

Chapter 3

Experimental Procedure

Measurements of natural and fallout radionuclides in marine surface sediments and seagrass collected from the Egyptian coastal waters of the Red Sea have been made using high resolution-spectrometry, Mechanical (Granulometric), and Geochemical Analysis. Activity levels of uranium isotopes, thorium isotopes, ^{226}Ra and ^{40}K were determined in the samples. In this chapter we describe the experimental procedure in the steps of Samples collection, Preparation of samples, Radiometry Analysis, Mechanical (Granulometric) Analysis, Geochemical Analysis, Instrumentation, Activity Measurements and Measuring of gamma-ray spectra of powdered samples. Also, we will describe the instruments which we use in our study like Golden Software Surfer (V.8), Geographical Position System GPS (Magellan), Atomic Absorption Spectrophotometry (AAS) using GBC-932ver.1.1 with detection limits of 0.01 ppm and sodium iodide detector 3×3 inch (NaI (TI) model (802) with a 2048 multichannel analyzer (MCA).

1 Samples Collection:

Eighty-four samples of sediment have been collected from Red sea coastline. Samples collection was considered the locations throughout four cities (Qusier, Safaga, Hurghada, Ras Ghareb,) in Red sea governorate, Egypt, as shown in figure 2.3. 27 samples have been collected from three region in Qusier city named (El Edua area (south town), Qusier Harbour (Middle town), North Flaminko villager (North town)). 18 samples have been collected from three regions on Safaga city named (Km 17 Mangrove area, Abu Tartour Harbor and Touristic Harbor) from south to north respectively. 21 samples have been collected from three regions on Hurghada City (North Safier Hotel, Hurghada Harbor and NIOF area) also from south to north. 18 samples have been collected from three regions on Ras Ghareb City named (El Sakala area, General Beach and General Company of petroleum). A complete list of all locations and sample number were presented in (table 2.1).

2 Samples Preparation:

Before proceeding with the different analyses of the sediment samples, the sediments were gently washed several times by distilled water to remove soluble salts then spread on glass sheets and left to dry in air. Each sample (about 1 kg) was divided into fourth parts. These parts were treated as follows:

- The first part was stored as a reference.
- The second part, for radiometry analysis has been used.
- The third part used for mechanical (Granulometric) analysis.

- The fourth part was used for chemical and geochemical analysis.

Surface sediment samples were collected by hand, grab sampler and scuba diving. Three different environmental zones such as (i) beach, (ii) intertidal zone and (iii) offshore zone until 8 m water depth represent these localities. Scuba diving was used in areas rich in corals where grab sampler failed to collect samples.

2.1 Radiometry Analysis

Sample (about 500 gm) was washed in distilled water, crushed, homogenized and dried at about 110°C to ensure that moisture is completely removed. In the final step of preparation, the samples were sieved through a 200 mesh, the optimum size to be enriched in heavy minerals. Weighted samples were placed in a polyethylene beaker of 200 Cm³. The beakers were completely sealed for 4 weeks to reach secular equilibrium where the rate of decay of the progeny becomes equal to that of the parent (radium and thorium) (ASTM, 1983; ASTM, 1986) This step is necessary to ensure that radon gas confined within the volume and the progeny will also remain in the sample.

2.2 Mechanical (Granulometric) Analysis

Electroformed sieves are now available that take the range of analysis below the 31 μm permitted by woven-wire sieves. This has extended the range down to 5 μm , but not for routine analysis (James, 1991). About 100 gm of prepared sample were taken for mechanical analysis, which was carried out using a standard set of sieves, shacked in a Ro-Tap shaker for 20 minutes. The sieves were arranged where 1 Φ interval separates each sieve from another. The used sieves are 2.0, 1.0, 0.5, 0.25, 0.125 and 0.063 mm in addition to the ban. These sieves have the equivalent -1, 0, 1, 2, 3 and 4 Φ values, respectively. The collected sieve fractions were accurately weighed. Each ban fraction weighing more than 5% of the analyzed sample was analyzed for silt and clay using the pipette method (Carver, 1971).

2.3 Geochemical Analysis

In the National Institute of Oceanography and Fisheries. Chemical and Geochemical analysis were carried out. Samples for geochemical analysis were produced by splitting the dry samples. Ten grams of each prepared subsamples of all collected samples were ground using an agate mortar (Retsch Mortar-method), passed through a 80 mesh sieve and kept in dry, clean bag waiting for analysis.

