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OUTDOOR GAMMA RADIATION MEASURMENT IN ORDER TO ESTIMATE THE ANNUAL EFFECTIVE DOSE AND EXCESS LIFE-TIME CANCER RISK FOR RESIDENTS OF TEHRAN, IRAN

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ABSTRACT:

Introduction: Gamma ray radiation can cause ionization and harmful effects on human health due to its high levels of energy. However, contrary to popular belief, natural sources of gamma radiation are far greater in number than artificial sources. This study aims to determine the environmental gamma dose rate and the zoning map of Tehran, and estimate the annual effective dose and the excess risk of cancer in Tehran.
Materials and methods: This study is descriptive and cross-sectional. In it, the researchers measured the gamma radiation rate using a Geiger Muller detector at 50 outdoor stations in Tehran during the winter and the spring of 2016. The data was zoned using Arc GIS 10.3.
Results: The average background environmental gamma dose rate in Tehran was obtained at 605.54 nsv/h. There is a statistically significant difference between radiation in winter and in spring ($P<0.05$). The annual effective dose for the inhabitants of Tehran and the cancer risk were estimated to be 0.74 mSv and 2.29×10^{-3} respectively.
Conclusions: The annual effective dose and cancer risk in the lifetime of a Tehran city resident due to background gamma radiation were higher than the global average. Epidemiologic studies are recommended to assess the likely prevalence of chronic diseases associated with natural radiation among the residents of Tehran.

INTRODUCTION

Since their creation, humans have been constantly exposed to ionizing radiation and materials in the earth's crust. The set of this radiation is called background radiation [1]. The environmental gamma radiation, which is highly variable in each region, depends on factors like the materials of the earth's layers, the height from the ground level, and materials used in buildings [2]. The gamma ray is produced during the decay of a radioactive nucleus. In the daughter nucleus, changes in energy occur with electromagnetic radiation. This ray is made of gamma photons. Also, the gamma photon is generated when the nucleus

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changes from an excited state to a stable one, and the radiation releases electrons and energy while passing through the body or any other material as a result of the photoelectric phenomenon, Kempton, or the making of the ion-pairing process [3, 4]. Background gamma radiation refers to terrestrial, cosmic, and atmospheric gamma radiations, or radiation of gamma caused by the loss of radioactive material because of the testing of nuclear weapons or nuclear power plants. The environmental gamma radiation rate varies in different regions and depends on factors like the radiation properties of soil and rock, natural properties of building construction materials, and the types of residential buildings. Environmental gamma radiation varies with time and it is difficult to determine its exact amount [5]. Environmental gamma radiation is caused by radioactive elements with a long half-life which exist in primary rocks of the earth's crust. The amount of radioactive elements is variable in water and depends on the geological structure of the area. It is usually found in deep wells [5, 6].

