The Assessment of Environmental Radioactivity in Haqal Village in Saudi Arabia and its Impact on Public Health

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Abstract – *The senior project study aims to monitor Environmental Radioactivity (ERA) within Heqal village, located in a high background radiation area. The research includes measuring radiation levels in air, water, sand, and granite in the village's region using a Geiger counter and other radiation detection apparatus. The collected data was analyzed to ascertain the village's radiation exposure levels. The significance of this research is that it helped identify potential sources of radiation exposure that may have contributed to the village's elevated cancer rate. The study provides decision-makers and public health officials with essential information for developing strategies to reduce radiation exposure and prevent future cases of cancer in the kingdom. We collected various samples from several locations at the village, including residential areas, agricultural fields, and water sources, using chemical separation techniques to analyze their radioactive content in the laboratory* **[1]**. *The results of this study contribute substantially to understanding villages worldwide with high incidence rates of cancer and to informing future radiation monitoring and management strategies in comparable communities. The results of one of the granite rocks samples showed specific activity of the Potassium-40, at 1703 Bq/kg, which is five times higher than that found in Qassim, Saudi Arabia for the Potassium-40* **[2]**. *The overall potential sources of the radiation exposure are identified, and the effective prevention strategies are devised, making this study is a crucial step towards enhancing public health outcomes in Saudi Arabia.*

Keywords: Radiation dose rate, Granite, Soil, Radon, Adham, Natural radioactivity

I. Introduction

Both ecology and human health can suffer in the presence of radioactive materials. To protect individuals and the environment, it is crucial to monitor and control the levels of radioactivity in the environment. One method for monitoring this is through radiation detection and analysis of granite rocks, soil, and water. This monitoring provides information that can be utilized to assess potential risks associated with exposure to radioactive elements and to develop mitigation plans. In order to determine whether there is a connection between the high cancer rates reported in the region [3] and radiation exposure rates in Haqel, our inquiry will examine the ambient radiation exposures in the region.

As we continue to rely on technology, it is crucial that we understand the impacts of radiation on our surroundings and take the necessary precautions to minimize its negative consequences. Our study may contribute to the development of knowledge and comprehension of radiation harm. This paper will identify possible radiation exposure sources and provide important information on the level of contamination. It will also help determine whether existing safety regulations successfully protect public health. The report includes information on the methods used, the results of the study, and any recommendations.

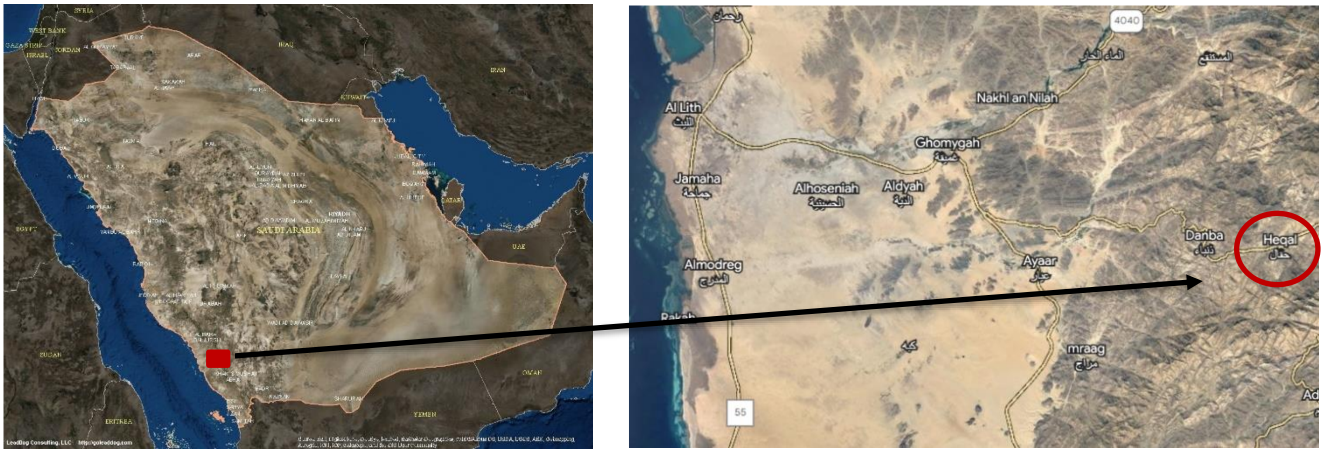

Fig.1 Studied area.