➤ **For total carbonates,** To determine the carbonate content, one gram of each prepared sample were treated by (1N HCL acid), filtered and washed several times by distilled water, dried and reweight in order to calculate the percentage of carbonate content of the sediments.

➤ **For organic carbon and total organic matter**, One gram of each crude sample was burned to 550 °C for about two hours. The organic matter content of the sediments was determined by sequential weight loss at 550 °C (Dean, 1974 & Flannery *et al.*, 1982 & Brenner and Binford, 1988).

➤ **For heavy metals**, about 0.5 gm of well homogenized ground sediment samples were accurately weighed on an analytical balance and then transferred into a Teflon beaker and then were completely digested by using a mixture of concentrated nitric, perchloric and hydrofluoric acids, with the ratio 3 : 2 : 1 respectively according to (Chester *et al.* 1994). Acids were slowly added to dried sample and left overnight before heating. Samples were heated for two hours on hot plate at temperature of approximately 200 °C, then left to cool and filtered to get rid of the nondigested parts. The solution was justified to volume of 25 ml, and then the concentration of the elements was determined by Atomic Absorption Spectrophotometry (AAS) technique, using GBC-932 ver. 1.1 with detection limits 0.01 ppm of the National Institute of Oceanography and Fisheries, Red Sea Branch. Results were expressed in ppm.

3 Instrumentation

In this study, many instruments and software have been employed to determine activity concentration, location of collected sample, chemical analysis, Geochemical analysis, statistical analysis and graphical software.

3.1 Activity Measurements

Activity measurements were performed by γ -ray spectrometry, employing a 3 × 3 inch. Scintillation NaI(Tl) detector. The hermetically sealed assembly is coupled to a personal computer-multichannel analyzer (Canberra AccuSpec). A dedicated software program (Genie 2000) analysed each measured γ -ray spectrum. To reduce γ -ray background, a cylindrical lead shield (100 mm thick) with a fixed bottom and movable cover shielded the detector. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick) to absorb lead X-rays. In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples.

3.2 Location of Samples

The locations (Co-Ordinates) were determined by using Geographical Position System GPS (Magellan). The physical criteria of water (temperature, salinity, pH, oxidation reduction potential (Eh), specific conductivity (SPC) and total dissolved salts (TDS) were measured directly in the field using Hydrolab Instrument (HANNA HI 9828) during collecting of samples at the studied localities.

3.3 Geochemical Instruments

Grain size analysis providing basic information for the geochemical investigations of marine sediments was carried out by mechanical wet sieving. Geochemical analysis was carried out on all sediment samples including the determination of total carbonate (TC) content, the determination of total organic matter (TOM) by sequential weight loss at 550 °C (Dean, 1974; Flannery et al., 1982; Brenner and Binford, 1988). Concentrations of the metals; Mn, Zn, Cu, Pb, Ni, Co and Cd were determined according to Chester et al. (1994) (Chester et al., 1994) by Atomic Absorption Spectrophotometry (AAS) using GBC-932ver.1.1 with detection limits of 0.01 ppm (National Institute of Oceanography and Fisheries, Red Sea Branch). Results were expressed in ($\mu\text{g g}^{-1}$).

3.4 Statistical Analysis

The obtained data of the granulometric, components, geochemical, and chemical analyses were dealt statistically in order to exclude the characteristic parameters. The statistical treatment includes the average, standard deviation, geometric means, correlation coefficient were done using Excel.

3.5 Graphical Software

Golden Software Surfer (V.8) was used to draw the bottom profile and facies for all studied transects. In addition to, the sediment samples of each transect were located on map, which was taken from Google Earth Pro as image and then georeferenced by ArcGIS (v.10) using WGS 1984 as Geographic Coordinate System.

4 Gamma Spectrometry

Gamma spectroscopy is an extremely important nuclear and radio analytical measurement method that determines the energy and count rate of gamma rays emitted by radioactive substance. A detailed analysis of the gamma ray energy spectrum is used to determine the identity and quantity of gamma emitters present in a material. The equipment used in gamma spectroscopy includes a detector, a multichannel analyzer, associated amplifiers and data readout. The spectrometer system used in this study consists of sodium iodide detector 3×3 inch (NaI (Tl) model (802) with a 2048 multichannel analyzer (MCA). Its hermetically sealed assembly which includes a high resolution NaI (Tl) crystal, photomultiplier tube, an internal magnetic/light shield, aluminum housing and a 14-pin connector, Preamplifier, main amplifier, analogue to digital convert and Canberra Multichannel Analyzer (MCA) with Genie 2000 software as shown in the block diagram in (fig, 1.8). The applied detector has the following specifications:

- (1) Resolution 7.5% specified at the 662 keV peaks of ^{137}Cs .
- (2) Window aluminum 0.5 mm thick, density 147 mg/cm³

(3) REFLECTOR- oxide; 1.6 mm thick; density 88 mg/cm³.

