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ASSESSMENT OF NATURAL INDOOR RADON EXPOSURE OF ASWAN GRANITIC COUNTERTOPS, PORT SAID UNIVERSITY, EGYPT

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تقييم التعرض الطبيعي للرادون بالأماكن المغلقة من أسطح الجرانيت المصرية، جامعة بور سعيد، مصر

الخلاصـــة: تستخدم جامعة بورسعيد الجرانيت للديكور، الذى توفره الصناعة. أجري تفسير نوعي وكمي على المختبر الجيولوجي الذي تغطيه أسطح الجرانيت المصري. ومن الناحية النوعية، فإن شذات اليورانيوم تتواجد بشكل عشوائي وينتشر في جميع أنحاء المختبر الذيُ يظهر غاز الرادون المحاصر الذي تزيد انبعاثاته في الأماكن المغلقة. ومن الناحية الكمية، فإن تركيزات النشاط الاشعاعي Th٢٣٢ وRa٢٢٦ و K٤٠ المقاسة في المختبر الجيولوجي أعلى منها في ساحة الكلية التي تصل إلى ٥ و ٣,٥ و ٤,٥ مثل على التوالي. سجل مؤشر مكافئ الراديوم ومؤشر المخاطر الخارجية ومؤشر المخاطر الداخلية لأسطح الجرانيت المصرية ٢٤٤,٠٨٨ و ٠,٦٥٩ و٠,٩٦٥ Kg/Bq على التوالي. ومعدلات الجرعة الممتصة في الأماكن المغلقة المحسوبة من النشاط الاشعاعي المقاس هي ٢٢٠ nGy/h أيضا متوسط معدل الجرعة الفعالة السنوي ٠,٤٣٨ mSv/y وهو قريب جدا من متوسط قيم الجرعة المكافئة الفعالة السنوية (في الأماكن المغلقة) وهو ٤٥٠ μSv/y ونتيجة لذلك، فإن هذا المؤشر العالي للخطر الداخلي ، ومعدل الجرعة الممتصة، ومتوسط معدل الجرعة الفعالة السنوي لأسطح الجرانيت يعكس التعرض الداخلي للرادون ومنتجات من عناصر سلسلة التحلل وهي المسئول الاول عن مدة الإشغال للمختبر وزيادة المخاطر الصحية على العاملين (الأساتذة ، والطلاب والعمال). وأخيرا فإن مؤشر تركيز النشاط للمختبر الجيولوجي يمثل ١,٨٣٢ mSv/y متجاوز ١ mSv/y. حيث وجد أن معامل خطر الزائد للإصابة بالسرطان مدى الحياة (ELCR) الذي تم تقييمه خلال الدراسة الحالية على أساس الجرعة السنوية بالاماكن المغلقة هو ١,٦١×١٠^-٣^، وهو أكثر من خمسة امثال المتوسط العالمي البالغ ٠,٢٩×١٠^-٣^ ونتيجة لذلك فإن مؤشر تركيز النشاط و ELCR هي أيضا تنبيه لاستخدام اسطح الجرانيت كغطاء زخرفي في المختبرات كمكان حضور مستمر للإنسان مثل الجامعات. وتأكيدا على سيطرة غاز الرادون الصاعد من أسطح الجرانيت في المختبر الجيولوجي باعتباره أكثر المساهمين والمسؤول الأول عن التعرض الداخلي داخل المختبرات الجيولوجية، فمن المتوقع أن تكون هذه الدراسة مفيدة في إنشاء بيانات اساسية واضحة في وضع معايير التعرض الإشعاعي لسلسلة تحلل العناصر المشعة الطبيعية في اسطح الجرانيت المنتجة محليا.

ABSTRACT: *Port Said University uses decorative granite in its building supplied by the Egyptian industry. The qualitative and quantitative interpretation was carried out on the geological laboratory covered by Egyptian granitic countertops. Qualitatively, uranium anomalies are randomly oriented and spread all over the laboratory showing trapped radon gas which increases the indoor radon emissions. Quantitatively the measured activity concentrations of 232Th, 226Ra, and 40K recorded in the geological laboratory are higher than Faculty's yard which reaches 5, 3.5 and 4.5 times respectively. Radium equivalent, external hazard index and internal hazard index of Egyptian granitic countertops recorded 244.088, 0.659 and 0.965Bq/kg, respectively. The indoor absorbed dose rate calculated from the measured activities is 220 nGy/h. Also the average annual effective dose rate is 0.438 mSv/y which is very close to the average values of annual effective dose equivalent (indoor) of 450µSv/y. Consequently, the higher internal hazard index, absorbed dose rate, average annual effective dose rate of granitic countertops reflect the indoor exposure to radon and its daughter products which is mainly harmful on the occupancy and the increase of health risks to workers (professors, students and labors). Finally, the activity concentration index of geological laboratory is 1.832mSv/y which extremely exceeds 1 mSv/y. The Excess Lifetime Cancer Risk (ELCR) factor assessed during the present study on the basis of indoor annual dose was found to be $1.61x10^{-3}$, which is more than five times the world's average of $0.29x10^{-3}$. As a result, the activity concentration index and ELCR are also an alert about constructing decorative cover (granitic countertops) in laboratories as continuous attending place for humans such as in the Universities. As a confirmation of domination of radon in granitic countertops in geological laboratory as the most contributor and first responsible of the indoor exposure inside the geological laboratories, therefore the present study is expected to be helpful in creating baseline data and in setting standards on radiation exposure for natural series nuclides in locally produced granitic countertops.*

1- INTRODUCTION

The common level of radioactivity in building materials is one of the significant reasons for outer presentation to γ-rays. By the assurance of the radioactivity level in building materials, the indoor radiological danger to human wellbeing can be evaluated. Amid the most recent decades, there has been an expanding enthusiasm for the investigation of radioactivity in different building materials (Ravisankar et al., 2012). Natural stone discovers its way into homes and colleges as a component of the blocks, bond, sheetrock, floor and divider tiles, and in addition our beautiful heavy countertops. This stone is mined from the earth's crust in quarries, and after that made accessible to home developers, all through the world.

