Radiation map for King Abdulaziz University campus and surrounding areas

Essam Aboud, Faisal Alqahtani and Helmy Osman Abolnaga

“Achieved by the Center for Geohazards, King Abdulaziz University, Jeddah, Saudi Arabia; “National Research Institute of Astronomy and Geophysics (NRIAG), Cairo, Egypt; “Department of Petroleum geology and sediments, Faculty of Earth Sciences, King Abdulaziz University, Jeddah, Saudi Arabia; “Nuclear Materials Authority, Cairo, Egypt

ABSTRACT
King Abdulaziz University (KAU) buildings are expanded to accept more students and research centers. Many of the new buildings were constructed using granitic rocks as building materials. Granitic rock contains radioactive elements (U, Th, K). These elements by time emit radiation which could affect human health. Surely, radiation dose depends on radioactive element percentage in the rock, open or closed area, radiation period, etc. When radiation occurs, gamma rays (or radon gas produced by the decay of U and Th) are detected everywhere causing damage in human body cells when being high. For the above-mentioned reasons, Geohazards Research Center, KAU surveyed the whole university campus and surrounding areas using gamma ray spectrometer in order to map the radioactive elements and estimate the dose rate. Results indicate that most of all university buildings have low dose rate while the new buildings have little high dose rate (3.46 mSv/y). These high values are due to the new granitic building materials covering the walls, floors, columns, ponds of agriculture. As the university staff are not staying their lives within the university, fewer hazards occur, but more safety recommendations should be taken into consideration.

1. Introduction
King Abdulaziz University (KAU) was officially established in 1967 as a private university in the western region of the Kingdom of Saudi Arabia. Seven years later, it was converted to be the only public university under the council of ministries of Saudi Arabia. During that time, the university buildings were constructed from limestone, sandstone, brick, natural stone, and concrete. Nowadays, the university campus is expanded in new buildings to accept more faculties, research centers, as well as students. The new buildings have used often granitic rocks in decoration for walls and floors. These rock types have radioactive elements in their contents and emit by time gamma rays which, if the dose rate radiation more than global radiation save limit (1mSv/y) according to (ICRP, 2000), it can affect the health of staff and students.

We are exposed daily to small amounts of radiation from natural sources of radioactive material. Much of this natural radiation comes from radioactive materials in building materials and in soil in the environment. Some building materials contain low levels of radioactive material. Building materials that are made up of sandstone, concrete, brick, natural stone, gypsum, or granite are most likely to emit low levels of radiation. The levels of radioactive materials found in building materials are very low. These low levels of radioactive material, and the radiation emitted by them, are unlikely to harm human health. In certain cases, radioactive radon gas may be released from building materials, herein, protection taken into consideration.

Based on the prior information, Geohazards Research Center (GRC), King Abdulaziz University (KAU) decided to measure the gamma radiation within the university campus to evaluate the radiation hazards. In that regard, we used the RS-700 gamma ray spectrometer system to survey the main university campus and surrounding areas. The RS-700 system is a carbon/airborne and marine spectrometer for radiation monitoring applications. It has advanced features; digital signal spectrometers, integrated GPS, gamma detector systems, and a specially designed Carbon-Fiber detector package construction. During the survey, the RS-700 was mounted on the top of the car (Figure 1) and recording was continuous while moving. More details about the system are in ‘Data source’ section.