II. Literature Review

Radiation exposure is typically measured in millisievert per year (mSv/year). Granite rocks are known to contain high levels of gamma-emitting uranium, thorium, and potassium, which can have detrimental effects on the environment **[4]**. Moreover, radon gas, which is produced from the decay of uranium and thorium, can enter buildings and pose health risks to occupants **[5]**. In a study **[6]**, the potential risks associated with exposure to radioactive elements were investigated in the Adham Governorate, southwest of Saudi Arabia. The study found that granite rocks support Haqal and that high granite mountains in the region are affected by rain, which can cause uranium to pollute water, pasture, and agriculture. The study determined the uranium, thorium, and potassium contents of wells in the region and calculated the radiation exposure. The study found that Haqal had a radiation exposure of 1.56 mSv/year **[6]**. The researchers also tested 17 drinking water wells for radon and found that the radon concentration in most wells in Haqal exceeded the international limit by approximately six times.

III. Problem Statement

Our current study aims to assess the potential health risks associated with radiation exposure in the Haqal area, where an abnormal number of cancer cases have been reported [3]. Specifically, we aim to measure the levels of radioactivity in the area and identify potential sources of radiation, including gamma-emitting uranium, thorium, and potassium, as well as radon gas. By providing accurate and detailed information on the sources and levels of radiation, we hope to help policymakers and public health officials develop effective mitigation strategies to protect the health of the local population. Our study will contribute to a better understanding of the environmental and health impacts of radiation exposure in the Haqal area and provide valuable insights for future research and policy decisions.

IV. Study Methodology

In this section, the process that was followed during the study to collect samples and data, as well as to analyze it, will be explained.

IV.A. Sample Collection and Preparation

To collect water samples, six locations were selected in the research region, and two samples were taken from each location. Two different methods were used to collect the samples for radioactive analyses [7]. The first method involved taking water samples by filling cleaned containers, using a numbering system, to detect gross alpha and beta particles. The second method involved using Optiphase Supermax cocktail in vials to detect radon gas. The cocktail was prepared in sterilized vials, and a sample was taken from a pipe without exposing the water to air except the fourth sample, which, unfortunately, was not possible to extract without exposing to air. To prevent the loss of radon gas, the vial was carefully filled with 8 milliliters of water sample. To preserve water samples, the vial was placed in a freezing-resistant container with ice.

Fig.2 Samples locations.

The container was sealed to prevent leaks and damage. The container was transported quickly to the destination, then the samples were stored in the fridge until the next stage of the experiment, which involved analyzing the samples the following day.

Meanwhile, ten soil samples were collected using a shovel and plastic bags. A 3-4-inch-deep hole was dug, the top layer was scraped off, and the samples were placed into plastic bags as a representative set [8]. Five granite rocks with high exposure rates, containing Uranium Thorium and Potassium, were extracted with the assistance of a geologist [9]. Six samples were collected from Haqal area, and the chunks were placed in double-layered bags. The samples were numbered and stored using the same procedure as the soil samples.

IV.B. Background Radiation Assessment

The background radiation levels were measured using SPIR-Ident Mobile [10] during the samples' collection. To determine the level of radiation exposure in Haqal village, a radiation examination was performed. During the mission, a Getac V200 rugged laptop was utilized to assess the SPIR-Ident Mobile data and locate the location samples.