Late news stories have raised worries about the possibility of radiation originating from Egyptian granite countertops. Interest for rock countertops has expanded ten times over the previous decade particularly here in Egypt. As their popularity has developed, so have the sorts of granites accessible. Granites can incorporate various descendants radioisotopes that emit gamma rays with intensities powers and energies extending from around many keV to ~ 2.6 MeV. The utilization of such ornamental stones as building materials in a home can subsequently bring about the long haul entire body introduction of the inhabitants to this radiation (Llope, 2011).

It is workable for any granite sample to contain fluctuating groupings of uranium that can deliver radon gas, a source of alpha and beta particles and gamma rays. Some granite utilized for countertops may contribute differently to indoor radon levels. Some granite may transmit gamma radiation above regular background levels. While radiation levels are not regularly high, estimation from various granite sorts may uncover higher than anticipated levels on a case-by-case premise. Extraordinary consideration has been paid to deciding radionuclide concentrations in building materials in numerous nations (Al-Jundi, et al., 2009; Turhan, 2008; Mavi and Akkurt, 2010; Constantin et al., 2009; Kobeissi et al., 2008; El-Taher and Makhluf, 2010; El-Taher and Madkour, 2011; Konstantin Kovler, 2009; Pavlidou et al., 2006).

These gases frequently referred to as radon and thoron individually, decay into active product that can convey inner radiation dosages when breathed in (Steck, 2009). Radioactive radon gas gathers in encased spaces like underground mines or houses. Radon is a noteworthy patron to the ionizing radiation measurements got by the overall public (ICRP, 1993). Indoor exposure to gamma rays, basically dictated by the construction materials, is innately more noteworthy than outdoor exposure if materials from the earth are utilized for construction as granitic countertops. At the point when the span of inhabitance is considered, indoor introduction turns out to be considerably more critical (Merle and Enn, 2012).

The principle reason of potassium and uranium anomalies in the industrial zone in Port Said city, Egypt, is because of the aggregation of bits of granites, originating from a stone refine production line which is considered the primary provider of countertops in the city. This may demonstrate the artificial source containing traces of potassium and uranium (Attia et al., 2014).

Here in Egypt there are no principles or rules endorsing the satisfactory levels of radioactivity in granitic countertops. What's more, the health implications associated with radon and the lack of radiological data regarding the ornamental stone utilized as countertops in laboratories and inside university buildings, the objective of the present study was to gauge radon emanation from decorative-stone material using spectrometric methods.

Consequently, it is becoming an obligatory task for us to investigate the specific activity concentration of radionuclides in our university laboratories, in order to develop standards and to assess risks for its population.

The objective of the present study is to determine the specific radioactivity concentrations of natural radionuclides ^{232}Th, ^{226}Ra, and ^{40}K in granite countertops in laboratories, Port Said University. In order to measure the radioactivity concentration and estimate the radiation hazards from granitic countertops, there is a vital question, in all University policy buying decorative granite, is it safe? To answer of this question, it is a necessity of the university to pay attention for the ripped out installed granite countertops, and check if they have very high radiation measure or not, before planning to install. This depends on determination of the following: the specific radioactivity concentrations and the average radium equivalent activity (Raeq), total absorbed dose rate (D), external (Hex), internal (Hin), Annual effective dose rate (AED), Excess Lifetime Cancer Risk (ELCR) and gamma radiation (Iγr). These hazard indices have been estimated and compared with the recommended limits from the UNSCEAR report.

2. METHODOLOGY

The designed and regular stone slab samples investigated in the review are illustrative of embellishing stone generally made and imported to Port Said University, to use as countertops. The vast majority of the samples in the geological laboratory (Fig. 1) incorporated into the study had a single polished surface, comparable thickness, and densities of about 2.5-3.0 g/cm^3. A granitic countertop, expelled from a nearby home, was trisected and included in the study.

Spectrometric survey was conducted in the Faculty's yard (Fig. 2) the Faculty's building specially the geological laboratory (Fig. 8) and and utilizing gamma ray spectrometer (RS-230 BGO Super SPEC) (Radiation Solutions Inc., 2009). The field methodology for portable gamma ray spectrometry depends on the purpose of the survey and the environmental problem being investigated. The type of spectrometer, detector volume, measurement time (The samples were counted for a sufficiently long time (240secs) to reduce the counting error), and mode of measurement (ASSAY mode) depend on the radiation environment and the sort, volume and distribution of radionuclide sources (IAEA, 2003a).

The new (RS-230 BGO Super-Spec gamma beam) Spectrometer offers a coordinated plan with full climate insurance, substantial identifier, usability and the most noteworthy affectability.

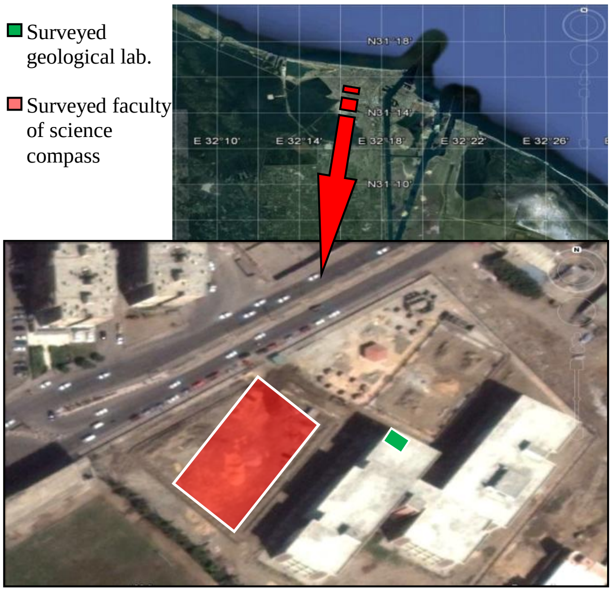

Fig. (1): The study area (Faculty of science, Port Said University).