Environmental gamma radiations are actually radiations caused by the decay of uranium and thorium as natural radioactive resources that pollute environmental resources of their surroundings [6]. Background radiation always exists in the environment and everyone is constantly exposed to it. Gamma rays are high-energy electromagnetic radiation called photons and are emitted from the nucleus. They are like x-rays, but with a shorter wavelength and more energy. If more energy is released, very penetrating gamma rays will be produced. To prevent its penetration, a several-inches-thick coating of high-density metals like lead or thick concrete is used [7, 8]. The radiations release energy when they come into contact with the body. This energy can damage tissues. The destructive effects of radiations range from some minor and temporary impairment of physical exertion to serious consequences such as shortening of life, reduced body resistance, reduced reproductive power, development of cataracts, blood cancer, and damage to the foetus in the form of teratogen and mutagen [8]. Radiation causes ionization in the molecules of living cells. This ionization leads to the release of an electron of atoms and ions, or charged atoms. These ions cause danger to cells while reacting with other cell atoms. For example, the molecular water near the DNA is ionized and these ions react with DNA and break its chain if the gamma rays pass through the cell. In low doses, such as those we receive daily from background radiation, cells frequently rebuild themselves. In higher doses (up to 100 rem) cells cannot do so. So, they are altered permanently or they die. The altered cells may permanently produce abnormal cells during cells proliferation. These cells may become cancer cells under certain conditions [9]. So, radiation exposure can be considered as a cause of the increased risk of cancer. Gamma radiation is a high-energy emission. The energy of gamma photons is 10,000 times higher than that of visible light photons in the electromagnetic spectrum. Accordingly, gamma photons may run their course hundreds or thousands of metres in the air until they lose all their energy. The primary source of exposure to gamma is natural radio-nuclides, especially potassium 40 in the soil, water, and food such as meat and bananas [10,11]. According to the latest information provided by the United Nations Scientific Committee on the effects of atomic radiation, the annual global average dose per person is 2.4 mSv, 1/1mSv of which is produced by environmental gamma radiations caused by cosmic radiations and radioactive materials in the earth's crust. The rest, 3/1 mSv, of this annual global average dose is caused by the radon gas [3]. The global effective dose of gamma radiation in the soil caused by external radiation is equal to 0.5 mSv. The average exposure from artificial sources, including losses caused by nuclear explosions, nuclear accidents, and normal operation of nuclear power plants, as well as medical exposures, diagnosis, and treatment as a result of the use of radioactive materials and radiation devices, is estimated to be 0.8 mSv/year [3]. In recent years, several studies have been conducted to evaluate the natural background radiation in Iran and other countries. For example, in a similar study in Sweden in 2008, the internal and external exposure were measured as well as external ionization dose rate from natural and synthetic sources [12]. The average annual effective dose for the residents in some areas of Baghdad was 0.729 mSv [13]. The exposure rate for those who live in the province of Camagüey, Cuba, was estimated by measuring the natural background gamma. Gamma spectrum of the soil and the absorbed dose rate in air were measured. Portable x-ray measurements with an ionization chamber of RSS-112 were taken at sampling sites, and on average, the outdoor absorbed dose of 63.6 nGy/h was obtained from cosmic radiation and terrestrial gamma-rays [14]. In a study in Tehran in 2005, it was reported that the measured average radiation rate in air and the average effective dose for each person in Tehran were equal to 102 nSv/h and 125 μSv respectively [15]. In a study conducted in 2008 to determine the environmental gamma dose rate and to estimate the annual effective dose in the cities of Ardebil and Sarein, the outdoor environmental gamma dose rate of 265, 219, and 208 nSv/h were obtained for Ardebil, Sarein and the sewage course of Sarein's hot springs respectively. The annual effective doses received by the residents of Ardabil and Sarein were 1.49 mSv and 1.35 mSv respectively [16].

A study on background radiation in city of Kerman in 2003, showed that the cities of Bardsir and Kahnooj had the highest and the lowest background radiation rates respectively [17].

Another study in the city of Zanjan in 2008 showed that the average rate was equal to 126 nsv/h [18]. In a study in Sabzevar in 2014, it was reported the annual effective dose of 0.85 mSv and cancer risk of 3.39×10^{-3} for the residents of Sabzevar, Iran [19]. Considering the relationship between the incidence of cancer and other disorders caused by cosmic radiations, this study was aimed at evaluating the outdoor natural gamma radiation as well as determining the received annual effective dose and the risk of cancer caused by gamma radiation in Tehran in 2016.

MATERIALS AND METHODS

This study is descriptive and cross-sectional, and was conducted in the winter and spring of 2016 to determine the background radiation dose rate in Tehran. To select the measurement points, a detailed map of Tehran's 22 urban district boundaries was prepared and divided into north, west, east, central, and south zones.

Then, using the table of random numbers in SPSS, 10 points were selected in each geographical area to measure the background radiation. Following the sample size formula and similar studies, 50 measuring points were randomly determined with an equal number in each zone. The measurements were carried out in the middle of winter and the middle of spring 2016. There was no obstacle in front of any of the studied points at least within a radius of 5 m and the selected land was as flat as possible. The dosimeter was installed at a height of 1 m from the ground in the north-south direction on a tripod. Each measurement lasted for 30 m, during which almost 30 numbers of the dosimeter were read and recorded in the checklist. Fig.1 shows the 50 measured stations in which the environmental gamma radiation was measured in an outdoor space.

The dosimeter used in this study was a survey meter designed to monitor x, gamma, and beta radiations (Ion Chamber Survey Meter). The device sensitivity was calibrated by Karaj Pars Isotope Company, Atomic Energy Organization of Iran.

