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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 8 (10): 1376-1379, 2005
ISSN 1028-8880

Assessment of Excess Cancer Risk Due to Soil Activity in Some Areas of South Punjab

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Abstract: The measured mean activities of ^{226}Ra, ^{232}Th, ^{40}K and ^{137}Cs in the soil of Bahawalpur, Bahawalnagar and Rahimyar Khan Districts were 32.9, 53.6, 647.4 and 1.8 Bq kg^{-1}. The average absorbed dose rate calculated from these activities was 62.1n Gy h^{-1} and the annual equivalent dose rate was found to be 0.5 m Sv y^{-1}. Effective doses to different body organs were derived from annual equivalent doses with the help of tissue weighting factors. Fatal cancer risks were assessed by using ICRP 60 Model. Estimations incurred 309 deaths per year due to cancer.

Key words: Absorbed dose rate, annual equivalent dose rate, tissue weighting factors

INTRODUCTION

The estimation of exposures of human populations from the various sources of radiation is an important and continuing goal of research. Many radionuclides occur naturally in terrestrial soils and rocks and in building materials derived from them. Upon decay, these radionuclides produce an external radiation field to which all human beings are exposed. In terms of dose, the principal primordial radionuclides are ^{40}K, ^{232}Th and ^{238}U. Both ^{232}Th and ^{238}U head series of radionuclides produce significant human exposures[1]. In addition to these naturally occurring nuclides, the fallout ^{137}Cs is also present in the soil. The decay of radionuclides in soil produces a γ-β radiation field in soil that also crosses the soil-air interface to produce exposures to humans.

Radioactive materials that decay spontaneously produce ionizing radiation, which has sufficient energy to strip away electrons from atoms creating ions or to break some chemical bonds. Any living tissue in the human body can be damaged by ionizing radiation. The body attempts to repair the damage, but sometimes the damage is too severe or widespread, or mistakes are made in the natural repair process. The long-life health effect of ionizing radiations is cancer. The estimated fatal cancer cases in the USA are 500 per 10,000 persons per sievert per year[2]. Other effects include nausea, weakness, hair loss or diminished organ function. Fetus in the womb is also affected by radiation. These effects include smaller head or brain size, poorly formed eyes, abnormally slow growth and mental retardation[3]. Studies indicate that fetuses are most sensitive between about eight to fifteen weeks after conception. They remain somewhat less sensitive between sixteen and twenty five weeks old.

In the area under study the soil activity is higher than the world average which may cause the enhanced cases of cancer in this area. Some measures may be adopted to decrease the activity by removing the top layer of soil and adding less active materials before the construction of dwellings.

MATERIALS AND METHODS

The area under study extends three districts namely Bahawalnagar, Bahawalpur and Rahimyar Khan. The area lies between 27°40'-30°22' North latitudes and 60°45'-73°58' East longitudes. The areas of Bahawalnagar, Bahawalpur and Rahimyar Khan District are 8878, 24542 and 11880 sq. km, respectively. According to, 1998 census[4-6] the population of this area was 7635500 persons.

Two methods of evaluating external exposures from naturally occurring radionuclides have been used. The first is simply to summarize directly measured external γ dose rates in air outdoors and indoors, subtracting the dose rate due to cosmic rays. The second is to calculate the external gamma dose rates in air from measurements of the concentrations of the relevant radionuclides in soil. The two methods have provided generally consistent estimates of exposure. Surveys to determine the concentrations of radionuclides in soil have also been made. These results can be related to exposures by using estimates of the dose rates in air per unit concentration of radionuclide in soil. In this study the later method is adopted. In order to calculate the external dose rate, knowledge of the specific gamma activities in soil is essential. The samples were collected during August, 2003 and the activity of soil was measured using standard

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methods of sampling and HPGe γ-spectrometer present in Pakistan Institute of Science and Technology, Nilore, Islamabad, Pakistan[7].

RESULTS AND DISCUSSION

Results showed that the ^{226}Ra concentration is normally used instead of ^{238}U since there may not be equilibrium between them. The highest activity of ^{226}Ra, ^{232}Th and ^{40}K is found in Minchinabad and minimum in Derawer Fort, Fort Abbas and Liaqatpur, respectively. ^{40}K is the only nuclide present in appreciable amount. ^{137}Cs is found to be minimum in Bahawalpur and maximum in Rahimyar Khan (Table 1).

When ionizing radiation passes through matter, including tissue, it deposits some of its energy in the traversed material as a result of electrical interactions. The resulting ionization of body tissue causes chemical changes in the irradiated cells that can potentially lead to biological damage. The fundamental dosimetric measure of this energy transfer is the absorbed dose, which is defined as the amount of energy deposited by the radiation in the tissues and organs of the body. The absorbed dose rate in air was measured by Eq. 1[8].

$$D = (0.604A_{Th}+0.462A_{Ra}+0.0417A_K+0.001A_{Cs})\ n\ Gy\ h^{-1} \quad (1)$$

Where, A_{Th}, A_{Ra}, A_K and A_{Cs} are the activities of ^{232}Th, ^{226}Ra, ^{40}K and ^{137}Cs, respectively. The measured absorbed dose rates are given in Table 2. Brazil, China, France, India, Iran and Italy have the highest absorbed dose rates with average ranging from 340 to 2800 n Gy h^{-1}[1].