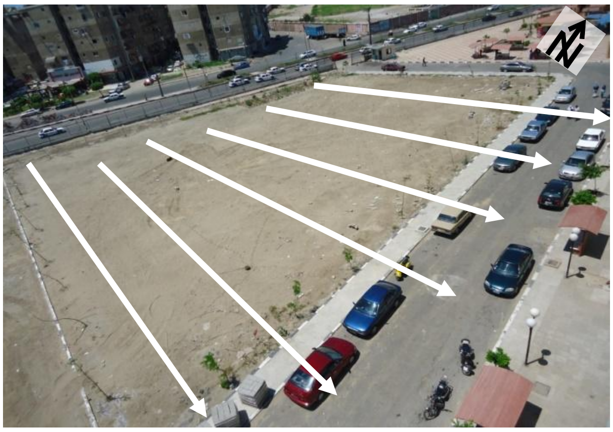

Fig. (2): Faculty of Science campus (Faculty's yard) and the seven spectrometric profiles.

With a 6.3cu INS BGO locator gives regularly 3x equal execution over similarly estimated Sodium-Iodide detectors. This unit offers clients a full assay capacity with inside information stockpiling and PC information recovery and show. The spectrometer records 1024 channels of ghastly information in the range 0−3 MeV, and utilizations self-balancing out to minimize spectral drift and that the K data is shown in % and the U and Th data in ppm. The RS-230 BGO spectrum stabilization system integrated inside the unit that uses the low radiation levels from surrounding geology to perform this analysis. In principle the system accumulates spectra internally while the system is powered ON and once a high enough level has been achieved then a complex analysis takes place to determine the correct spectrum position. This analysis results in an error measurement that the system uses internally to correct these effects. Note that this process is completely independent of the user. Typical Automatic Stabilization takes 5-10 minutes depending on local conditions. (Radiation Solutions Inc., 2009).

3. RESULTS AND DISCUSSION

3.1. Faculty's yard:

Above 70 stations were measured at Faculty's yard, along 7 parallel profiles striking in the NW-SE direction (Fig. 2). The profile separation was 10m and the station spacing was 7m.

Spectrometric contour maps:

The total count contour map of the Faculty's yard (Fig. 3) shows a relatively uniform radioactivity, ranging from 59.5 to 70.3 cps, there are no anomalies and no clear directon of increasing or decreasing radioactivity. The contour maps of Potassium, Uranium and Thorium concentrations of the Faculty's yard (Fig. 4, 5 and 6), show nearly the same weak radiometric print as total radioactivity ranging from (0.2 to 0.8%, 0.3 to 1.95 ppm and 0.6 to 3.4 ppm respectively) which are represented as the background for the three radioelements concentrations in the study.

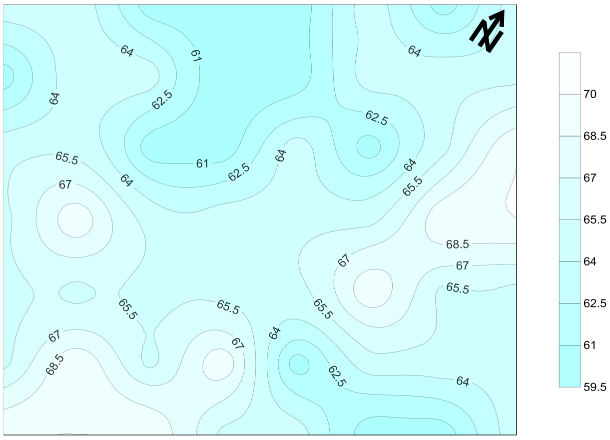

Fig. (3): Total count contour map Faculty's yard.

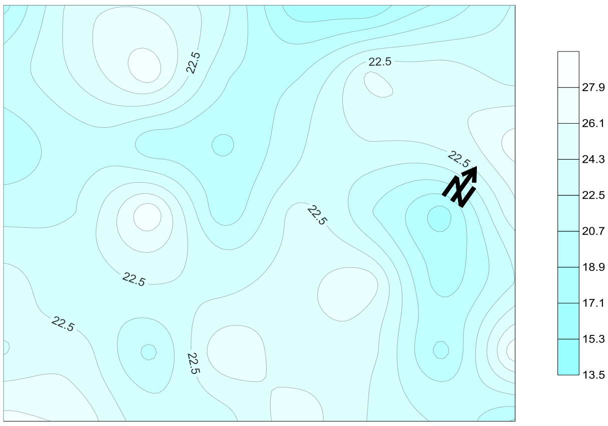

Fig. (4): Potassium concentration (%) contour map Faculty's yard.

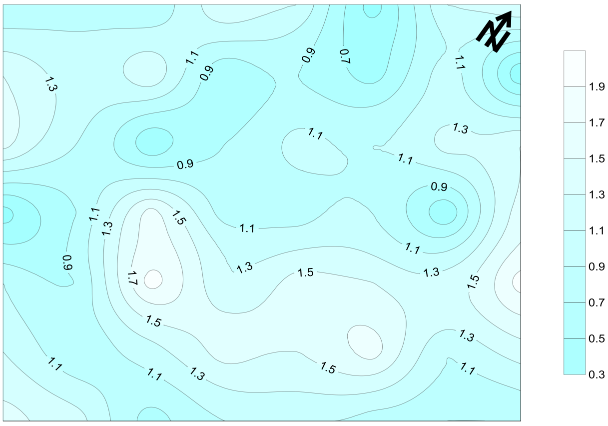

Fig. (5): Uranium concentration (eU) contour map Faculty's yard.