IV.C. Radioactivity Analysis

The groundwater wells and drinking water supplies were monitored using the gross alpha (α) and gross beta (β) screening technique [11], which identify whether there is a need for analysis or action. A 50-milliliter (mL) aliquot was filtered using a 100-mL conical flask, heated at 60 degrees Celsius (°C) for 40 minutes, and then transferred to a 20-mL polyethylene liquid scintillation vial. The sample was cleared by vigorous shaking and the addition of a general-purpose liquid scintillation cocktail. Also control samples were prepared, and two samples were analyzed: a standard sample consisting of 12 mL of cocktail and 8 mL of distilled water, and a pure α-emitter (Americium-241 or ^{241}Am) containing 2 disintegrations per minute (dpm) of β-emitter (Potassium-40 or ^{40}K) in equilibrium with its daughter Yttrium-90 (^{90}Y). Finally, the samples were cooled for three hours before they were counted using the 1220 ultra-low-level liquid scintillation detector [7] to detect only the energy radiation. The device efficiency (E) in Eq. 1 and specific activity (A) for gross α or gross β are calculated after counting the samples and the control samples using Eq. 2 [12].

$$E = \frac{C_{st} - B}{60 \times A_{st}} \tag{1}$$

$$A\left(\frac{\text{Bq}}{\text{L}}\right) = \frac{C_{sa} - B}{60 \times E \times v} \tag{2}$$

Note that C_{st} is the count rate stander (in counts per minute or cpm) while B is the blank sample count rate in the same counting window (cpm). The spiked activity (in Becquerels or Bq) is A_{st}, while C_{sa} is the count rate of the sample (cpm), v is the sample size (L), and E is the device efficiency.

A clear water sample was prepared in a polytetrafluoroethylene- (or PTFE-) coated scintillation counting vial with mineral oil, and radon was extracted into the organic phase. The sample was stored in an ice-filled thermos bottle for transportation to the laboratory [7]. Laboratory samples were prepared, including standard and blank samples, and were measured with the prepared batch.

Secular equilibrium was reached by the Ra-226 standard with its direct daughter Rn-222 and short-lived radon progenies (Po-218 and Po-214). At equilibrium, the activity concentration of Rn-222 is equal to that of Ra-226. The samples were cooled and counted using the 1220 ultra-low-level liquid scintillation [13] counter with α/β separation counting mode. Partially resolved peaks from Rn-222 and Po-218 were observed in the spectrum, indicating a total counting efficiency of 300 percent. Potentially disruptive radionuclides were found to have remained in the aqueous phase, and the extraction of Rn-220 was observed to have been extremely short lived, lasting only 55 seconds, using Eq. 1 to calculate the device efficiency (E) and Eq. 2 to calculate Rn-222 specific activity (A) above.

The soil samples were dried by placing them in a vacuum drying oven at 200°C for an hour to remove all moisture and prepare the samples for analysis. Furthermore, the rock samples were ground using a Powder Rock Grinding Mill. When the recording of the weight of the rock sample was completed by then, the ground powder was collected in a clean container and labeled with the sample name and date and stored for 30 days in order to reach secular equilibrium.

For the soil and rock samples, the 500 mL volume was measured, then the sample was transferred to a clean beaker. The weight, quantity, and date of each sample were recorded. The detection material of a High Purity Germanium (HPGe) radiation detector is a pure germanium crystal [14], and when gamma rays interact with the crystal, they create an electrical signal that is amplified and analyzed to determine the energy and type of the gamma rays. After doing this, the detector enclosure was completed. When the Marinelli beaker was positioned within the detector in the crystal's center, and the detector well was sealed to prevent light from penetrating the detector, the Gamma Acquisition and Analysis software was activated to ensure that all parameters, including detector type, energy range, counting time, and calibration, were accurately configured. By setting the timer for 86,400 seconds (24 hours) and starting it, the counting procedure was then completely initiated. Periodically, the process was observed to ensure that there were no fluctuations or interferences.

For the Spectrum Analysis, the data was preserved, and the software was utilized to examine the gamma spectrum and to identify any irregular peaks. The net counts, intensity, and energy of each peak were calculated by magnification and emphasis processes. Finally, the detector efficiency for each energy was calculated. The analyzing system utilized a standard reference source with a known specific activity of a gamma-emitting isotope, and the efficiency was calculated by the analyzing system. Lastly, the specific activity (SA) was calculated using the intensity of each energy, as in Eq. 3, and then the average specific activity for each sample was determined.

$$SA(\frac{Bq}{kg}) = \frac{A}{E \times I_s \times m} \quad (3)$$

Note that A is the activity in Bq, I_s is the intensity of each energy, E is the device efficiency, and m is the mass of each sample in kilograms (kg).

