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Evaluation of Natural Radioactivity and Trace Elements in some Yemeni Rocks

A Thesis for

M.Sc. Degree in Physics

By

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Abstract

In this study, ١٤ rock samples were collected from different sites in Yemen (Ma'rib, Al Jawf, Sana'a, Dhamar, Amran, Ibb, Al Bayda and Al Dalea). The samples were prepared for two gamma-ray techniques (passive and active techniques), natural radioactivity and neutron activation analysis.

For natural radioactivity, samples were prepared to be measured by HPGe. Samples were crushed. A ١٠٠ cc of each sample was put in a plastic container and sealed well. Sealed containers were kept for at least one month for secular equilibrium. HPGe detector with efficiency of ٣٥٪ and ١.٩ keV resolution was used. Each sample was counted over night (٢٤ hrs). Spectra were collected and analyzed using Genie٢k software. Counting repeated three times for each sample and the average was taken. Activity concentrations were calculated for ^{٢٢٦}Ra, ^{٢٣٢}Th series, and ^{٤٠}K isotope. Results show that samples ١٣ and ١٤ (Gneissose Granite-highly weathered) have the highest activity concentrations, whereas sample ٧ (Albitite) has the lowest.

In general, results show that activity concentration of ^{٢٢٦}Ra (^{٢٣٨}U) ranges from ١,٩±٠,٣ Bq/kg [sample٧ (Albitite)] to ٨٧٩٧,٢±٢١,٨ Bq/kg [sample١٤ (Gneissose Granite-highly weathered)] with an average of ١٠٠٨,٦ Bq/kg. Also, activity concentration of ^{٢٣٢}Th ranges from ٠,٨ ± ٠,٢ Bq/kg [sample ٧ (Albitite)] to ٢٤٩٨٤,١±٤٠,١ Bq/kg [sample ١٤ (Gneissose Granite-highly weathered)] with an average of ٢٧٢٠,٤ Bq/kg. In addition, activity concentration of ^{٤٠}K ranges from ٢,٢ ± ٠,١ Bq/kg [sample ٧ (Albitite)] to ٢٠٦٤,١ ± ٣٩,٤ Bq/kg [sample ١٤ (Gneissose Granite-highly weathered)] with an average of ٩١٢ Bq/kg.

Classifying samples to main groups according to their geological origin, the average activity concentrations of ^{226}Ra, ^{232}Th, and ^{40}K, were ١٤,١±١,٠, ١٩,١±١,٣, and ٤٩٠,٦±٦,٨ Bq/kg in volcanic rocks; ٣٤,٠±١,٩, ٦٧,٩±٢,١, and ١١٥٣,٧±١٢,٥ in sedimentary rocks; ٣٤٦٨,٨±١٣,٨, ٩٣٩٨,١±٢١,٨, and ٩٥٨,٩ ±٢٤,٨ Bq/kg in igneous rocks.

Consequently, the absorbed dose rate, radium equivalent activity, external hazard index and internal hazard index, are the highest for samples ١٣ and ١٤ (Gneissose Granite-highly weathered) and the lowest for sample ٧ (Albitite).

Estimated absorbed dose rate ranges from ١,٤٤ nGy/hr [sample ٧ (Albitite)] to ٢٠٥٠٠,١٠ nGy/hr [sample ١٤ (Gneissose Granite-highly weathered)] with an average of ٢٢٨٢,٨٤ nGy/hr. Radium equivalent activity ranges from ٣,٢ Bq/kg [sample ٧ (Albitite)] to ٤٤٦٨٣,٤ Bq/kg [sample ١٤ (Gneissose Granite-highly weathered)] with an average of ٤٩٦٩,١٢ Bq/kg. Internal hazard ranges from ٠,٠١[sample ٧ (Albitite)] to ١٤٤,٤٥[sample ١٤ (Gneissose Granite-highly weathered)] with an average of ١٦,١٥. External hazard ranges from .٠١[sample ٧ (Albitite)] to ١٢٠,٦٧ [sample ١٤ (Gneissose Granite-highly weathered)] with an average of ١٣,٤٢.