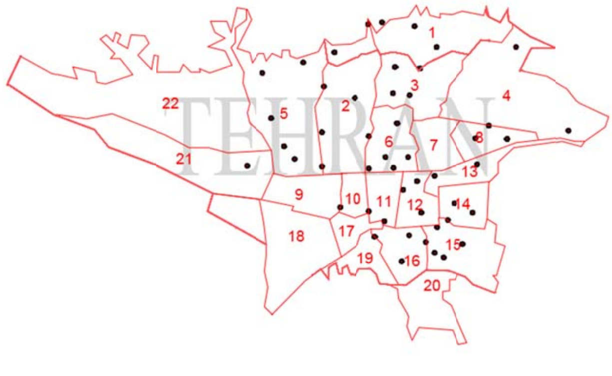

Fig.1. Specified stations in the city to measure the gamma radiation

The sensitivity of the device is within 0.05μsv/h and 50msv/h.

To evaluate the effects of ionizing radiation on biological systems with a focus on humans, the dose quantity defined on the basis of the absorbed dose, according to the international commission on radiological protection that was selected as the main focus on the effects of ionizing radiations. According to the definition, the equivalent dose can be got by multiplying the absorbed dose by the qualitative factors:

$$(DE = D \times QF) \quad (1)$$

D: absorbed dose; and Qf: qualitative factor. The qualitative factor is different for various radiations and it is equal to 1 for X, gamma, and beta radiations. The new unit of the equivalent dose is Sv in the international system [20]. The temperature and atmospheric pressure, which were obtained in the measurement using the Multipurpose Anemometer GM8910, have been put in the following formula so that the value of the K_{TP} coefficient is obtained with respect to the environmental temperature and pressure.

$$K_{TP} = \frac{273.15 + T[°C]}{293.15} \times \frac{1013.15}{P[mbar]}$$

Then, to obtain the final number, the average data at each station was multiplied by the K_{TP} coefficient, which was obtained considering the temperature and pressure in each station and the coefficient error of 1.04 presented in the Geiger Muller Calibration certificate.

$$A = X \times K_{TP} \times 1.04$$

A = final data per station (μsv/h)
X = average data per station (μsv/h)
K_{TP} = coefficient of temperature and ambient pressure of each station
1.04 = Device's calibration fault coefficient
The relation between the equivalent dose and the absorbed dose is as follows:

$$H (Sv) = Wr \times D (Gy)$$

Wr is the relation of the radiation weight factor, the amount of which is equal to 1 for all photons and electrons (ICRP60). That is, the equivalent dose in terms of air Sv is numerically equal to the absorbed dose in terms of Gy.

To estimate the annual effective dose from the background gamma radiation in Tehran, the following formula was used according to UNSCEAR-2000.

$$E (Sv) = H (Sv) \times 0.7$$

E and H are respectively effective and equivalent doses based on Sv. A conversion coefficient of 0.7 was used for adults. This coefficient is equal to 0.8 and 0.9 respectively for children and infants respectively [3]. Finally, data were analysed with SPSS and Excel. The results were compared with the global standards. Then, the zoning map of Tehran was prepared with the Arc GIS 10.3, (Inverse Distance Weighting (IDW)) interpolation method. Then, the excess lifetime cancer risk for the residents of Tehran was assessed with this equation [21] :

$$ELCR = AED \times DL \times RF$$

Where
ELCR = Rate of cancer risk
E= Annual effective dose in mSv
DL= Average life expectancy in years
RF = Cancer risk coefficient in terms of years
Which is considered equal to 0.057 [22].

RESULTS AND DISCUSSION

The coefficients of the absorption dose in the air converted to the equivalent dose in outdoor and indoor spaces are expressed in nGy/h. The factor of residence outside the building is considered to be 0.2. The annual outdoor radiation dose of the residents of Tehran per year is estimated in mSv using the following relation [3]:

$$Outdoor(mSv/h) = 605.54(nGy/h) \times 8760(h) \times 0.7(Sv/Gy) \times 0.2 = 0.74\, mSv$$

A similar amount has been reported in the UNSCEAR-2000 (0.07) [3]. Estimating the annual effective dose from background radiation in Tehran requires the measurement of indoor exposure.

The risk of cancer caused by the gamma radiation can be calculated based on the following relation [21]:

$$ELCR = 0.74 \times 70.1 \times 0.057 = 2.956$$

According to this relation, the risk of cancer caused by gamma radiation during a lifetime is more than the amount of global average (0.29×10^{-3}) [23].

The average absorbed dose rates are as following: 429.94 nSv/h for winter; 781.14 nSv/h for spring; and the total average of two seasons is 605.54nsv/h. The annual effective equivalent dose for the residents of Tehran:

0.527 mSv in winter; 0.958 mSv in spring; and the total overall average is 0.74msv, which is higher than the global average [3]. According to the analysis carried out in SPSS using the statistical test of paired samples statistics, the $P_{value} < 0.05$ was obtained, which shows a significant difference between the exposures in winter and spring.