(4) Magnetic/light shield-conetic lined steel.

A gamma-ray incident on the detector generates a linear charge pulse, which is delivered to the preamplifier. The detector is directly connected to the preamplifier by pulse mode of connection. The pulse carries the energy and time information. The preamplifier matches the detector with the linear amplifier, converts the charge into voltage pulse an amplifiers lit.

The linear amplifier, besides amplification, it is really a signal processor: it converts the signal form received from the preamplifier into a form suitable for measurement; it cuts the signal tail to prevent pile up, and restore the baseline. The amplifier generates semi-Gaussian shaped unipolar pulses with different peaking times. The input voltage in the mV range and the output voltage is in the range of 0 - 10 V. From the amplifier the signal goes into the MCA, which is an adapted by clipping an ADC (Analogue to Digital Converter) board.

The ADC converts the analog voltage into a digital number. In the MCA these numbers (proportional to pulse heights) are sorted in appropriate memory channels. After a prescribed time, and after a sufficiently large number of events are collected, the events are plotted as a histogram of: the number of pulses versus pulse heights (channel number, or pulse energy if an energy calibration was performed).

5 Sodium Iodide Detector (NaI(Tl))

Thallium activated sodium Iodide [NaI(Tl)] detection system is used in the detection of gamma rays. When gamma-ray strikes the NaI crystal some of the atoms in the crystal will become excited and emit photons (scintillation) in the ultra-violet to visible range as the atoms fall to their lower energy state. The thallium provides an additional set of energy bands in the solid that contribute to the conversion of the energy of electrons into light (scintillation photons). The scintillation photons incident on photocathode liberate electrons by photoelectric effect. The liberated electrons are accelerated by a strong electric field from high voltage in the PMT tube. As they are accelerated, they collide with electrons in the dynodes releasing more electrons. This causes multiplication of electron flux (by factor of 10⁴ or more) from its initial value. The magnitude of this charge surge is proportional to the initial amount of charge liberated at the photocathode of the PMT tube. The initial number of photoelectrons liberated at the photocathode is proportional to the amount of light incident on the phototube, which in turn is proportional to the amount of energy deposited in the scintillator by the gamma ray thus the output signal produced is proportional to the energy deposited by the gamma ray in the scintillation medium (Tsoufanidis, 1995; Hastings *et al.*, 1991). The pulses from the anode are fed into multichannel analyzer (MCA) for analysis. The MCA records and store pulses according to their energy values in the MCA channels. The data collected is presented in form of a spectrum. This comprises of background radiation and photo peaks from the radionuclides present in the sample. Since a radioactive source produce gamma rays of various

energies and intensities a detailed analysis of this spectral data is used to determine the identity and quantity of radionuclides present in a sample. The detector is calibrated using source of specific energy peaks like standard reference sample so that each channel is assigned specific energy values.

6 Energy Calibration:

When we used a gamma spectrometer for identifying samples of unknown composition, its energy scale must be calibrated first. Calibration was performed by using the peaks of a known source. Because the channel number is proportional to energy, the channel scale can be converted to an energy scale by energy calibration. Energy calibration is important for the identification of radionuclides by their characteristic emission. To calibrate the applied spectrometer for energy measurements, it is necessary to know the approximate energies of radiation source. The detection array was energy calibrated using standard sources, ^{133}Ba (356.1 keV), ^{137}Cs (661.9 keV) and ^{60}Co (1173.2 and 1332.5 keV). The standard sources were located over the detector on face-to-face geometry.

