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DOSES ARISING FROM NATURAL RADIATION SOURCES IN HONG KONG

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Abstract-The first reactor of the Daya Bay nuclear power plant, located 30 km from Hong Kong, should become operational at the end of 1993. People in Hong Kong are more concerned with their exposures to radiation, both man-made and natural. The local environmental background radiation baseline values should be established well before 1993 so that the radiological impact of the power plant on the environment can be assessed. However, there has not been much information on these aspects. In view of the situation, the Radioisotope Unit of the University of Hong Kong has launched a series of studies with the general goal of gaining a better understanding of Hong Kong's natural background radiation and a more accurate estimate of the natural radiation exposure of the local people. The scope of the measurement programmes is described and the doses from the various sources are derived.

INTRODUCTION

The dose of natural radiation that a person receives depends on a number of factors such as the height above sea-level at which he lives, the amount and type of radionuclides in the soil in his neighbourhood and the amount that he takes into his body in air, water and food. The total annual "whole body" equivalent dose from natural sources of radiation is estimated by the United Nation Scientific Committee on the Effects of Atomic Radiation to be 2 mSv (UNSCEAR 1988).

Modifications of the environment and man's activities can increase the "normal" exposure to natural radiation. Examples of this include mining, flight at high altitudes and the use of building materials containing naturally-occurring radionuclides. Even living within a house is often sufficient to increase radiation exposure because restricted ventilation leads to an accumulation of radioactive gases and their decay products.

The CASE OF RADON

The total annual dose varies considerably with location but the 1988 UNSCEAR report quotes an average of 2.4 mSv/year for populations of industrialised countries from both man-made and natural radiation sources and the major component being due to the naturally occurring radon.

In Hong Kong most people live and work in high-rise buildings, unlike other less densely populated places where relatively more people work and live in houses resting directly on the Earth's crust. However, because of its hot and humid weather, closed air conditioning is not uncommon nowadays in Hong Kong. Under these unique indoor conditions, it will be of general interest to measure the indoor ^{222}Rn and ^{220}Rn levels. So, a small-scale survey was undertaken on the University of Hong Kong campus in 1985.

I. Measurement of Radon Decay Products in Hong Kong

With the help of a personal computer, a five-count filter method which is an inexpensive and easy way for measuring ^{222}Rn and ^{220}Rn daughters in a 15-minutes grab sampling air was developed. Based on data collected from the campus of the university in the Spring of 1985, the annual equivalent dose received by the population of Hong Kong is estimated to be 1.13 mSv from ^{222}Rn daughters and 0.25 mSv from ^{220}Rn daughters, the ratio of the two contributions being 4.5:1 (Tso and Li 1987).

II. Measurement of ^{222}Rn Concentrations in Hong Kong

From the result of the small scale survey on the University of Hong Kong campus, we have found that the annual exposure to ^{222}Rn daughters in Hong Kong is 50% higher than the global average of 0.76 mSv. However, the dose was estimated from a grab-sampling technique for instantaneous radon daughter measurements. In order to confirm this somewhat higher radon dose in Hong Kong, another survey aiming at integrated radon dose measurement began in 1987. In this second survey, we had to use a so-called passive method to take a large number of measurements within a week under the same climatic conditions in order to avoid seasonal variations.

Charcoal canisters of 10 cm in diameter were dispatched to a large number of residential dwellings to adsorb radon gas for 2 to 4 days. Each canister contained 70 g of activated charcoal under a wire gauze and retainer ring, and the cover was taped closed with plastic electrical tape. A label with identification number was affixed on the top of the cover, with exposure starting and stopping times and date to be completed by the user.

About 150 charcoal canisters were exposed and examined. Over 95% of the sampling sites were in urban areas or satellite towns where typical population density and buildings were found. The rest were in rural areas where the population density and type of houses were less typical. It is therefore believed that the samples do represent the majority of the Hong Kong population, though inhabitants in rural areas were not thoroughly considered in this survey.

The concentration obtained in one of the samples was 190 Bq m^{-3} which is much higher than the others with an overall arithmetic mean of 41.4 Bq m^{-3}. This sample was taken from a basement room of a castle built about 120 y ago. The room has windows that open up to a surrounding garden, and therefore it is suspected that the radon comes mainly from the underlying soil and finds its way into the room through cracks in the floor structure. Since this type of living environment is rarely found in Hong Kong, the reading has been discarded from the overall analysis; further study on this particular site has been planned.

The equivalent dose due to ^{222}Rn from the result of our second survey is 1.31 mSv (Tso and Leung 1991) which is consistent with the result from the grab sampling technique for instantaneous radon daughter measurements.

TERRESTRIAL GAMMA RADIATION DOSE IN HONG KONG

Since the gamma dose depends on the same sources that give rise to the high radon levels measured in Hong Kong, it is of value to measure the local gamma dose and compare it with the global average.

Gamma dose-rate measurements have been conducted in different areas throughout the territory of Hong Kong since 1987. Like the large-scale surveys done in many other countries, this

extensive terrestrial gamma radiation survey was done with the objective to determine the average exposure of Hong Kong's population to terrestrial gamma radiation. This carries particular implications in Hong Kong, as it is highly urbanized and terrestrial gamma radiation depends heavily on the types of building materials and the density of buildings (Tso and Li 1992).