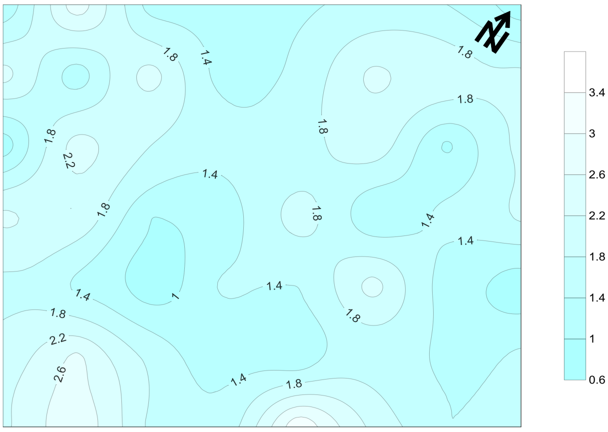

Fig. (6): Thorium concentration (eTh) contour map Faculty's yard.

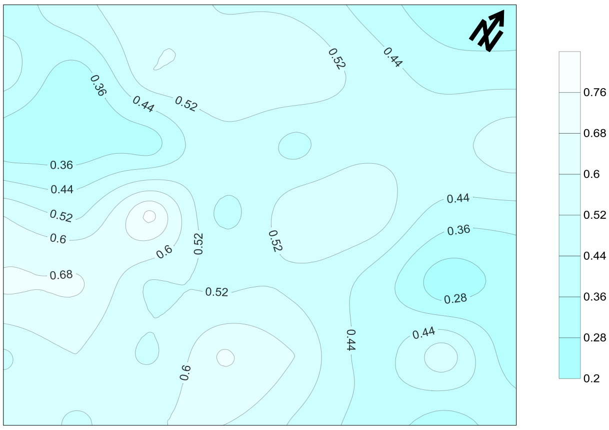

Fig. (7): Dose rate (nSv/h) contour map Faculty's yard.

3.2. Geological Laboratory:

The present study target was surveying the laboratory of geology department; faculty of science, Port Said University to quantify spectrometry after it was locked for four days (weekend-halts) in summer season.

Kobayashi (2006) stated that with beginning the ventilation demonstrates sudden decrease of radon concentration since its concentration in air is much lower in outdoor than in indoor. The laboratory contains 6 Aswan granitic slabs with dimensions 400 X 50cm and 10 granitic slabs with dimensions 400 X 40cm. More than 70 stations recorded, along 7 parallel profiles were directed in the E-W direction (Fig. 8). The profile separation was 90cm and the station spacing was 40cm. The lowest recorded readings in the potassium, uranium and thorium channels at the ground yard of the Faculty's building were considered to be the average background values. These readings were found as being 0.2%, 0.3ppm, and 0.6ppm respectively. The obtained data were contoured to give the following maps; total count (T.C.), K, U, Th and dose rate (DR).

Spectrometric contour maps:

T.C. contour map:

The T.C. map of the geological laboratory (Fig. 9) shows a range of radioactivity from 110 to 260 cps, which reflects the various material compositions that construct the laboratory which include Wood, metals, ceramic materials and granitic countertops. Three anomalous zones could be detected all over the Laboratory and their values are (260, 254 and 230 cps). These anomalies have the same direction; all are parallel and follow exactly the two studied granitic countertops.

Fig. (8): The geological laboratory and the seven spectrometric profiles.

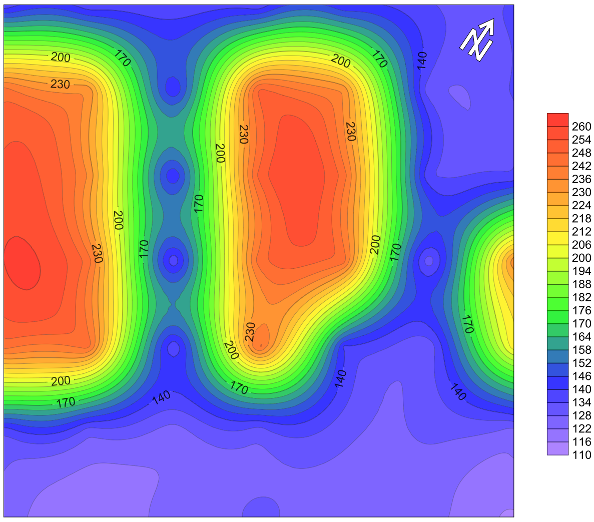

Fig. (9): Total count contour map of geological laboratory.

Potassium contour map:

The potassium contour map (K %), (Fig. 10) shows a wide variation from 0.6 to 3.6 %, which reflects the various material composition that construct the laboratory as mentioned before.

Potassium contour map, as one of the three main radioelement contributors is very similar to the total count map. Three anomalous zones could be detected all over the Laboratory and their values are (3.45, 3.15 and 2.65%).

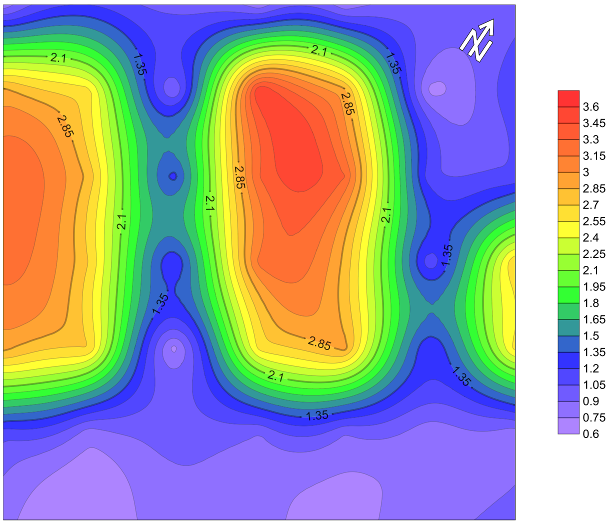

Fig. (10): Potassium concentration (%) contour map of geological laboratory.

These anomalies have the same direction; all are also parallel and follow exactly the two studied granitic countertops.