The absorbed dose is independent of the type and energy of the radiation; however, the extent of radiation damage varies with the type and energy of the radiation.

A weighted sum of the radiation dose equivalents in most radiosensitive tissues and organs is named as annual equivalent dose. The annual equivalent dose with occupancy factor 1 can be calculated as[9]:

$$H_T = TQDx10^{-6} \quad (2)$$

Where, H_T is annual equivalent dose, 10^{-6} is the factor converting nano into milli and D is the absorbed dose rate in air in n Gy h^{-1}. Q is used to convert absorbed dose in air to effective dose. Its value is 0.7, 0.8 and 0.9 Sv Gy^{-1} y^{-1} for adults, children and infants, respectively in case of environmental exposure to gamma rays of moderate energy[1] and T is time in hours in one year, i.e., 8760. From Eq. 2 the annual equivalent dose in the area under study has been calculated (Table 3).

Table 1: Activity of different nuclides in the different towns

	Mean activity (Bq kg^{-1})			
Towns	^{226}Ra	^{232}Th	^{40}K	^{137}Cs
Fort Abbas	29.9	48.6	669.1	2.6
Minchinabad	36.5	58.4	696.1	2.9
Hasilpur	30.9	49.9	651.2	1.2
Bahawalpur	35.1	57.6	633.9	0.8
Liaqatpur	36.0	58.4	584.8	1.1
Derawer Fort	28.8	51.1	677.9	2.9
R.Y. Khan	31.6	49.4	657.6	0.8
Sadiqabad	34.2	52.4	608.2	2.3
Mean	32.9	53.6	647.4	1.8

Table 2: The absorbed dose rates in the soil of different towns

Towns	D (n Gy h^{-1})
Fort Abbas	71.1
Minchinabad	81.2
Hasilpur	71.6
Bahawalpur	77.5
Liaqatpur	76.3
Derawer Fort	72.5
Rahimyar Khan	71.9
Sadiqabad	72.9
Mean	74.4

Table 3: The annual equivalent dose rates of different towns

Towns	Annual equivalent dose (m Sv y^{-1})
Fort Abbas	0.5
Minchinabad	0.5
Hasilpur	0.5
Bahawalpur	0.5
Liaqatpur	0.5
Derawer Fort	0.5
Rahimyar Khan	0.5
Sadiqabad	0.5
Mean	0.5

From Table 3 it is obvious that the annual equivalent dose rate is 0.5 m Sv y^{-1} in all the area under study whereas the world average terrestrial annual equivalent dose is 0.48 m Sv y^{-1} with range of 0.3-0.6 m Sv y^{-1}[1].

The harm induced by radiation exposure has also been found to depend on the specific organ or tissue irradiated. The risk of induced cancer or hereditary disorders varies between organs for the same equivalent dose. To account for the various susceptibilities of the organs and tissues, a set of tissue weighting factors has been developed[2]. The effective dose is obtained by multiplying the equivalent dose in each organ by the corresponding tissue weighting factor and summing the result for each organ to give a total effective dose to the body. Effective dose is a measure of dose designed to reflect the amount of radiation detriment likely to result from the dose. Values of effective dose from any type of radiation and mode of exposure can be compared directly. The effective dose rate delivered to each organ can be calculated as:

$$E = \sum_T W_T.H_r \quad (3)$$

Where, H_T is the equivalent dose in tissue T and w_T is the tissue weighting factor for tissue T. Table 4 represents the

Table 4: Tissue weighting factors for different organs and their measured values for the area under study

Tissue or organ	Tissue weighting factor (W_T)	Dose to organs (m Sv y^{-1})
Gonads (testes or ovaries)	0.20	0.100
Red bone marrow	0.12	0.060
Colon	0.12	0.060
Lung	0.12	0.060
Stomach	0.12	0.060
Bladder	0.05	0.025
Breast	0.05	0.025
Liver	0.05	0.025
Oesophagus	0.05	0.025
Thyroid gland	0.05	0.025
Skin	0.01	0.005
Bone surfaces	0.01	0.005
Remainder	0.05	0.025
Whole body	1.00	0.500

Table 5: Estimated fatal cancer risk (except leukemia) in the population of the area under study

Cancer site	Risk factor fatal cancer per 10,000 persons (Sv^{-1})	Estimated total fatal risk (Y^{-1})
Colon	149.0	8
Lung	78.7	4
Stomach	74.3	4
Bladder	49.6	1
Breast	32.7	1
Liver	30.0	1
Oesophagus	14.9	1
Thyroid gland	7.5	1
Skin	2.0	1
Bone surfaces	9.3	1
Remainder	424.0	9
Whole body	773.0	309

tissue weighting factors for different organs of the human body and the measured doses for the area under study. It is obvious that the dose to different organs of the people in the area under study are 0.1 m Sv y^{-1} for gonads, 0.025 m Sv y^{-1} for bladder, breast, liver, oesophagus and thyroid gland, 0.06 m Sv y^{-1} for red bone marrow, colon, lung and stomach, 0.025 m Sv y^{-1} for remainder and 0.5 m Sv y^{-1} for whole body.

