SJIF IMPACT FACTOR: 4.183 CRDEEPJournals
International Journal of Environmental Sciences Amaal. A. Tawfik Vol. 4 No. 1 ISSN: 2277-1948
International Journal of Environmental Sciences Vol. 4 No. 1. 2015. Pp. 1-6

IJES

Full Length Research Paper

Environmental Monitoring based on TLD-100 (LiF:Mg,Ti) Thermoluminescent Detector

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Abstract

New-Cairo city in Egypt, is considered one of the most important residential areas in Egypt, so it was important to conduct a study to determine the natural background radiation level and radiation dose expected for the inhabitants of this region. Concentration of natural radioactive materials, especially available U238, Ra226, Th232, and K40 in construction materials and soil, as well as absorbed dose from cosmic rays, is the most important source of the people for effective doses from the natural radiation. An environmental radiation monitoring system using standard TLD-100 (LiF:Mg, Ti) as high-sensitive detectors was applied to control the radiation exposure over the area of New-Cairo city. Indoor and outdoor gamma radiation dose rate measurements at 13 regions in New-Cairo city in Egypt using TLD have been performed. Measurements were made on a monthly during a period of one year. The results have been compared with those found by other investigators for different locations of the world. A variation of monthly indoor gamma radiation the type: $d = 1.0733\ m^2 - 13.748m + 84.103$ where d is the indoor dose rate (nGy/h) and m is the month. The indoor gamma annual effective dose of New-Cairo city is in the range from 239 to 265 µSv/y, an average value of 249 µSv/y. The outdoor gamma annual effective dose of New-Cairo city is in the range from 31 to 48 µSv/y, an average value of 37 µSv/y. The annual effective dose to the adult population of the locations will vary from 277 to 296 µSv/ywith an average value of 285 µSv/y.

Keywords: *TLD; New-Cairo city; gamma radiation dose; effective dose; background radiation level*

Introduction

Natural environment radionuclides are responsible for the most external exposure of gamma radiation. This contributes radionuclide of the natural series U-238, Th-232 followed by K-40 universally present in the Earth (Sherber, 1997, Salama, et al.2006, Zortzis, and Taert 2004 Ghiassi-Najad 2001). The world mean specific concentration of K-40 (Activity per unit mass) is 370 Bq/kg, varying from 100 to 700 Bq/kg (Zortzis, and Taert 2004). The United Nations Scientific Committee on the effects of Atomic Radiation, UNSCEAR (2000), establish that, the world mean dose from natural radiation sources of normal areas is estimated to be 2.4 mSv/y, while that for all man-made sources, including medical exposure, is about 0.8 mSv/y (Macullay, and Moran 1988, Furukawa M and R. Shingaki, 2012,), Thus 75 % of the radiation dose received by humanity is come from natural radiation sources. Based on these radiation levels from this fact one can certify that the knowledge of primordial radionuclides, such U-238, Th-232 and K-40, is very important for evaluation of the rate of exposure and absorbed dose by the population (Sivakumar et al. 2001, Kanna et al. 2002,El- Zakla et al. 2007).

Man has continuously been exposed to a natural background of ionising radiation from the environment in which he lives. Dose measurement is acknowledged to be a vital part of the quality assurance process and the use of thermoluminescent dosimeters (TLDs) is a recommended method of dose measurement (Michael F. et al, 2010, COR NRPB, 1992). Thermoluminescent detectors (TLD) are widely used for monitoring of environment for ionising radiation in environment and natural background kerma rates. The external radiation exposure comes mainly from the natural radiation. Natural gamma-ray background generally refers to the gamma radiation from radioactivity in the environment, i.e., from terrestrial sources and building materials and from cosmic rays. The distribution of external exposure due to terrestrial radiation in a given place depends on the geographical characteristics of that place and atmospheric conditions. There are several international studies reported for measurement of terrestrial gamma radiation background levels to assess the dose to the population. The assessment of external exposure due to terrestrial radiation shall be addressed in this paper. Environmental gamma-ray background was measured at dwellings of New Cairo city in Egypt to estimate effective annual dose to the public from gamma radiation coming from the man's surrounding environment, which impacts the body and can be harmful to different organs due to the high penetration property of gamma-ray. There has been interest in the determination of the average gamma radiation dose and the average annual effective doses to which the population is exposed.

In New Cairo city, information about indoor and outdoor gamma radiation dose exposure is very limited and no such information was available for some districts. It was therefore felt that an evaluation of indoor and outdoor gamma radiation dose rate exposure was very much necessary for ascertaining the baseline data on background radiation level, and indeed such a program has been undertaken for the study areas. Monthly variation of gamma dose rate has also been studied.

Material and Methods

In this study, LiF:Mg:Ti (TLD-100) dosimeters, ^{90}S/^{90}Y Irradiator and TLD reader and Harshaw Model 4000 were used.