Equivalent Uranium contour map:

The uranium contour map (Uppm) of the geological laboratory (Fig. 11) shows values ranging from 1.4 to 8ppm. Uranium anomalies have different forms and randomly oriented in addition to the spread on all sides of laboratory rather than not taking the same form of studying granitic countertops as evident in (T.C. and K%) contour maps (Figs. 9 & 10). There are three merged closures and they occupy the same locations of studying granitic countertops. The values of the U anomalies are (7.4, 6.4 and 5.2ppm). According to the time of measurements (after locking the laboratory for 4 days), the radon gas (^{222}Rn) (disintegration daughter of ^{226}Ra in uranium decay series) escaped and was trapped which gave it the opportunity to increase the radioactive emissions recorded during measuring process.

Main reason of merging the anomalies related to the studying granitic countertops is the ventilation that contributes in spreading the emissions of indoor radon all over the laboratory. As mentioned by Jing Chen et al., 2010 who stated that utilizing materials with higher radon exhalation rates than the background, without ventilation the place, the radon levels would be raised.

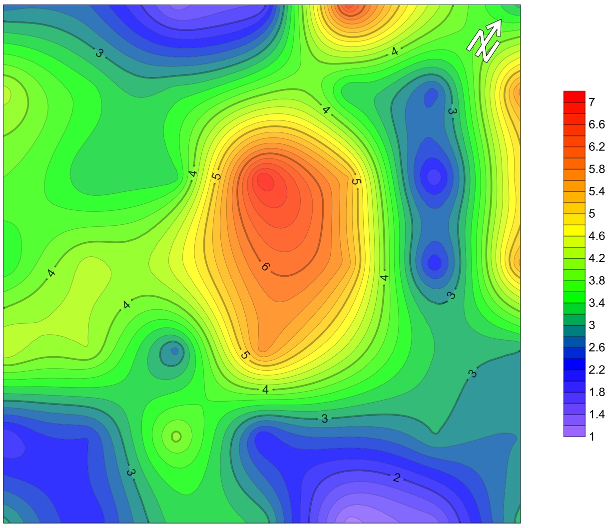

Fig. (11): Uranium concentration (eU) contour map of geological laboratory.

Equivalent Thorium contour map:

The thorium contour map (Thppm) of the geological laboratory (Fig. 12) shows values from 2 to 18ppm. Thorium contour map is very similar to the total count map of (T.C.) as one of the three main radioelement contributors. Three anomalous zones could be detected all over the laboratory and their values are (18, 14.5 and 14 ppm). These anomalies have the same direction; all are also parallel and draw exactly the two studying granitic countertops.

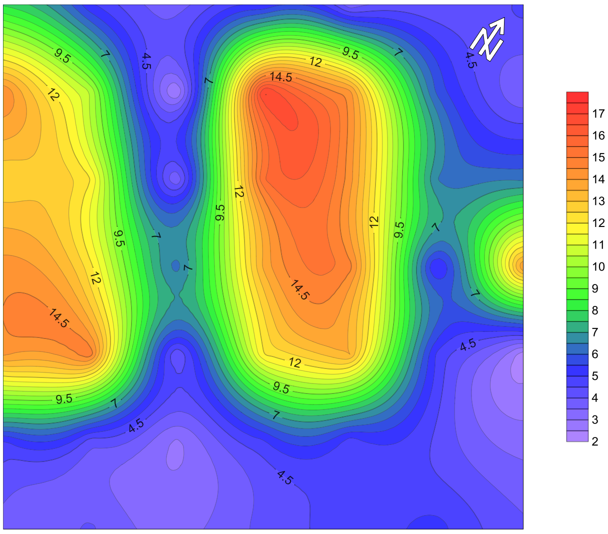

Fig. (12): thorium concentration (eTh) contour map of geological laboratory.

Dose rate contour map:

The dose rate map (DR) of the geological laboratory (Fig. 13) shows a radioactivity varying from 35 to 145nSv/h. Three anomalous zones whose values are (145, 130 and 115nSv/h). The three DR anomalies in the laboratory have the same locations in the four maps (T.C., K, U & Th), (Figs. 9, 10, 11 & 12) which confirm the response to the emitted radiations of the studying granite countertops.

The accuracy of the measurements (measuring time) is cleared in the best definition of boundaries of granitic slabs and the incomplete anomaly on the right side of the laboratory; its incompleteness because this part of the countertop was cut according to the laboratory design as shown in (Fig. 8).

Dose rate contour map (Fig. 7) which represents the field measurements of dose rate in Faculty's yard shows very weak radioactivity dose rate ranging from 13.5 to 27nsv/h compared with the dose rate contour map of geological laboratory (Fig. 13).

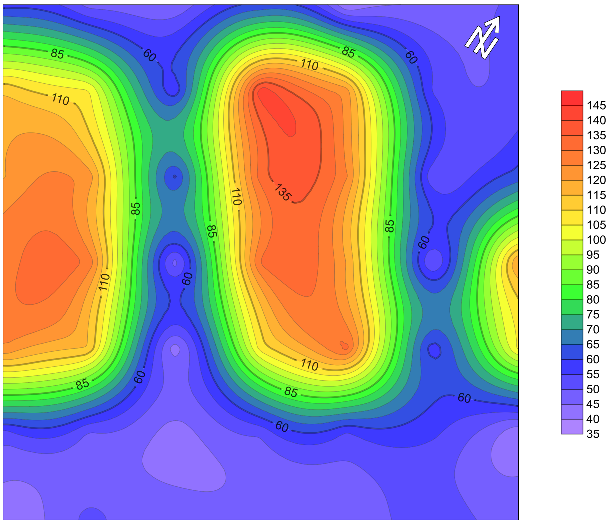

Fig. (13): Dose rate (nSv/h) contour map of geological laboratory.

Table (1) shows the measuring ranges of T.C., K%, U, Th and DR in the Faculty's yard and the geological laboratory containing granitic countertops according to qualitative description of radiometric maps (T.C., K, U, Th and DR).

To estimate the health risks, these qualitative studies should be reinforced by various hazard indices (quantitative studies).

Table (1): Measuring ranges of total count, potassium, uranium, thorium and dose rate in the geological laboratory and the Faculty's yard.