The main campus of KAU is located among five provinces, Al Nassem, Abrouq Ar Rughamah, Al Sulaymanya, Al Fayhaa, and Al Jamiah province as shown in Figure 1. The surveyed area covered the main campus as well as the above-mentioned provinces to generate maps for radioactive elements such as Uranium, Thorium, and Potassium. Moreover, the radiation exposure rate is estimated to reveal radiation dose rate map.
The idea of gamma ray detection is not new; however, it is considered as the first trail in Jeddah city. Osman, Aközcan, and Kulali (2019) surveyed the university campus in Istanbul, Turkey, and estimated the annual dose rate within the campus area. Hedley, Roudier, and Peterson (2016) surveyed Dairy farm at Massey university, Auckland, in order to map the radioactive elements and their effects on the environment. Omori, Wakamatsu, Sorimach, and Ishikawa (2016) surveyed the Fukushima Medical University campus, Japan after the Fukushima nuclear power plant accident to create a map for gamma dose rate. Mohamed, Alghadi, and Al-Shamani (2016) measured the gamma ray in granite samples that are used as building materials within Al-Madinah Al-Munawarah, Saudi Arabia and concluded that the annual effective doses are comparatively lower. Al-Kawazini, Said, and Attaelmanan (2016) measured the background radiation within German Jordanian University, Jordan, and concluded that the background radiation in the Jordanian dwelling varies from one site to another depending upon the building materials used, type of building, ventilation and over which basin in Jordan they are located. Rehman, Islam, Rahman, Begum, and Ahsan (2014) surveyed the Atomic Energy Center, Dhaka, Bangladesh (AECB) for the environmental issue and health risk imaging. Sanderson, Cresswell, Hardeman, and Debauche (2004) studied the background radiation in Belgium using the airborne gamma ray survey.

In the current study, from 14 to January 16, 2019, we surveyed the university campus (~10 km²) using the RS-700 system. Primary results indicated that, within the university campus, the highest annual dose rate is 3.66 mSv/y in and around the new Faculties Buildings Zone, FBZ (e.g. Faculty of Sciences, Engineering, Marine Sciences, Earth Sciences, and Agriculture, Metrological, and Arid areas). For double check, on March 12, 2019, we re-surveyed the FBZ in more detailed using the same system and found that the dose rate is still in the high range (≥3.66 mSv/y). It indicates that the FBZ area has high radiation hazard and precautions should be taken into consideration.

2. Geology settings

The Kingdom of Saudi Arabia has two main rocks units, the Precambrian igneous and metamorphic basement, known as Arabian shield, and the sedimentary rocks known as the Arabian shelf. The Arabian shield covers most of the western part of Saudi Arabia representing one-third of the total country’s area (Al-Shanti, 2009). On the other hand, the Arabian shelf covers the eastern and northern part of the kingdom representing two-thirds of the total area of Saudi Arabia (Al-Shanti, 2009). The current study area is located within the western part of Saudi Arabia.

According to Moore and Al-Rehaili (1989), the stratigraphic sequences and rock units that characterized the area of King Abdulaziz University and surroundings have sedimentary and igneous rock types that can be distinguished from the geologic map. The university area is mainly constructed over recent sediments (e.g. Quaternary) as shown in Figure 2. The southern part is constructed mainly over sabakakh deposits. These rocks are represented by several formations started from the Precambrian age (e.g. Samran group represented by Misarrah formation which consists of chlorite to amphibolite schist, metabasalt, and meta andesite). Followed by Precambrian, uncertain affinity rocks are metagabbro and gabbro. The post tectonic intrusive rock includes the pre-kamil
suite intrusive rocks of Digbij complex is represented by diorite. Kamil suite of Qattanah complex is represented by massive hornblende, granodiorite to biotite monzogranite. The volcanic and metamorphic rocks of Quaternary age are covering most of the north and east portions of the study area. These rocks are arranged by old age as follows: Reef limestone and veneers of fossiliferous sand, followed by undifferentiated alluvial van sand and gravel deposits, eluvial, talus and eolian deposits. The recent sabakah deposits are formed in the south portion of the study area consisting mainly of sand and clay. The Quaternary alluvial deposits are abundant in the study area where the university and surrounding inhabited area are constructed (Figure 2).

3. Granites and radiation hazard

Due to its decorative appearance, granitic rock became a popular building material where it has various attractive colors. From a composition point of view, it contains naturally radioactive elements such as radium, uranium, and thorium. Gamma rays are derived from radionuclides belonging to $^{238}$U and $^{232}$Th series and $^{40}$K (basic radioactive elements of granites) that are present in the earth’s crust (UNSCEAR, 2017). These radionuclides origins emerge from the primordial radionuclides ($^{238}$U, $^{232}$Th) that have considerable long half-lives (Akkurt, 2009; Uyanik, Uyanik, & Akkurt, 2013; Aközcan, 2014; Akkurt, Uyanik, & Günçoğlu, 2015; Kara, Kara, & Akkurt, 2016; Çetin, Öner, & Akkurt, 2016; Demir, Kvırov, Üstün, Cesar, & Boztosun, 2017; Kara, Yildiz, & Akkurt, 2017; Seçkiner, Akkurt, & Günçoğlu, 2017; Günyay, 2018; Günyay, Saç, İçhefed, & Taşköprü, 2018a, 2018b). The radioactivity of granitic rock is differing according to their radioactive element contents.