For neutron activation analyses which was carried out in Dubna Nuclear Research Reactor, Moscow, Russia, samples of about ٠,٢ g were packed in sealed polyethylene packs for short-lived elements which were irradiated for ٣ min and cooled for ٢-٣ min. Spectra of induced γ-activity then measured for ٥ and ١٠ min, respectively. Long-lived radionuclides were determined using activation with the epithermal neutrons. Primarily packed in aluminum cups, rock samples were repacked after irradiation for ٤ days, and then were measured for the first time for ٤٥ min since ٤ days of cooling and for the second time for ٩٠ minutes since ٢٠ days of cooling.

The elements Sc, Cr, Fe, Co, Ni , Zn, As, Se, Br, Rb, Ag, Sb, Cs, Ba, La, Ce, Sm, Tb, Yb, Hf, Ta, W, Au, Th and U, were determined. Samples were irradiated for ٤ d. After ٤-٥ days of decay the samples were repacked and then measured twice for medium and long-lived isotopes twice respectively.

Measuring time varied from ١ to ٢ hrs. To determine the short-lived isotopes of Mg, Al, Cl, V, Mn, Cu, Al, In, and I. Samples were irradiated for ٣٠ s and measured twice after ٣-٥ min and ٢٠ min of decay for ٥-٨ and ٢٠ min, respectively. To determine Cu, K, Na the same samples were re-irradiated for additional ٣٠ min, and after ١٢-١٥ hrs of decay measured for ٣٠ min.

Gamma spectra were measured using Ge-(Li) detectors with a resolution of ٢,٥ keV for the ^{٦٠}Co ١٣٣٢,٥ keV line, with an efficiency of about ٦٪ relative to a ٣x٣" NaI detector for the same line. Data processing and element concentration determinations were performed. For long-term irradiation, single comparators of Au (١ μg) and Zr (١٠ μg) were used. For short-term irradiation a comparator of Au (١٠ μg) was used.

Results show that the highest elemental concentrations are Zr (٢٢٦١,١ ppm), then Mn (١١١٣ ppm) in trace elements group. For marine origin elements group Mg (٤٠٠٠٠ ppm) is the highest, then Na (٦٩٨٠ ppm). For oil origin elements group V (١٣٣,٥ ppm) is the highest, then Ni (٨٥ ppm). And, for major elements group, Ca (٣٠٩١٠٠ ppm) is the highest, then Al (٥٦٥٨٠ ppm), and Fe (٢٠٦٧٠ ppm).

Contents

Chapter II: Materials and methods

Chapter III: Results and Discussion

List of Tables

List of Figures

١- Introduction

The main purpose of environmental sampling and analysis is to obtain data which describe a particular site at a specific point at time from which an evaluation can be made as basis of possible action. In this direction, the collection of valid samples is the vital first step [١]. To get precise information, the samples should be representative and accurately selected and analyzed. In order to obtain meaningful data, sampling must be carried out with clear purpose and with understanding of the problem and the physical condition that exist. The concentration and distribution of a radionuclide in the environment are changeable with time and location. In sampling program, especially two items should be carefully considered. These two items are the location of sampling sites and the number of samples. They depend on the spatial homogeneity of the system under study. The sample sizes are depending on the analytical technique, the transportation system and the need for replicating measurements. The frequency and duration of sampling depend on the temporal homogeneity of the system [٢].

The steps in designing and conducting a sampling program can be summarized as follows:

١. Defining the objective problem,

٢. Determination of the sample designs,

٣. Selection of the collection method,

٤. Samples collection and samples analysis,

٥. Selection of the parameters to be determined,

٦. Selection of the measurements technique, and

٧. Data analysis and interpretation.

Environmental radiation monitoring measurements may need to satisfy at least one of the following objectives:-

١) To assess pollution effects on man and his environment.

٢) To obtain a historical record of environmental quality and provide a data base for future use in, for example, epidemiological studies.

٣) To study and evaluate pollutant interactions and patterns.

٤) To follow long-term trends.

٥) To provide public assurance.

٦) To demonstrate compliance with statutory limits and practice

٧) To establish and active the emergency procedure.

١,١ Natural radioactivity and Natural Radiation sources

All materials contain at least some traces of natural radioactivity. The relative abundance of the natural radioisotopes in the terrestrial reservoirs is directly derived, though modified during geological time, from the isotopic composition at the time of formation of solar system.

Natural radiation sources are classified into three components [١, ٤]:

١- Cosmic rays,

٢- Cosmogenic radionuclides,

٣- Primordial radionuclides.