Location	TC in (cps)	K (%)	U ppm	Th ppm	Dose rate in (nSv/h)
Geological laboratory	110-260	0.6-3.6	1-7	2-17	35-145
Faculty' yard.	59.5-70.3	0.2-0.8	0.3-1.95	0.5-3.4	13.5-27

These quantitative studies include specific activity concentrations, the average radium equivalent activity (Raeq), total absorbed dose rate (D), external (Hex), internal (Hin), Annual effective dose rate (AED), Excess lifetime cancer risk (ELCR) and gamma radiation (Iγr). These hazard indices have been estimated and compared with the recommended limits from the UNSCEAR report.

3.3. Radioactivity indices:

Activity concentration:

The radioelement concentrations in ppm were transformed to activity concentrations in (Bq/kg) of the ^{232}Th, ^{40}K and ^{226}Ra radionuclides using the transformation components created by IAEA (IAEA, 2003c).

As indicated by common and maximum activity concentrations in natural building stones utilized for building materials in the EU (Mustonen et al., 1999), the maximum activity concentration of potassium recorded in the geological laboratory (1126.8 Bq/Kg) is 4.5 times of that recorded at the Faculty' yard (250.4 Bq/Kg) (Table 2), while its range from typical maximum activity concentrations is (640-4000 Bq/Kg).

Table (2): The activity concentrations of Potassium, Uranium and thorium of granitic countertops in geological laboratory and Faculty' yard:

Location	Max	Min	Mean	StDv
	Bq/Kg			
K-L.	1126.8	187.8	524.43	314.01
K–F.Y.	250.4	62.6	150.91	40.08
Ra-L.	87.68	16.05	46.5	14.6
Ra– F.Y.	24.7	3.7	14.48	4.84
Th-L.	69.42	8.93	31.26	18.87
Th–F.Y.	13.8	2.84	6.71	2.44

L.: Geological laboratory no. 1

F.Y.: Faculty Campus

The maximum activity concentration of Radium recorded at geological laboratory (87.68 Bq/Kg) is equal to 3.54 times of that recorded at Faculty's yard (24.7Bq/Kg), while its range from typical maximum activity concentrations is (60-500Bq/Kg), the maximum activity concentration of Thorium recorded at geological laboratory (69.42 Bq/Kg) is equal to 5 times of that recorded at Faculty's yard (13.8 Bq/Kg) (Table 2), while its range from typical maximum activity concentrations is (60-310 Bq/Kg), (Mustonen et al., 1999). As a result, the activity concentrations of K, Ra and Th measured in geological laboratory containing granite countertops show higher values than recorded at Faculty's yard which reach 4.5, 3.54 and 5times respectively. It is worth nothing that these maximum recorded values do not exceed the maximum activity concentrations in natural building stones used for building materials in the EU.

Radium equivalent activity (Ra_{eq}):

As suggested by the Organization for Economic Co-operation and Development (OECD), examination of the non-uniform distribution of radioactivity in materials containing K, Ra and Th has been made utilizing a typical index Ra_{eq}, representing both the total activity and furthermore the radiological hazard of the building materials. Ra_{eq} is characterized as the weighted sum of the activities of over the three radioelements (OECD, 2009). To assess the radiological risk of the granitic countertops used, it is helpful to figure the radium equivalent activity by equation no. (1), (Papadopoulos et al., 2010; Alharbi et al., 2011; Asgharizadeh et al., 2012; Thabayneh, 2013).

$$Ra_{eq} = (A_{Th} \times 1.43) + A_{Ra} + (A_K \times 0.077) \quad (1)$$

Where A_{Ra}, A_{Th}, and A_K are the activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, respectively. The calculated values of the radium equivalent Ra_{eq} for the studied granitic countertops are given in Table (3). Egyptian granites (geological laboratory) record radium equivalent (244.088 Bq/kg) higher than Indian granite and Chinese granite (241.20 and 127.8 Bq/kg respectively) and equal to Saudi granite (244.19 Bq/kg) and lower than the Turkish red granite (284.33 Bq/kg) (Mohamed et al., 2015 and Najam et al., 2013). Based on this criterion, it is observed from Table (3), that the Ra_{eq} values for the studied granitic countertops are lower than the recommended limiting value of 370 Bq/kg OECD (2009).

Table (3): Radium equivalent activity, External hazard index, Internal hazard index, Absorbed dose rate, Alpha-index, Annual effective dose rate, Excess lifetime cancer risk of geological laboratory:

Location	Ra_{eq} Bq/kg	H_{ex} Bq/kg	H_{in} Bq/kg	DR nGy/h	AED µSv/y	ELCR $x10^{-3}$
Geological laboratory	244.08	0.65	0.96	219.91	0.80	1.61

External hazard index:

The point in using these indices for granitic countertops is to place a limiting value on the dosage level (ICRP, 1990), with respect to that recommended by the International Commission on Radiological Protection (ICRP) report (Ghose et al., 2012; Kobeissi et al., 2013). Based on the presented formula, the index value would need to be less than unity (Ghose et al., 2012; Kobeissi et al., 2013; Alharbi et al., 2011) in order to limit the radiation risk to that for a dose of 1.5mSv/y. The external hazard index (H_{ex}) is given by following equation no. (2):

$$H_{ex} = A_{Ra}/370 + A_{Th}/259 + A_K/4810 \quad (2)$$

It is assumed that 370 Bq/kg of ^{226}Ra, 259Bq/kg of ^{232}Th, and 4810 Bq/kg of ^{40}K produce the same gamma-ray dose rate. The value of this index must be less than unity for the radiation risk to be negligible. The calculated values of the external hazard index (H_{ex}) for the studied samples are given in Tables (3) and Egyptian granitic countertops record H_{ex} (0.659Bq/kg) is higher than the Indian and Chinese granites (0.651 and 0.345Bq/kg respectively) and equal to the Saudi granite (0.659 Bq/kg) and lower than the Turkish red granite (0.767 Bq/kg). The values of H_{ex} for the studied granites countertops are less than unity (Mohamed et al., 2015; Najam et al., 2013).