Sometimes granite rocks contain radioactive elements more than others. When present, these radioactive elements will decay into radon gas that may be released from the granite rock over time. However, since granite is generally not very porous, less radon is likely to escape from it than from a more porous stone such as sandstone.

Releasing radon gas beneath homes soils is higher in risk than radon from granite building materials. Additionally, radon from granite rock (e.g. in kitchens or bathrooms) is likely to be diluted due to well ventilated. The risk of radon (half-life of 3.8 days) that it accumulates in a closed area or room and affects the populations, which increases the risk of cancer. Radon and smoking causing lung cancer but together chances of getting lung cancer are higher.

4. Data source

GRC has a mobile radiation survey system, RS-700. It is a self-contained spectrometer designed for mobile gamma ray detection. This system was configured to detect gamma ray radiation during the survey. The RS-700 system consists of two 4-l Sodium Iodide nobbled with Thallium (NaI) detectors, a Trimble GPS global positioning system (GPS), power sources, vehicle with trailer, RS 701 console multi-channel analyzer and a laptop computer for real-time gamma ray and GPS position monitoring as well as data collection (Figure 3).

The NaI detectors are rectangular prisms, 73.1 cm long by 16.2 cm wide by 17.2 cm high. The detectors are mounted on the underside of the trailer, approximately 27.5 cm from the ground surface and parallel to each other, with a 29 cm separation between the detectors. The long axis in the direction of travel, on the underside of a utility trailer pulled by a small utility vehicle, pulls the trailer. The NaI detector array on the trailer was towed at a target scan speed of 1 m per second. Data from each NaI detector and the GPS were collected on a field laptop computer equipped with the proprietary software to operate the detection equipment.
5. Results and interpretation

The quaternary sediments are differing in its radioactivity according to the source rocks. The output radioactive maps from the current study reflect these differences except the faculties area (e.g. Faculty of Sciences, Engineering, Marine Sciences, Earth Sciences, and Agriculture, Metrological, and Arid area) where buildings are lined/decorated with large quantities of pink granite which has high radiation content; however, they were built on low radiation deposits. Based on the radioactive anomalous map, the study area can be classified into five zones. Al Sulaymaniyah Province Zone (SPZ), Housing University Zone (HUZ), Faculties University Zone (FUZ), Al Fayhaa Province Zone (FPZ), and North University Zone (NUZ) as shown in Figure 4.

The Total Counts (TC) radiometric map (Figure 4) shows five local zones with different radioactivity anomalies. The high radioactivity value reaches >800 cps at the FUZ while the low value (56 cps) is at the NUZ. Table 1 shows the statistical treatments of radioactive elements distribution within the university and surrounding areas.

The inspection of the TC map reveals that the radioactivity can be classified according to the origin of the rock types before constructions. The FUZ is an exception where the high radioactivity is due to the pink granites that were used in the buildings, walls, floors, columns, etc. These granitic rocks increase the accumulation of radon gas inside the buildings and consequently increase the reading of gamma ray. On the other hand, HUZ, on the east, as well as SPZ, on the northeast, are constructed over granitic rocks. Consequently, these...
zones represent a relatively high radioactive value (290 cps). On the west, outside the university campus, FPZ is mainly constructed over Sabakhah deposits, these deposits accumulate the dissolved uranium minerals in water, which may relatively increase its radioactivity. The NUZ, northern KAU, represents the low radioactive province in the study area, where it still has no buildings or any human activities and it is covered with sediments derived from the northern part. The rest of the study area is characterized by undifferentiated alluvial fan sand and gravel deposits, and eolian deposits. These deposits have low radioactivity.