V. Results

The detection of the gross alpha (Table I) and gross beta (Table II) radiation in the water samples is an essential step in determining the quality of water. The gross alpha radiation is produced when radioactive isotopes, such as radium, uranium, and thorium, decompose in water. The gross beta radiation is produced when radionuclides emanate beta particles. If the radiation level exceeds the regulatory agencies' acceptable limit, it poses a risk to human health.

In this instance, the liquid scintillation analysis revealed that the samples have not exceed the accepted limits of the gross alpha and gross beta limits of 0.5 and 1 (Bq/L), respectively, according to World Health Organization (WHO) [15]. This is a significant result because it indicates that the water sample is safe for agricultural and potable applications. In addition, the water is safe for human consumption in terms of gross alpha and gross beta.

Table I Haqal water gross α results

Sample	Gross α(Bq/L) ± Ɛ
1	0.395±0.109
2	0.020±0.106
3	0.227±0.125
4	0.076±0.119
5	0.359±0.130
6	0.311±0.128

Table II Haqal water gross β results

Sample	Gross β(Bq/L) ± Ɛ
1	0.263±0.743
2	0.154±0.743
3	0.278±0.762
4	0.154±0.751
5	0.793±0.774
6	1.086±0.779

The study findings demonstrate the significance of routinely monitoring water sources for radon, particularly in areas where high levels of radon are known to exist. As shown in Table III, the radon levels have exceeded the acceptable limit according to United States Environmental Protection Agency (EPA) report which is 11.1 (Bq/L) [16]. Furthermore, it highlights the importance of implementing proper water treatment methods [17], such as ventilation, to reduce radon levels to tolerable levels. Additionally, elevated radon levels in potable water are cause for concern because they may increase the risk of lung cancer and other health problems.

Table III Rn-222 in Haqal water results

Sample	Rn-222 (Bq/L) ± Ɛ
1	10.103±0.553
2	20.276±1.077
3	0.510±0.077
5	19.460±1.035
6	51.349±2.680

For the soil samples result, shown in the Table IV, the greatest and the average specific activity of Uranium-238 that was found are around 23 and 15 Bq/kg, respectively, while the average in an area such Qassim area, Saudi Arabia is 31 Bq/kg [18]. In addition, the range of Thorium-232 found in Qassim was from 13 to 49 (average 31) Bq/kg [2], yet the greatest and the average specific activity in our study of Thorium-232 are 46 and 18 Bq/kg, respectively.

Potassium-40, on the other hand, Qassim has specific activity ranged from 64 to 340 (average 202) Bq/kg [2], but the highest and the average specific activity levels that were identified in our study are 883 and 504 Bq/kg, respectively. Potassium-40 levels are higher than typical activity range found in Qasim.

Note that the normal range of the Naturally Occurring Radioactive Materials (NORM) that were observed during the study were actually in deep soil, our findings were 3–4 inches deep. On the basis of our findings, the radioactivity in the soil is thought to be around average comparing to Qassim in terms of uranium and thorium; nevertheless, the radiation emanating from potassium might be dangerous given that some of the samples surpass the normal level seen in soil.

Table IV Soil summary

	Specific activity (Bq/kg)		
NORM	Haqal's greatest	Haqal's average	Qassim's average
^{238}U	24	15	31
^{232}Th	46	18	31
^{40}K	883	504	202

As shown in Table V, the greatest and the average specific activity of Uranium-238 in the granite rocks that were collected are around 45 and 30 Bq/kg, respectively, whereas in Qassim, the series of Uranium-238 average specific activity was found to be 23 Bq/kg [2]. And the average specific activity level of Thorium-232 found in Qassim's granite was 30 Bq/kg [2], where the maximum and the average specific activity of Thorium-232 found in Haqal's granite, was 59 and 45 Bq/kg respectively.

Potassium-40, on the other hand, has an average specific activity level of 340 Bq/kg found in Qassim [2], but the highest and the average specific activity levels that were measured are 1703 and 1048 Bq/kg respectively. The two values are much greater than the ordinary range found in Qassim. Consequently, the levels exceeded the standard NORM, which indicates that they might have been unsafe in terms of the Potassium-40.