Internal hazard index:

In addition to the external hazard, radon and its short-lived progenies also represent a hazard to the breathing organs. The internal exposure to radon and its daughter products is evaluated by the internal hazard index (H_{in}), which is given by equation no. (3) (Papadopoulos et al., 2010; Alharbi et al., 2011):

$$H_{in} = A_{Ra}/185 + A_{Th}/259 + A_K/4810 \quad (3)$$

For the safe use of a material in the construction of dwellings, H_{in} should be less than unity. The calculated values of H_{in} for the studied granitic countertops are very close to unity (Table 3), and H_{in} of Egyptian granites countertops record (0.965 Bq/kg), higher than all, Indian and Chinese granites and also Saudi and the Turkish red granites (0.868, 0.407, 0.791 and 0.818 Bq/kg respectively) (Mohamed et al,. 2015; Najam et al., 2013). It is important to take the higher value of the internal hazard index of granitic countertops which reached the criterion into account because it reflects the indoor exposure to radon and its daughter products. Indoor exposure becomes even more significant when it is the first responsible for the duration of occupancy and the increase of health risks to workers (professors, students and laboeers).

Absorbed dose rate:

The quantities generally used for estimation of external exposure due to terrestrial radionuclides are absorbed dose rate in air and annual effective dose. The absorbed dose rate in air expresses the received dose in the open air from the radiation emitted from radionuclides activity concentrations in the environmental materials. This factor is important and vital to assess when considering radiation hazard to a biosystem. The absorbed dose rate in indoor air due to gamma ray emission, DR (nGy/h) at 1m above the ground level owing to the concentration of ^{226}Ra, ^{232}Th and ^{40}K were calculated using equation no. (4) (Papadopoulos et al., 2010):

$$DR = 0.92A_{Ra} + 1.1A_{Th} + 0.08A_K \quad (4)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K (Bq/kg) respectively. The DR in indoor air calculated from the measured activities in Egyptian granitic countertops (220 nGy/h) in table (3), is lower than Indian and Saudi granites (237.19, 226.17 nGy/h respectively) and higher than Chinese and Turkish red granites (117.95 and 134.02 nGy/h) (Mohamed et al., 2015; Najam et al., 2013). The average indoor DR of Egyptian granitic countertops used in geological laboratory, Port Said University (119.12nGy/h) is about one and half times higher than the world average indoor absorbed gamma dose rate of 84 nGy/h (population weighted), as quoted in the UNSCEAR report (UNSCEAR, 2000). The higher average of DR of granitic countertops in addition to indoor exposure increase the probability of health risk on all bodies working inside the Faculty specially those who are close to the geological laboratories, because the absorbed dose rate is a measure of the energy deposited in a medium by ionizing radiation per unit mass.

Annual effective dose rate:

To appraise the yearly effective dose (AED), considered the conversion coefficient, (0.7SvG/y) from the absorbed dose in air to effective dose. The world average indoor and outdoor occupancy factors are 0.8 and 0.2, respectively (UNSCEAR, 2000). The average fraction of time spent indoor (occupancy factors) in geological laboratory are 0.6, 0.4 respectively. The effective dose rate in units of mSv/y was evaluated using the equation no. (5), (UNSCEAR, 1998):

$$Effective\ dose\ rate = DR \times 24\ h \times 365.25\ days \times 0.6 \times 0.7SvGy^{-1} \times 10^{-6} \quad (5)$$

Accepting a 60% occupancy factor, the corresponding indoor annual effective dose rates due to the radionuclides of granitic countertops extended from 0.229 to 0.809µSv/y, with a mean of 0.438µSv/y. This mean annual effective dose rate is also very close to the average values of annual effective dose equivalent (indoor) reported by (Orgunt et al., 2007) is 450µSv/y. So, it is affirmed that the annual indoor radon exposure effects from granitic countertops inside closed geological laboratories represent danger to laborers.

Excess lifetime cancer risk:

Excess Lifetime Cancer Risk (ELCR) manages the likelihood of developing cancer over a lifetime at given exposure level. It is displayed as an estimation of cancers expected in a given number of people on exposure to a carcinogen at a given dose. It is significant that an expansion in the ELCR causes a proportionate increment in the rate at which an individual can get cancer of the breast, prostate or even blood (Avwiri et al., 2013). Based upon figured estimations of annual effective dose, the ELCR was ascertained using the following equation no. (6), (Taskin et al., 2009);

$$ELCR = AEDE \times DL \times RF \quad (6)$$

where AED is the Annual Effective Dose, DL is the average duration of life (40 years) and RF (Sv^{-1}) is fatal risk factor per Sievert, which is 0.05 as per Sievert ICRP-60 for the public (Taskin et al., 2009). The ELCR factor assessed during the present study on the basis of indoor annual dose (E_{in}) was found to be $1.61x10^{-3}$ (Table 3), which is more than five times the world's average of $0.29x10^{-3}$. ELCR is also an alert about constructing decorative cover as granitic countertops in laboratories as continuous attending place for humans such as Universities.

Gamma activity concentration index:

Measured gamma activity concentrations from previous section were utilized to compute activity concentration index (Iγ) Because more than one radionuclide contribute to the dose, it is reasonable to present examination levels in the form of an activity concentration index. The activity concentration index should also take into account regular ways and amounts in which the material is utilized in a part of building. Keeping in mind the end goal to inspect whether the samples meet these limits of dose criteria, the representative level index, Iγ, used to evaluate the level of gamma radiation (γ) hazard associated with the natural radionuclides in particular examined granitic countertops, is defined by (Avwiri et al., 2013; Thabayneh, 2013; Mohamed et al., 2015). The following activity concentration index (Iγ) equation no. (7), is derived for identifying whether a dose criterion is met:

$$I\gamma = A_{Ra}R/150 + A_{Th}/100 + A_K/1500 \quad (7)$$

Where C_{Ra}, C_{Th}, C_K are the radium, thorium and potassium activity concentrations (Bq/kg) of the granitic countertops. The Iγ values in (Table 4) certify the results of dose rate maps, it is clearly noticed that the calculated activity concentration index of the Faculty's yard which represents (0.356mSv/y) less than the dose criterion used in a building 1 mSv/y (European commission, 1999), but for geological laboratory, with studying granitic countertops, the Iγ represents (Max: 1.832mSv/y) is higher than the Faculty's yard, and extremely exceeds 1 mSv/y and is higher than Egyptian granite sample analyzed by Shoeib and Thabayneh (2014) which is (1.57mSv/y).