***^{90}S/^{90}Y Irradiator*:**

The type of this irradiator is Harshaw Model 2000. It has a ^{90}S/^{90}Y source with an activity of (0.9 mCi). At the end of the irradiation cycle a solenoid driven shutter is automatically closed to shuts of the shutter (light on-open). The total number of revolutions of the turntable inside the calibration system.

LiF:Ti,Mg (TLD-100) Dosimeter:

The thermoluminescent (TL) material chosen to perform gamma dose measurements in this study is TLD-100 . Measurements were performed using LiF:Mg:Ti (TLD-100) chips. This dosimeter is sensitive been used for integrated dose measurements. It used because of their energy independence and low fading. It has high sensitivity, low leak, good resistance against heat, moisture, and other environmental factors, and un-sensitive to light. They have filters for protection to disturbant radiation. The TLDs used were manufactured by the Bicron Company, LiF:Mg, Ti (TLD-100).

The individual relative sensitive factors and repeatability for all dosimeters used in this work were investigated for gamma radiation, 1 cGy, ^{137}Cs source. The TLD calibration factors have been determined, in air, for different X-ray beam kVp obtained with a Siemens Polymat 50 equipment. Dose evaluations for TLD calibration were carried out with a dosimetric system Radcal, model 9015, with a 6 cc ionisation chamber 90X. The X-rays used were of 63, 66, 70, 73, 77, 81, 85, 90 and 96 kV. The energy dependence curve for the response of the TLDs used was determined using the above-mentioned qualities in terms of effective energy. This procedure allowed the correction of the TLD response with respect to each beam quality considered. This method is quite effective for TLD-100.

The chips were annealed (using TLD Oven, Model PTW-TLDO, Germany). TLDs were calibrated using TLD irradiation facility. The TLDs were annealed at 400 ^{o}C for 1 h followed by 2 h at 100 ^{o}C to eliminate all residual signals without the effecting on TLD sensitivity.

Three locations from 13 regions distributed in all around New-Cairo city were investigated as shown in figure (1). One house was selected from each location. Three TLD chips were put in a special plastic bag in each sites and left over the roofs of the houses. Each three TLD package were placed inside the houses at 1 m above the ground for one month for indoor measurements. Another three TLD chips were put in a special plastic bag and left in living rooms of the same houses for one month for outdoor measurements. TLDs were replaced with new one every one month. The procedure was repeated for 12 times during one year, to ensure continuity of monitoring for a period of one year.

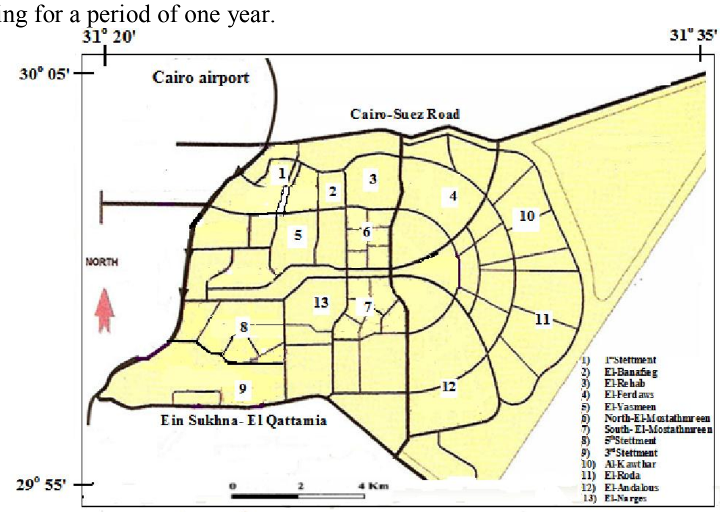

Figure 1. Regions of New-Cairo city that was investigated

TLD chips were read out using a TL reader (Harshaw Model 4000 TLD System) at a constant rate. The detailed procedures for annealing, and calibration and read out of TLDs are described in reference (Mollah et al. 1986).All dosimeters were evaluated in a TL reader Harshaw 4000. The reading and annealing conditions are presented, respectively, in Tables (1) and (2). For the Dose Cal software, the tube output of the different X-ray machines was measured using, in the case of IPPMG, a calibrated ionisation chamber Radcheck Plus X-rays exposure meter, Model 06-526 NAD, and, in the case of IFF, a Radcal Model 202520_5-3.

Table 1. Reading conditions of TLDs in the Harshow 4000 TLD reader For (LiF:MgTi)

Preheat (°C)	**100**
Temperature rate (°C/s)	**10**
Maximum temperature (°C)	**300**
Anneal temperature (°C)	**0**
Preheat time (s)	**10**
Acquire time (s)	**30**
Anneal time (s)	**0**
High voltage (V)	**680**

Table 2. Annealing conditions of (LiF:MgTi)

Annealing	Stabilization annealing
400 °C/1h +100 °C/2h	100 °C/15 min

Results and discussion

Relationships between the experimental results obtained with the TLDs and calculations using the output measurements gave no significant differences in the results as shown in figure 2.