Table V Granite rocks summary

	Specific activity (Bq/kg)		
NORM	Haqal's greatest	Haqal's average	Qassim's average
^{238}U	45	30	23
^{232}Th	59	45	30
^{40}K	1703	1048	340

As shown in Table VI, the maximum and average dose rate detected are 0.1 μSv/h and 0.086 μSv/h, respectively, which are equivalent to 0.8766 and 0.753 mSv/year, respectively. These amounts of background radiation are considered safe since they did not excess the dose limit specified for public health according to ICRP Publication 82 [19], which is 1.0 mSv/year. While in Literature Review the dose rate was 1.56 mSv/year**.** Therefore, this difference between the Literature Review and our results may be explained by the lack of Haqal coverage in our study.

Table VI Haqal background evaluation

Measurement	Value
Maximum dose rate	0.1 μSv/h
Average dose rate	0.086 μSv/h
Maximum counts	1641cps
Average counts	1509 cps

However, at location 48, shown in Fig. 3, the dose rate started to increase but we were not able go farther to where the dose rate was increasing due to lack of authorization. The increase in dose rate at location 48 may be attributed to the presence of a nearby uranium or other sources of natural radiation. Further investigation would be necessary to determine the cause of this increase and assess any potential health risks. It should be noted that due to the limited scope of this study, the findings presented here are not necessarily representative of the entire region and further research may be necessary to fully assess the radiation levels in the area.

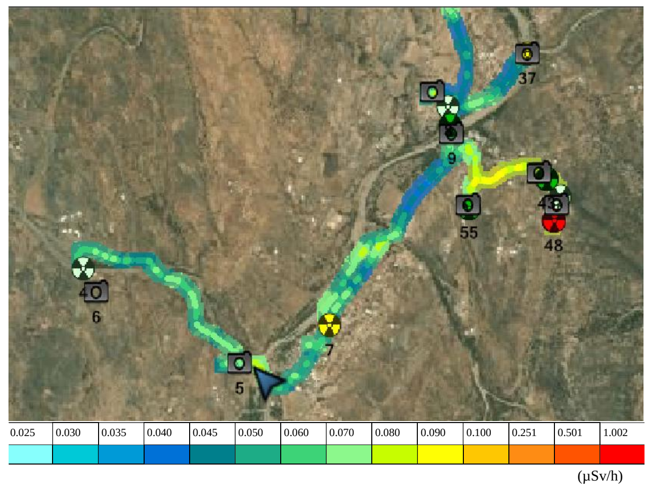

Fig. 3 The dose rate map of Haqal

VI. Conclusions

The findings of this study demonstrate the importance of continued monitoring and evaluation of environmental radioactivity in the Saudi Arabian village of Haqal. The investigation revealed an absence of gross alpha and gross beta radiation in the water sample, indicating that the water from the same source may be utilized for various purposes without any risks. However, the study also identified areas that have the potential to exceed safe radiation limits, which underscores the need for ongoing monitoring and evaluation to ensure that radiation levels in Haqal remain within acceptable ranges.

The practical implications of these findings are significant for policymakers, public health officials, and other stakeholders. The study highlights the importance of raising awareness about the dangers of drinking water with high radon levels and the need for monitoring water sources for harmful contaminants such as radon. Additionally, the findings emphasize the necessity of performing routine evaluations of environmental radioactivity in the region to quickly identify and resolve any possible hazards to public health.

Furthermore, the study fills a gap in the existing literature on environmental radioactivity in the region and provides valuable insights into the potential health risks associated with drinking water from certain sources. The high levels of Potassium-40 [20] identified in the study also require further investigation to fully understand its potential health effects. For example, the Rad-7 monitoring can be employed for identifying other possible sources of radon contamination.

Overall, the study's findings demonstrate the significance of scientific investigation in comprehending and addressing issues pertaining to public health. By taking the necessary steps to monitor and evaluate environmental radioactivity in the region, policymakers and public health officials can effectively safeguard public health and prevent potential hazards.

Our recommendations for future work include conducting further research into the causes and potential health risks associated with high levels of Potassium-40 in the region. To ensure that the radiation levels in Haqal continue to remain within acceptable ranges, it is crucial to keep observing and evaluating the village. As well as ventilation the water before drinking it since it has high levels of radon.

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