The measured gamma ray spectrometric data were treated statistically. The statistical analysis of the data includes, minimum (Min), maximum (Max), arithmetic mean (X), standard deviation (SD), and the percentage of Coefficient of Variability (CV) as shown in Table 1. The CV is determined as (SD/X) *100. The CV factor investigates the normality of the distribution of the data. If CV’s percentage is less than 100%, the unit exhibits a normal distribution (Sarma & Koch, 1980). When looking at Table 1, the highest CV value is 53.8% indicating the normal distribution of the data.

In addition to the above statistics, the Skew and Kurtosis values define the symmetry of the data and the distribution shape, which is either flatter or sharper than the normal distribution. For example, if the values of both are outside the range of −2 to +2, significant abnormality is expected in the data indicating that the data have not normal distribution (Sarma & Koch, 1980). TC histogram map shows that Skew is about 4.67 and Kurtosis is 35.1 indicating a significant abnormality in the data. We believe that this abnormality is due to the high values in and around the FUZ. Consequently, we have to make data zonation (e.g. SPZ, HUZ, FUZ, FPZ, and NUZ) and make statistics for each zone (Table 2).

### Table 1. Statistical treatments of the radioactive elements within King Abdulaziz University and surrounding areas.

| Statistical elements | TC (cps) | UC (ppm) | eTh (ppm) | K% | Exposure Rate (µR/hr) | Dose Rate mSv/yr |
|---------------------|---------|---------|-----------|----|----------------------|-----------------|
| No.                 | 402,297 | 402,297 | 402,297   | 402,297 | 31,812               | 402,107         |
| Min                 | 56.99   | 0.806   | 0.633     | 0.1635 | 1.008                | 0.0841          |
| Max                 | 817.7   | 23.61   | 31.34     | 15.73 | 43.94                | **3.66**        |
| X                   | 136.3   | 1.571   | 2.858     | 1.933  | 4.751                | 0.3598          |
| SD                  | 0.856   | 3.937   | 1.393     | 0.848  | 2.062                | 0.1717          |
| CV (%)              | 29.4    | 53.8    | 48.7      | 43.8   | 43.4                 | **47.72**       |

No. = Number of readings, Min = minimum, Max = Maximum, X = arithmetic mean, SD = Standard Deviation, CV = Coefficient of Variability.

| Faculty University Zone (FUZ) | Faculty University Zone (FUZ) | Housing University Zone (HUZ) | Housing University Zone (HUZ) | Sulaymaniyah Province Zone (SPZ) | Sulaymaniyah Province Zone (SPZ) | Northern University Zone (NUZ) | Northern University Zone (NUZ) | Fayhaa Province Zone (FPZ) | Fayhaa Province Zone (FPZ) |
|------------------------------|------------------------------|------------------------------|------------------------------|---------------------------------|---------------------------------|-------------------------------|-------------------------------|--------------------------|--------------------------|
| No.                          | 13,324                       | 26,477                       | 35,280                       | 40,142                          | 23,868                          | 23,868                        | 40,136                        | 23,868                   | 23,868                   |
| Min                          | 47                            | 95.79                        | 90.04                        | 150.1                           | 81.56                           | 81.56                         | 100.3                         | 81.56                    | 81.56                    |
| Max                          | 817                           | 210                          | 290.5                        | 40,142                          | 40,142                          | 40,142                        | 40,142                        | 40,142                   | 40,142                   |
| X                            | 136.3                         | 259                          | 173.8                        | 21.91                           | 21.91                           | 21.91                         | 21.91                         | 21.91                    | 21.91                    |
| SD                           | 0.856                         | 0.495                        | 0.495                        | 0.5945                          | 0.5195                          | 0.5195                        | 0.5195                        | 0.5195                   | 0.5195                   |
| CV (%)                       | 29.4                          | 29.4                         | 29.4                         | 29.4                            | 29.4                            | 29.4                          | 29.4                          | 29.4                     | 29.4                     |

Table 2. Statistical treatments of the radioactive elements within FUZ, HUZ, SPZ, NKZ, and FPZ.

