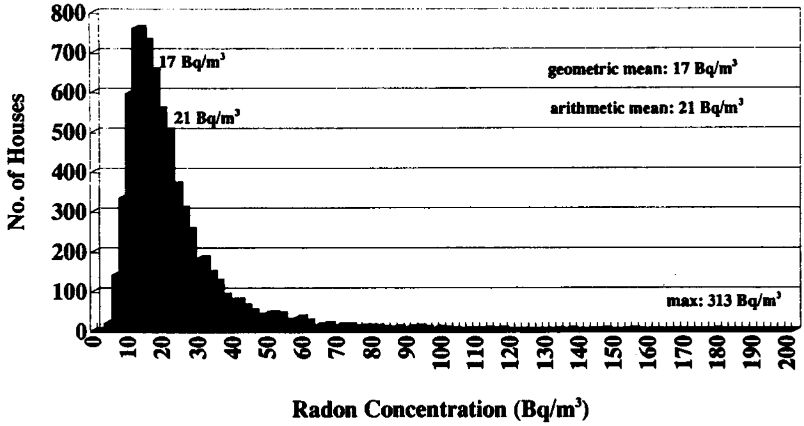

Fig. 1. Histogram of Indoor Radon Concentrations (6645 houses)

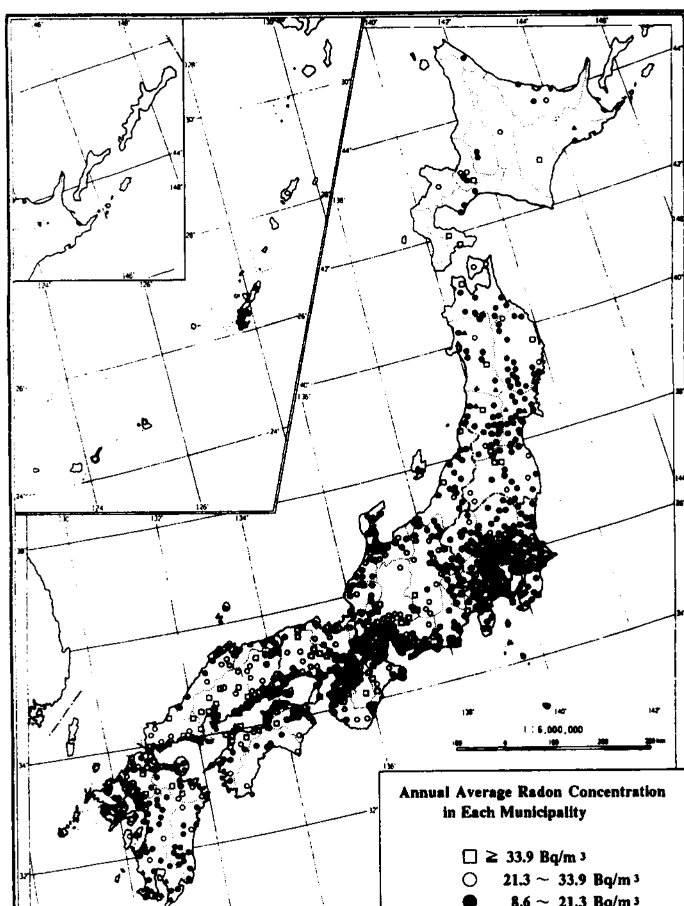

Fig. 2. Distribution of Indoor Radon Concentrations in Japan