Table (4): Gamma activity concentration index of geological laboratory and Faculty's yard:

Location	(Iγ) mSv/y		
	Max	Min	Mean
Geological Laboratory	1.832	0.502	0.927
Faculty's yard	0.356	0.177	0.264

The same results were obtained by the dose rate maps and certified through detailed high resolution analysis of the activity concentrations of radioactive nuclides (Table 4). In the mean time the gamma activity concentration index should be used only as a screening tool for identifying materials which might be of concern to be used as covering material (granitic countertops). According to this dose criterion, materials with Iγ ≤ 3 correspond to dose rates higher than critical value of 1 mSv/y, which is the highest value of dose rate in air recommended for population (UNSCEAR, 1993). Presently, there are no standards or guidelines prescribing the acceptable levels of radioactivity in decorative or other building materials in Egypt. As such, the present study is also expected to be helpful in creating baseline data and in setting standards on radiation exposure for natural series nuclides in locally produced granitic countertops.

Correlation coefficient of dose rate versus activity concentration index in geological laboratory and Faculty's yard (Fig. 14) demonstrate the strong correlation between dose rate and activity concentration index in geological laboratory, compared with that of the the Faculty's yard. First chart also confirms the domination of radionuclides in granitic countertops as the most contributor of the indoor exposure inside the geological laboratories. Conversely, the second chart shows that there is no definite source of radioactivity as resulted in radioelements and DR maps of Faculty's yard.

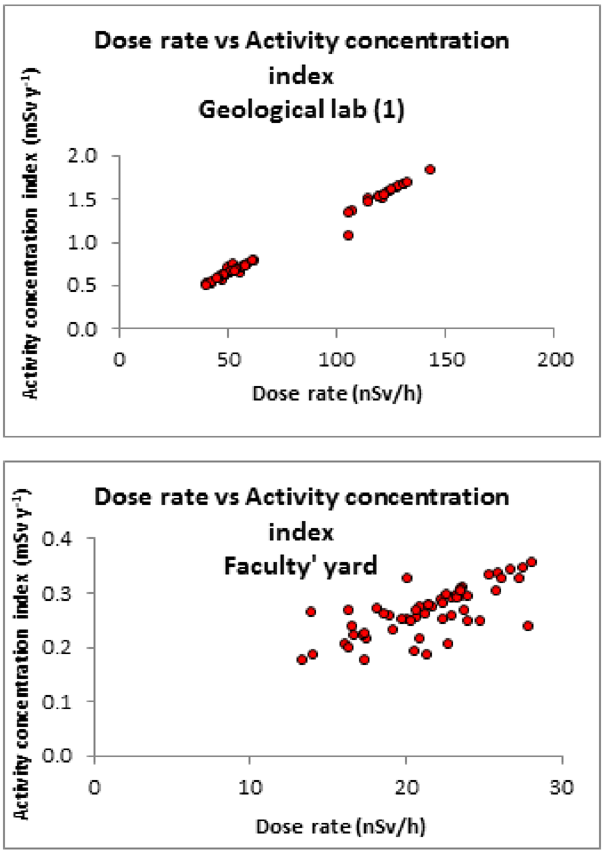

Fig. (14): Charts of dose rate versus activity concentration index in geological laboratory and Faculty's yard.

4. CONCLUSION

Qualitatively, uranium anomalies have randomly oriented forms in addition to their spread on all sides of laboratory while there are not taking the same form of studying granitic countertops was made clear in T.C. K% and Th contour maps. Accordingly, locking the laboratory for 4 days, the radon gas will escape and become trapped which gives it the opportunity to increase the indoor radon emissions recorded during the measuring process. T.C., K%, Th and DR maps of geological laboratory show two large anomalies which have same direction; both are also parallel and draw exactly the boundaries of the two studied granitic countertops in the geological laboratory. On the contrary, these maps of Faculty's yard show a relatively weak and uniform total radioactivity pattern.

Quantitatively, the activity concentrations of K, Ra and Th measured in geological laboratory containing granitic countertops show higher values than recorded at Faculty's yard which reach to 4.5, 3.5 and 5 times respectively. In addition the Ra_{eq} values of the studied granitic countertops are lower than the recommended limiting value of 370 Bq/kg. The average indoor absorbed dose rate of Egyptian granitic countertops used in the geological laboratory, Faculty of science, Port Said University (119.12nGy/h) is about 1.5 times the world average indoor absorbed gamma dose rate of 84nGy/h.

It is important to take the higher value of the internal hazard index of granitic countertops into account because it reflects the indoor exposure to radon and its daughter products. Indoor exposure becomes even more significant when it is the major responsible for the duration of occupancy and the increase of health risks to workers (professors, students and labors). The higher average of the absorbed dose rate of granitic countertops in addition to indoor exposure increase the probability of health risk on all bodies working inside the Faculty specially those who are close to the geological laboratories.

The activity concentration index is higher than the Faculty's yard and extremely exceeds 1mSv/y. The ELCR factor assessed during the present study on the basis of indoor annual dose, was found to be more than 5 times the world's average of ELCR and ELCR, is also an alert about constructing decorative cover as granitic countertops in laboratories as continuous attending place for humans such as in Universities.

Finally, the present study is also expected to be helpful in creating baseline data and in setting standards on radiation exposure for natural series nuclides in locally produced granitic countertops.

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