| Statistical elements | TC (cps) | UC (ppm) | eTh (ppm) | K% | Exposure Rate (µR/hr) | Dose Rate mSv/yr |
|----------------------|---------|---------|-----------|----|----------------------|-----------------|
| No.                  | 402,297 | 402,297 | 402,297   | 402,297 | 31,812               | 402,107         |
| Min                  | 56.99   | 0.806   | 0.633     | 0.1635 | 1.008                | 0.0841          |
| Max                  | 817.7   | 23.61   | 31.34     | 15.73 | 43.94                | **3.66**        |
| X                    | 136.3   | 1.571   | 2.858     | 1.933  | 4.751                | 0.3598          |
| SD                   | 0.856   | 3.937   | 1.393     | 0.848  | 2.062                | 0.1717          |
| CV (%)               | 29.4    | 53.8    | 48.7      | 43.8   | 43.4                 | **47.72**       |

No. = Number of readings, Min = minimum, Max = Maximum, X = arithmetic mean, SD = Standard Deviation, CV = Coefficient of Variability.
The distribution of radioactive elements (equivalent Uranium (eU), equivalent Thorium (eTh), and Potassium (K$^{40}$)) is displayed in Figure 5, 6, and 7 respectively. However, the three radioactivity maps (eU, eTh, and K$^{40}$) are correlated with the Total Counts (TC) map, they have differences in the distribution of their radioactivity.

6. Exposures and dose rate of radiation

Exposure radiation is the measure of ionization of air due to ionizing radiation (e.g. gamma rays). It can be calculated from the measured gamma ray using the following expression (Abuelnaga & Al-Garni, 2015; IAEG, 1991; Seligman, 1992a, 1992b)

$$\text{Exposure rate (\mu R/hr)} = 1.505 \times K(\%) + 0.653 \times \text{eU (ppm)} + 0.287 \times \text{eTh (ppm)}$$  (1)

Calculated exposure rate from Equation (1) comes only from radioactive sources in the earth and does not include cosmic ray component or any cesium fallout on the ground (Miftah et al., 2018). For simplicity, the dose rate which is defined by the quantity of radiation absorbed per unit time can be calculated from the exposure rate as below (IAEA, 1979):

$$\text{Dose rate (mSv yr^{-1})} \approx 0.0833 \times \text{exposure rate (\mu R/hr)}$$  (2)
The radiation dose rate of the study area is displayed in Figure 8. The dose rate map of the study area shows that there is a high dose rate in the FUZ (3.66 mSv/y) where the more granitic materials exist. The calculation of the dose rate helps to identify the areas with radioactive hazard. The European Council Directive (2013) reported that the level of indoor external exposure to gamma radiation due to building materials should be less than 1 mSv/y, (Quintana et al., 2018). This dose rate associated with the local geology of the sites (Furukawa & Shingaki, 2012).

Table 2 allows us to classify the distribution of the dose rate according to the standards of the International Commission on Radiological Protection (ICRP) regulations in terms of percentage as shown in the diagram of Figure 9. It indicates that the FUZ has percentage of dose rate as 53.18% indicating that this area is in radiation risk, where most of FUZ province has dose rate radiation exceed the global radiation limit (1mSv/y) but below the occupational exposure limit which is 20 mSv/y.

7. Conclusions
The current study, radiation map for King Abdulaziz University and surrounding areas, shows that there is a little high dose rate (>3.5 mSv/y) in and around the new faculties buildings of the university while the rest of the area has dose rate of radioactivity less than 1 mSv/y. It reflects safe side radiation dose rate in/around the university campus with an average value of 0.714 mSv/y. This value matched with the international slandered level.
as the recommendation of the International Commission on Radiological Protection (ICRP, 2000). The exception of these is the faculties area (FUZ), where it reflects some high level for radiation dose rate. Most of this province has radiation dose rate exceeds the global radiation recommended limit (1mSv/y) but below the occupational exposure limit which is 20 mSv/y (Radiation Safety Regulations, 2006). From the current study, we recommend the following actions to be taken into consideration:

(1) Measuring of radon concentration in the closed rooms and halls.
(2) Review indoor ventilation conditions and solve their problems.
(3) Periodic checks should be made on the exposure pathways.
(4) General information should be available for public to reduce their doses.
(5) Individual monitoring and training should take place.
(6) The individuals must know the risk of radon accumulation and its effects on health.

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ORCID

Essam Aboud http://orcid.org/0000-0002-1087-1059

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