By calculating the R^2 coefficient, it was determined that there is a weak correlation between height and the absorbed dose rate.

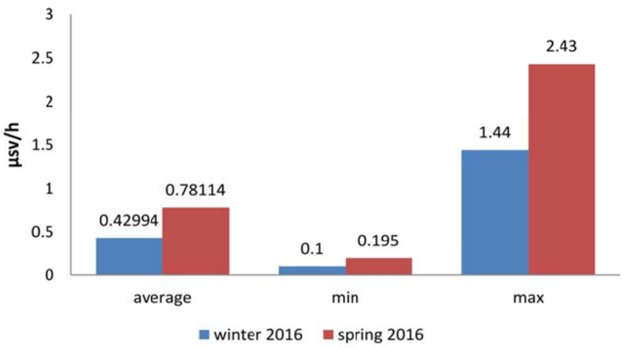

Fig.2. Comparison of the background gamma in winter and spring, 2016 in Tehran.

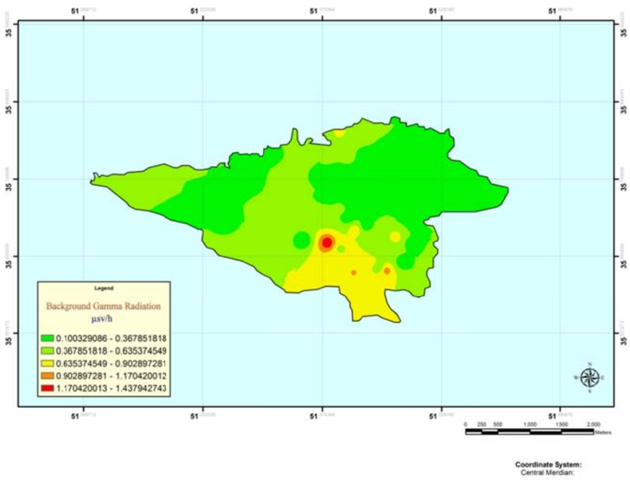

Fig.3. Zoning background gamma in Tehran (winter 2016)

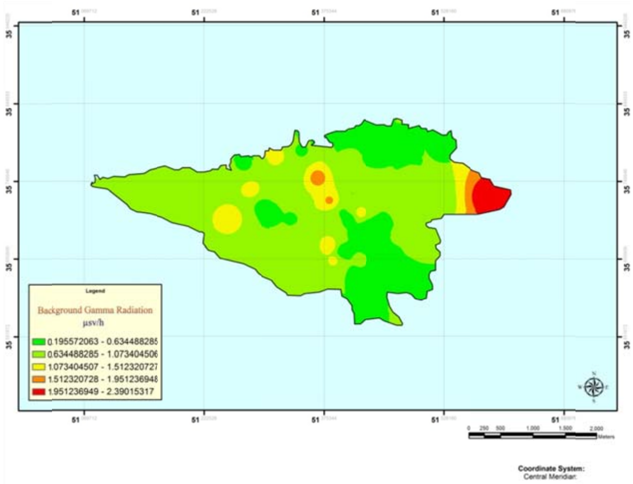

Fig.4. Zoning background gamma in Tehran (spring 2016)

Assessment of environmental radiations is one of the most important branches of health physics. Although most people are more concerned about exposure from artificial sources, the major exposure to people normally originates from natural radioactive sources. Natural ionizing radiations have the highest share in the total effective dose people receive. Thus, it is important to estimate the radiation dose per person [3, 24]. The natural gamma rate in each region is highly variable and depends on factors such as the materials of the earth's layers, altitude, latitude, and construction materials used in buildings [25, 26]. Measurement of the environmental gamma radiation at the 50 points in Tehran for the preparation of the radiation map of the city using the Geiger detector showed the lowest and highest doses at 0.1 μSV/h and 2.43 μSV/h for Taleghani park in the northern part of the city and Sahel Garden park at Hakimiyeh in the east respectively. The difference may be due to differences in the ingredients in the earth's crust in the different parts [3]. In this regard, it is recommended that studies are conducted on the qualitative and quantitative analyses of minerals. Geological information is needed in Tehran to establish an appropriate relationship between geographical features and the dose rate in those areas. Measurements in winter and spring showed that spring, with an average of 781.14 nSv/h, had a dose rate about twice than that of winter, with an average of 429.94 nSv/h. Given that cosmic radiations are one of the main causes of environmental radiation, which generally originate from solar activity and are sent to the earth, the amount of cosmic radiations is a function of the thickness of the atmosphere, the latitude, and the distance between earth and the sun. This distance is shorter in spring and the amount of ground-level radiation is higher.