The entire territory was divided into 18 areas: eight on Hong Kong Island, four in Kowloon Peninsula, and six in the New Territories. The official population figures for these areas, published in 1986 (Census and Statistics Department 1987), are used as guidelines to choose places with relatively high population for measurement. More indoor than outdoor measurements were taken, as people spend more time indoors and the indoor dose-rate is therefore, as far as human exposure is concerned, more significant.

In Hong Kong, public housing estates are the most densely populated, accommodating about 50% of the total population in the territory. As access to private apartments and offices is not always possible, measurements taken in covered areas surrounded by walls (e.g., elevator lobbies and hallways) were regarded as indoor samples. Hong Kong is so urbanized that there is very little area outdoors with a full soil half-space cover. Therefore, all outdoor measurements in this survey were taken on streets or walkways, usually with buildings nearby.

I. Indoor and Outdoor Gamma Dose in the 18 Areas of Hong Kong

In total, 270 (194 indoors, 76 outdoors) measurements have been made over the whole territory (1,067 km^2): 126 (87 indoors, 39 outdoors) from Hong Kong Island, 63 (49 indoors, 14 outdoors) from Kowloon, and 81 (58 indoors, 23 outdoors) from the New Territories. No samples were taken on Lantau Island, which, although bigger than Hong Kong Island, is virtually undeveloped and has a relatively small population. With a total population of 5,266,000 in the whole territory, there are, on average, 3.6 indoor samples and 1.4 outdoor samples per 100,000 people. The comparison between indoor and outdoor dose-rates over the various areas and the distributions of indoor and outdoor dose-rates were done (Tso and Li 1992). The overall mean indoor and outdoor dose-rates are 0.186 $\mu Gy\ h^{-1}$ and 0.162 $\mu Gy\ h^{-1}$ respectively. Weighting according to the population in each area, the population-weighted mean indoor and outdoor dose-rates are 0.189 $\mu Gy\ h^{-1}$ and 0.161 $\mu Gy\ h^{-1}$ respectively.

Adopting the conversion factor of 0.7 $Sv\ Gy^{-1}$ and outdoor occupancy factor of 0.2 as recommended by UNSCEAR (1988), the annual equivalent doses from indoor and outdoor terrestrial gamma for the 18 areas are calculated. The Mean annual equivalent dose from terrestrial gamma radiations for Hong Kong's population is 1.11 mSv, and the collective dose is 5,919 man-Sv.

II. Contribution of Building Materials to the Gamma Dose

Using a spectrometric measurement of soil samples, Leung et al. (1990) reported an average gamma dose-rate from soil of 0.0759 $\mu Gy\ h^{-1}$ in Hong Kong, which is significantly lower than the average outdoor terrestrial gamma dose-rate of 0.162 $\mu Gy\ h^{-1}$ obtained in this survey. This difference is due to the fact that very little of the outdoor environment within Hong Kong can be characterized as soil-covered. The degree of urbanization is such that the dose is dominated by the contribution from building materials. Taking Leung's 0.0759 $\mu Gy\ h^{-1}$ as the dose-rate from soil, a person who spends all his time away from any building materials will receive an annual equivalent dose of 465 μSv from terrestrial gamma radiation originating from the soil in Hong Kong. The difference between the total of 1,110 μSv and the dose from soil (645 μSv) represents

the increase over background that one would receive in a purely natural setting by living in a dense urban environment such as Hong Kong where the building materials represent a source of technologically enhanced natural radiation.

To confirm that the building materials in Hong Kong do contribute significantly to terrestrial gamma dose, a number of measurements were conducted in the middle of Happy Valley racecourse where the contribution of building materials is negligible (the distance from the nearest building is about 200 m). The dose-rate obtained is about one-third the average outdoor value in that area.

In Hong Kong, the major building material used is concrete that is made from sand aggregates and cement. Aggregates used are extracted either locally or from nearby cities in Guangdong Province and are predominantly granite. The high concentration of radionuclides in granite and the unique, densely packed high-rise apartments and office buildings are two important reasons for the high terrestrial gamma dose in Hong Kong.

EXPOSURE DUE TO NATURAL RADIATION FOR THE GENERAL PUBLIC IN HONG KONG

Besides radon and terrestrial gamma, the other two components of the natural radiation dose are cosmic and internal which were not measured locally because these components are not Hong Kong specific and can be adopted from other works. Appropriate doses from cosmic and internal radioisotopes adopted are 226 μSv (Cui et al. 1988) and 360 μSv (UNSCEAR 1988) respectively.

The % contribution of these natural radiation sources to the total dose received by the general public in Hong Kong is shown in the following table. These give rise to an effective annual equivalent dose of 3.286 mSv which is 65% higher than the global average.

Annual Dose of 3.3 mSv in Hong Kong from Natural Radiation Sources

Source	Mean Dose (μSv)	%
Radon and thoron decay products	1,600	48.5
Terrestrial γ-rays	1,100	33.7
Cosmic radiation	226	6.9
Internal radiation	360	10.9

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