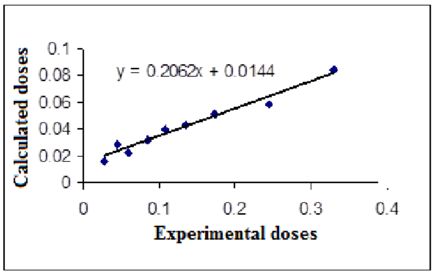

Figure 2. Relation between experimental and calculated doses for TLD calibration.

The precision of TLD was evaluated in a Harshaw 4000 TL reader. A mean reproducibility of 3.2% (1σ) was obtained. The indoor-effective gamma dose rate in air was measured using TLD-100 and was found to be in the range from 239 to 265 μSvy^{-1}, an average value of 249 μSvy^{-1}. The outdoor gamma annual effective dose of New-Cairo city is in the range from 31 to 48 μSvy^{-1}, with an average value of 37 Svy^{1}. The annual effective dose to the adult population of the locations will vary from 277 to 296 μSvy^{-1}, with an average value of 285 μSvy^{-1}. In general, the gamma exposures in all locations (in 39 houses) were found to be compatible with slightly higher values in some houses. The high exposure rates in these houses may be due to the relatively higher radioactive content of the materials used for building construction. Table (3) shows the results of the indoor and outdoor effective gamma dose at 1 m above the ground. The statistical analysis was performed. Given that the empirical gamma dose distribution must be very close to normal.

Monthly average dose rates in the study areas are shown in Figure (3); A curve $d=1.0733\ m^2 - 13.748\ m + 84.103$ where d is the indoor dose rate in (nGy/h) and m the month (m=1, 2, 3, etc.) is fitted in the data.

In Fig (3) the seasonal variation in the dose rate was observed. For the Fall season (September - November) is 50.05 nGy/h , while that for the Spring season (March-May) is 41.16 nGy/h . For the Summer (Jun-Agust) season is 48.08, while that for the winter season is72.21 The maximum absorbed dose rate achieved in December was 77.27 nGy/h, while the minimum in May 38.32 nGy/h. All the houses were inhabited, and based on the information from their inhabitants it was recorded that during Spring and Fall months the windows were always open (for cooling by air circulation), whereas they were open only in the day-time (i.e. for about 10h a day).

During Summer and Winter months, they used mostly (air condition) which increased the indoor dose rate is mainly due to their higher air exchange rates between indoor and outdoor atmosphere. It is evident from this analysis that an indoor dose rate reaches maximum, which is due to reduced ventilation during the winter and summer.

Table 3. Annual effective dose from indoor and outdoor terrestrial gamma rays in New Cairo city at 1m above the ground.

S. no.	Region	Ava.Indoor μSvy^{-1}	Ava. Outdoor μSvy^{-1}	Total μSvy^{-1}
1	1^{st}Stettment	*250*	*33*	*285*
2	El-Banafseg	*252*	*35*	*277*
3	El-Rehab	*243*	*38*	*281*
4	El-Ferdaws	*265*	*31*	*296*
5	El-Yasmeen	*247*	*42*	*289*
6	North-El-Mostathmreen	*251*	*39*	*290*
7	South- El-Mostathmreen	*239*	*48*	*287*
8	5^{th}Stettment	*246*	*36*	*282*
9	3^{rd}Stettment	*248*	*31*	*279*
10	Al-Kawthar	*253*	*40*	*293*
11	El-Roda	*249*	*32*	*281*
12	El-Andalous	*245*	*34*	*279*
13	El-Narges	*246*	*37*	*283*
	The mean value	*248.8*	*36.6*	*284.8*

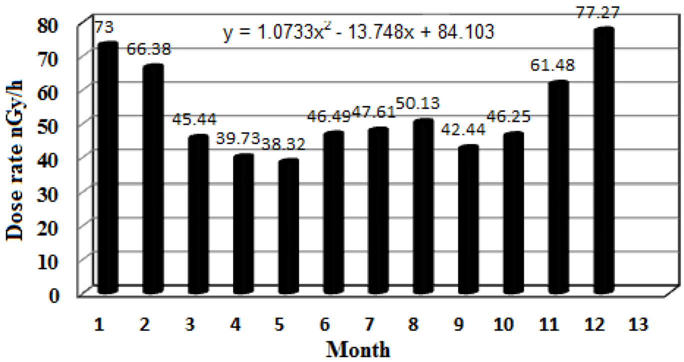

Figure 3. Monthly average dose rate in New-Cairo city

Conversely, the observed lower dose rates during the Spring and Fall seasons when the windows of the houses always remained open (the temperature of the environment, 20 – 25 ^{0}C , is mainly due to their lower air exchange rates between indoor and outdoor atmosphere. The monthly variation of gamma dose rate is modeled by a sinusoidal curve of the type:

$$(d = 1.0733m^2 - 13.748m + 84.103)$$

where d is the indoor gamma dose rate in nGy h^{-1} and m the month. As can be seen from Fig. (3), the curve completes a cycle after m = 12 months (1 year), i.e. the period is 12months. For a better understanding of this variation, the effects of ventilation and air exchange of the houses should be assessed. The effective dose was estimated using the conversion factors published in ICRP (1990) and UNSCEAR (1993). An indoor occupancy factor of 0.8 (average annual occupancy ≈7000 h/y in each dwelling) and a conversion factor of 0.7 Sv G/y have been used (Amrani 2000; Hewamanna et al. 2001; Mollah et al. 1989). The indoor annual effective dose for the study areas was calculated as a product of the measured annual dose, the conversion factor and the occupancy. Almost all of the buildings they live in are similar and made of brick and concrete. It is therefore assumed that the average value for the selected houses will represent the whole area under study.

Table (4) represents a comparison of the indoor gamma dose level in New Cairo city, from the present study, along with those found by other investigators from different locations of the world. The construction materials of the houses (buildings) have also been shown in the table. It can be seen from table that the present value is 2–3 times higher than those of others, except from

Hong Kong (Tso and Leung, 2000), where the value is much higher. This variation may be due to the geographical latitude, radioactive contents of the soil and building materials and the atmospheric radioactivity.

As most of people spend 80% of their time in indoor and 20% in outdoor environments, so it has been used from occupancy factor for calculating beam absorbing (0.8 and 0.2 for indoor and outdoor places respectively, UNSCER, 1998) we used conversion factors 0.7Sv/Gy and 1Sv/Gy for convert of absorb dose in air to effective absorb dose in tissue for terrestrial cosmic gamma radiation.

From table (4), it has been shown related information to the measurements of radiation exposure in crowded areas for different countries, frequency of absorb dose distribution by considering to population, hour effective dose for every person, and share of cosmic radiation in each area in indoor and outdoor. After that, it has been shown New Cairo city map gamma effective absorb dose. In most of cities, it has been evaluated ratio of indoor to outdoor gamma exposure rate for terrestrial radiation. In the measurements, we suppose that:

1-Detectors are placed in 1m higher than surface.
2-Detectors are placed in 1m from walls, in indoor.
3-Distance between detectors and walls and buildings in outdoor measurement was enough (at least 6m).
4-Measurment places are selected randomly.

Table 4. Indoor gamma exposures in some countries

Location	Dose rate (mGy/y)	Type of building Constructed materials	Reference
New-Cairo city	0.25	Brick, concrete, Marble, limestone and wood	Present study
Dhaka (Bangladesh)	1.54	Brick and concrete	Miah (2004)
Japan	0.37	Blanch schist	Chen et al. (1993)
Hong Kong	1.93	Concrete	Tso and Leung (2000), Hosoda (2005
Syria	0.22	Marble and limestone	Othman mahrouka (1994)
USA	0.41	Wod	Lindeken et al. (1973)
Australia	0.68	Brick, timber, asbestos and granite	Yeates and King (1973)
Austria	0.82	Brick, Concrete, Stone and wood	Tschirf (1980)
Spain	0.60	Brick, Concrete and stone	Garzon et al. (1981), Quindos L.S, 1992
Norway	0.86	Brick, Concrete and wood	Storruste et al. (1965)
Poland	0.50	Brick and Concrete	Pensko et al. (1969)
Greece	0.42	Brick and Concrete	Sakellariou et al. (1995)

The average individual repeatability of the dosimeters was less than 3%, for all materials, for a dose of 1 cGy due to 137Cs gamma rays. Of course, if very low doses are intended to be measured, the repeatability will be worse due to the higher influence of the TL dosimeter intrinsic background. It is important to mention that the results obtained with all types of dosimeters, LiF:Mg, Ti, present good agreement,

Conclusion

The gamma total effective dose rate in the study are as follow a normal distribution and range from 277 to 296 μSvy^{-1}, in good agreement with our previous study. The result is compared with the literature values. A variation of monthly gamma dose rates was observed. For better studies of this variation, additional measurements of air exchange rates of the houses should be performed. The average annual effective doses contributed from the indoor and outdoor gamma exposure to the inhabitants at the study areas were found to be 285 μSvy^{-1}. The outdoor gamma annual effective dose of New-Cairo city is in the range from 31 to 48 µSv/y, an average value of 37 µSv/y. The annual effective dose to the adult population of the locations will vary from 277 to 296 µSv/y with an average value of 285 µSv/y.

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