Estimates of radiological cancer risk are based on epidemiological studies of human populations exposed to high doses of radiation. The main source of information on the risk of radiation-induced cancer following whole-body exposure to external radiation comes from the follow-up studies on the Japanese survivors of the 1945 atomic bombings of Hiroshima and Nagasaki. Other studied populations include miners exposed to high concentrations of radon and its decay products in air, early radium dial painters who inadvertently ingested appreciable amounts of radium and patients treated with high doses of medical x-rays, or given radium-224, radium-226 or thorotrast (thorium oxide). Additional information has been derived from extensive experiments on animals and other organisms.

Problems associated with the use of data on excess cancers in Japanese bomb survivors to predict consequences at lower levels of dose and dose rate have been extensively discussed in BEIR, UNSCEAR and ICRP reports. One problem is how to extrapolate the data on increased numbers of cancer experienced by the bomb survivors in the first 40 years following exposure to predict the increase that will occur over the total lifespan of the population. Various models relating the increase of cancer with age after exposure have been used to obtain lifetime risk estimates.

A second problem is how to apply the lifetime risk of various cancers occurring in a Japanese population to other populations. Because of different cancer incidence patterns in Japan and other countries, extrapolation to other populations is difficult. The ICRP 60 estimates were obtained by averaging results from two different extrapolation models and applying them to the population of five countries.

A third problem is the extrapolation of data from populations exposed to various whole body doses of external radiation at high dose rates, to predicted effects of radiation at low dose rates. Based on theoretical considerations, experimental animal studies and some limited human data, ICRP 60 has adopted the convention of dividing the cancer risks observed at high doses and high dose rates of x- and γ-rays by a dose and dose rate effectiveness factor of two in order to obtain cancer risk estimates for low doses of ionizing radiation at low dose rates. UNSCEAR[10] defined low doses as less than 200 m Sv and low dose rates as less than 0.1 m Sv min^{-1} or 6 m Sv h^{-1}; it should be noted that these doses and dose rates are very high compared to typical public doses.

Despite these problems and the uncertainties involved, an estimate of the probability of radiation-induced cancers is needed for use in radiation protection. Based on extrapolations from high dose epidemiological studies, ICRP publication 60 recommends lifetime fatal cancer risk estimates of 0.04 Sv^{-1} for the adult population and 0.05 Sv^{-1} for the entire population including all age groups, following a protracted whole body exposure of low dose and low dose rate radiation. Table 5 shows the estimates of fatal cancer according to ICRP 60 risk model.

The activities of ^{226}Ra, ^{232}Th and ^{40}K in the soil of Bahawalnagar, Bahawalpur and Rahimyar Khan were higher than the global average, which are 32,30 and 400 Bq kg^{-1}, respectively[1]. This higher activity reflected in absorbed dose rates whose global average is 57 n Gy h^{-1} and indicated more incidences of cancer. By applying risk model from ICRP 60 it was estimated that 39 persons per million per year might be died of

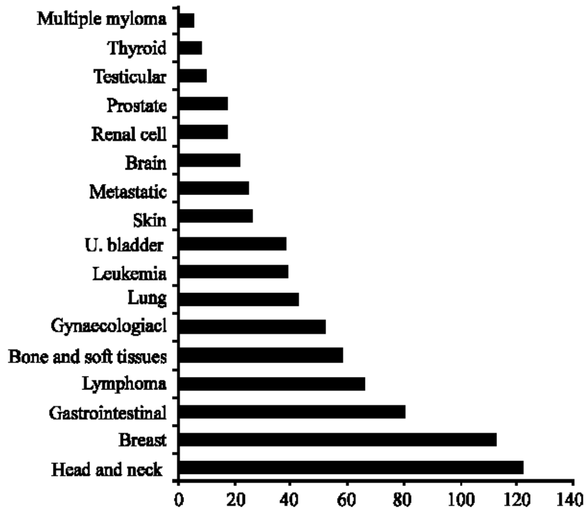

Fig. 1: Patients of different cancer sites coming to BINO in the year 2002

cancer due to terrestrial exposure. According to the latest census[2-4] the population of the area under study is 7635500 persons. Multiplying the estimated incidences with this figure a total of 309 cancer deaths each year is obtained.

Bahawalpur Institute of Nuclear Medicine and Oncology registered 739 cancer patients of different organ sites in the year 2002. According to this report there are more number of cancer cases in females than males. Figure 1 shows the trends in cancer in different organs and tissues.

Cancer risk due to natural and fallout radionuclides is of three fold; exposure, inhalation and ingestion. Risk due to exposure was estimated to be 309 cancer deaths per year with annual equivalent dose of 0.5 m Sv y^{-1}. A detailed estimate of cancer risk for each organ in different areas of the world (excluding Pakistan) can be seen in UNSCEAR, 2000 report. In the area under study risk due to inhalation of radon was estimated in a previous study and found to be 73 per million per year[11]. The more cancer incidences in females is due to gynecologic tumour and breast cancer.

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