The dose rate of Tehran was higher than those in Tabriz, Orumieh, Zanjan, Isfahan, Yazd, Meshkinshar, Ardabil, and Sabzevar with rates of 140, 138, 126, 147, 110, 355, 265, 134 nSv/h respectively. But it was less than the dose rate in Ramsar (1,300 nSv/h). The results of this study showed lower values of the average radiation rate compared with those found in the study in Tehran in 2005. They estimated the average radiation rate and the average effective dose for each individual in Tehran to be 102 nGy/h and 125 μSv respectively [15].

Also, the results of this study showed lower values of the average radiation rate compared with those of the study in Sabzevar. They estimated the annual effective dose of 0.85 mSv for the residents of Sabzevar and the risk of cancer as 3.39×10^{-3} [19].

CONCLUSIONS

According to the results of this study, the average dose rate in Tehran was 605.54nsv/h, which was greater than 59nGy/h reported by UNSCEAR-2000. Also, the annual effective dose of outdoor natural gamma radiation was 0.74 mSv among Tehran residents, which was much higher than the global average (0.07msv) reported by UNSCEAR-2000.

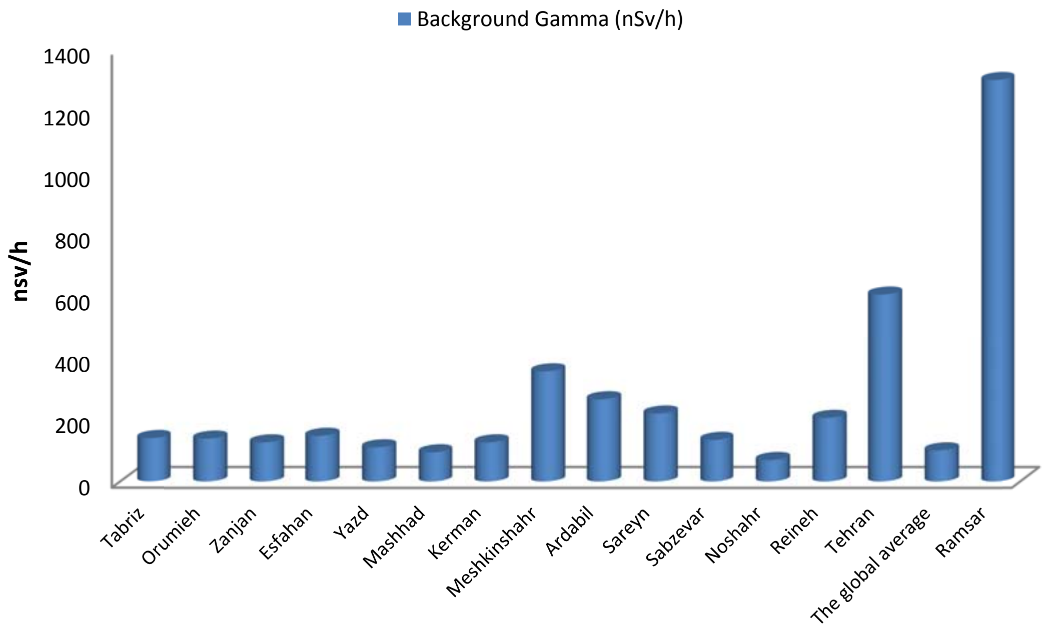

Fig.5. Comparison of the average dose rate of gamma radiation in Tehran with the global average and other cities in Iran [19]

It is recommended that these rates be measured in summer and autumn to compare the doses in all seasons. Preparing Iran's radiation map requires the designing and implementation of a study of Tehran's environmental radiation to complete studies in other areas. Epidemiologic studies are recommended to assess the likely prevalence of chronic diseases associated with natural radiation among the residents of Tehran.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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ETHICAL CONSIDERATIONS

This manuscript is an original work by the authors. All authors agreed to submit their manuscript to JAPH. The authors confirm that the manuscript has not been submitted or published elsewhere in any language.

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