BODY RADIOACTIVITY AND RADIATION DOSE FROM $^{40}K$
IN BANGLADESHI SUBJECTS MEASURED
WITH A WHOLE-BODY COUNTER

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A group of subjects of Bangladeshi adults from both sexes were studied for internal radioactivity and effective dose by measuring the whole-body activity of naturally occurring $^{40}K$ using a whole-body counter. The mean activity concentration in the whole body and effective dose due to naturally occurring $^{40}K$ for the average male were found to be $2.0 \pm 0.4 \text{ Bq.g}^{-1}$ and $100 \pm 26 \text{ mSv.y}^{-1}$, respectively and those for the average female were $1.7 \pm 0.3 \text{ Bq.g}^{-1}$ and $100 \pm 20 \text{ mSv.y}^{-1}$, respectively. The mean activity concentration in the whole body and effective dose for both sexes were $1.9 \pm 0.4 \text{ Bq.g}^{-1}$ and $100 \pm 25 \text{ mSv.y}^{-1}$, respectively. The effective dose from $^{40}K$ for subjects is below the value reported by the UNSCEAR.

INTRODUCTION

A measurement of body composition in human is useful in the assessment of obesity and in research on the effects of stress, malnutrition and the response to disease or therapy. In vivo human body composition is assessed by indirect methods, including densitometry by underwater weighing, measurement of total body water by isotope dilution and measurement of total body content by whole-body counting. Among these methods, whole-body counting of $^{40}K$ is used frequently because it is non-invasive and involves minimal subject inconvenience. (1)

Natural potassium is a mixture of three isotopes: $^{39}K$, $^{40}K$ and $^{41}K$ with mass percentages of 93.08, 0.0118 and 6.91, respectively. (2) A typical 20-y-old 70-kg adult male contains about 0.140 kg potassium with about 3,700 Bq of $^{40}K$. The 1461 keV gamma rays emitted from $^{40}K$ in the body can be detected with a whole-body counter.

The purpose of the present study is to investigate the mean activity concentration in the whole-body and the internal radiation dose from naturally occurring $^{40}K$ to the population of the People’s Republic of Bangladesh.

MATERIALS AND METHODS

Measurements of $^{40}K$ were carried out on a group of healthy Bangladeshi subjects of both sexes; most of them work at the Institute of Nuclear Science and Technology (INST) and nearby Institutions.

Whole-body counting system

Naturally occurring $^{40}K$ was determined with an INST whole-body counter (WBC) employing a single detector in the chair geometry. Details description of such an arrangement can be found elsewhere. (3) The counter employs a low background shielded room, and a NaI(Tl) scintillation detector of crystal size of 12.7 cm diameter $\times$ 12.7 cm in height in a chair geometry. The detector and bed are mounted in an iron frame. To reduce the external background radiation, the detector is surrounded by a shielding material consisting of lead and iron. The thickness of the lead and iron shields are 3.5 and

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2.5 cm, respectively. About 90% average external background radiation was reduced in the energy ranging from 0.1 to 3 MeV using this shielding configuration(6). Additional 0.93 mm of copper lining was used inside of the lead and iron shielding in order to reduce the low energy background, which is required to detect low energy photon (<100 keV). The detector is connected to a 35+ Canberra multichannel analyser, which is connected in turn to a PCTM computer system.

Calibration of WBC
The WBC was calibrated using a water phantom of weight 63.5 kg, which is a typical weight of Asian reference man(6), filled with KCl solution. The uniform activity distribution was assumed in the phantom. The phantom representing lungs, heart, liver and kidneys of an adult human body. The calibration coefficient was determined by dividing the net count rate for the 40K phantom by the amount of 40K in the phantom. The background count rate was measured using the same adult phantom that was used for 40K calibration, filled with only water. Weight correction was not done in this study. Therefore, uncertainty due to difference in weight between the phantom and the measured subject was included in the uncertainty value given for the subject.

Subjects monitoring
Subjects were selected randomly from among those assumed to be free of internal contamination by artificial radionuclides. The age of 90 male subjects ranged from 50 to 22 y, and the age of 35 female subjects ranged from 46 to 20 y. The weight of male subjects ranged from 73 to 50 kg, while the female subjects ranged from 70 to 40 kg. The heights of males ranged from 182 to 152 cm and the heights of females ranged from 167 to 149 cm. Subjects are positioned in chair geometry for about a 1 h counting time.

RESULTS AND DISCUSSION

The gamma-ray energy spectrum
The prominent photo-peak that can be observed from the spectrum is due to the photo-peak of the naturally occurring radionuclide, 40K at 1460 keV. In the γ-ray spectrum, other radionuclides such as 238U, 232Th and 137Cs were observed but the net peak area under the photo-peak energy of interest was insignificant i.e. at the background level. For this reason, only 40K activity has been determined in the present work.

Body 40K activity
The radioactivity due to radionuclides was measured from the relation,

$$A = \frac{\text{CPS}}{E_g \times I_g} \cdot \text{Bq} \tag{1}$$

Where, CPS is the count per second; $E_g$ is the efficiency of the detector for the energy of interest for 63.5 kg phantom = 0.0142; $I_g$ is the gamma emission probability = 0.11.

$E_g$ in Equation (1) depends on subject weights and geometries.

The mean activity concentration in the whole-body ($A_m$) was calculated from the following relation

$$A_m = \left( \frac{A}{W} \right) \cdot \text{Bq.g}^{-1} \text{y}^{-1} \tag{2}$$

Where, $A$ is the activity in Bq; $W$ is the body weight in grams.

Internal dose from 40K
The calculation of body effective dose due to naturally occurring 40K was based on the modified formula recommendation by the medical internal radiation dose Committee of the Society of Nuclear Medicine(7). While calculating the dose from gamma radiation, a correction for body weight was considered. Effective dose was then calculated from the
following equation:

\[ D = A_m \times (DCF_\beta + DCF_\gamma) \times a \times w^b \]  

(3)

where, \( D \) is the the effective dose (\( \mu \text{Sv yr}^{-1} \)); \( A_m \) is the mean activity concentration in the whole-body due to \(^{40}\text{K} \) (Bq g\(^{-1}\)); \( DCF_\beta \) is the dose conversion factor for beta ray of \(^{40}\text{K} \) (52.60 \( \mu \text{Sv yr}^{-1} \) per Bq g\(^{-1}\)); \( DCF_\gamma \) is the dose conversion factor for gamma ray of \(^{40}\text{K} \) (4.82 \( \mu \text{Sv yr}^{-1} \) per Bq g\(^{-1}\)); \( W \) is the average body weight for a subject at a given age in kg; and \( a \) and \( b \) are modifying constants for body weight. For individuals between 40 and 70 kg, the values \( a = 0.359 \), and \( b = 0.241 \) are considered(8).

In the present work, it has been found that the average annual effective dose for male is slightly higher than that for female. Moreover, the average effective dose due to only naturally occurring radionuclides for non-occupational workers is slightly higher than that for occupational workers. It may be mentioned here that no artificial radionuclides were found in the body of occupational workers, which means that the occupational workers are free from radioactive contamination. The maximum effective dose due to naturally occurring \(^{40}\text{K} \) was 160 \( \mu \text{Sv yr}^{-1} \) for male and 130 \( \mu \text{Sv yr}^{-1} \) for female.

Table 1 presents a summary of the results of the mean activity concentration in the whole-body and effective dose from \(^{40}\text{K} \) estimated in this work and also some data from the UNSCEAR 1993 report for comparison.

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REFERENCES