7 Efficiency Calibration:

An accurate efficiency calibration of the system is necessary to quantify the radionuclides present in the samples. It is essential that this calibration must be performed with great care, because the accuracy of all quantitative results will depend on it. It is also essential that all system settings and adjustments be made prior to determining the efficiencies and be maintained until a new calibration is undertaken. Small changes in the settings of the system components may have slight but direct effects on counting efficiency. (IAEA, 1989). Samples should be counted only in the types of container used to acquire the counting efficiencies. The density, volume and height of the sample in the container must be the same as that of the standards used for calibration. Any change of these factors will require additional calibrations to match the characteristics of the sample. In present work, the efficiency calibration curve was made using Reference Materials (IAEA-314). For any calibration standard analyzed on a given detector, the corresponding background file was used to subtract contributions of background peaks from the sample peaks. The net full-energy-peak area was calculated using the efficiency calibration procedure for each background subtracted peak in the standard spectrum which corresponds to a calibrated gamma-ray emission. The absolute detector efficiency at that energy was then calculated by dividing the net count rate in the full-energy peak by the decay corrected gamma-ray-emission rate of the standard source. After the absolute detection efficiency was determined for each calibration peak, weighted least squares fit was made to a polynomial expression of log of efficiency vs. log of energy. Efficiency curves were constructed from these full-energy-peak efficiencies (Wilson and Scott, 1992). The absolute efficiency has been calculated using (Uosif and El-Taher, 2005):

$$\eta_{Exp} = \frac{N_p \cdot 100}{I_\gamma \cdot TOC \cdot A_{BOC}} \quad (16)$$

Where N_p is the net peak area (count s^{-1}) at E_γ , I_γ the intensity of emitted γ -ray (%), TOC the time of counting (s), and A_{BOC} the activity (Bq) of the calibrated source at the start of counting (BOC). The activity of the calibrated source at the start of counting was calculated by :

$$A_{BOC} = A_{DOC} \exp[-\lambda(BOC-DOC)] \quad (17)$$

Where A_{DOC} is the activity (Bq) of the standard source at date of calibration DOC and λ (s^{-1}) is the decay constant.

FIT FUNCTION: Efficiency function was obtained by applying Weibull Model equation to the experimental efficiency data which is in the next form (Uosif and El-Taher, 2005):

$$\eta_{Th} = a - b \times \exp(-c \times E_\gamma^d) \quad (18)$$

Where E_γ represents energy in MeV, where a, b, c and d are coefficient data using eq.18, we can calculate the absolute efficiency, η_{Th} , at any specific energy E_γ if we know the energies and coefficient data. From the experimental efficiency curves, the coefficient data were determined at each distance by using a curve fitting system so-called curve Expert 1.3.

The absolute efficiency of the NaI (Tl) detector was calculated using standard sources (IAEA-314) which have known activity of ^{226}Ra (732 Bqkg $^{-1}$) and ^{232}Th (17.8 ppm). This reference material sample was collected from the Kalan area of the west Kalimantan Borneo, Indonesia and was donated by the Indonesian Atomic Energy Commission (IAEC). The material was air dried and then ground to pass through a 0.18 mm sieve before being homogenized. The material was dispensed into plastic bottles in 50 g units without any further processing. Subsequently, the samples were irradiated to a dose of 2.5×10^4 Gy using a ^{60}Co source to ensure long-term stability of the material by inhibiting microbial action. The obtained data are listed in table 2.2.

Table 2.2: Radionuclides used for efficiency calibration, (22-06-2013).

Nuclide	Energy	I_γ	(T1/2) y	Real time	A_0 (Bq)	λ	A (Bq)	Efficiency experimental	Efficiency theoretical
^{214}Pb	351.9	37.1	1.60×10^3	79917.3	36.6	4.33×10^{-4}	36.6	0.1980888	0.1950838
^{214}Bi	609.3	46.1	1.60×10^3	79917.3	36.6	4.33×10^{-4}	36.6	0.0340523	0.0394131
^{214}Bi	1764.5	15.9	1.60×10^3	79917.3	36.6	4.33×10^{-4}	36.6	0.0290227	0.0211409
^{214}Bi	1120.3	15	1.60×10^3	79917.3	36.6	4.33×10^{-4}	36.6	0.032026	0.0220629
^{228}Ac	911.1	29	1.41×10^{10}	79917.3	3.60	4.92×10^{-11}	3.6	0.0121077	0.0238013
^{212}Pb	238.6	43.6	1.41×10^{10}	79917.3	3.60	4.92×10^{-11}	3.6	0.3220368	0.3222749
^{212}Bi	727.2	6.65	1.41×10^{10}	79917.3	3.60	4.92×10^{-11}	3.6	0.0276711	0.0290841

Where the best agreement between experimental and theoretical absolute detection efficiencies of 3×3 inch detector for gamma energy shows in figure (2.16), while energy and shape calibration curves using (IAEA-314) standard source as graphs can be seen in figure (2.17).

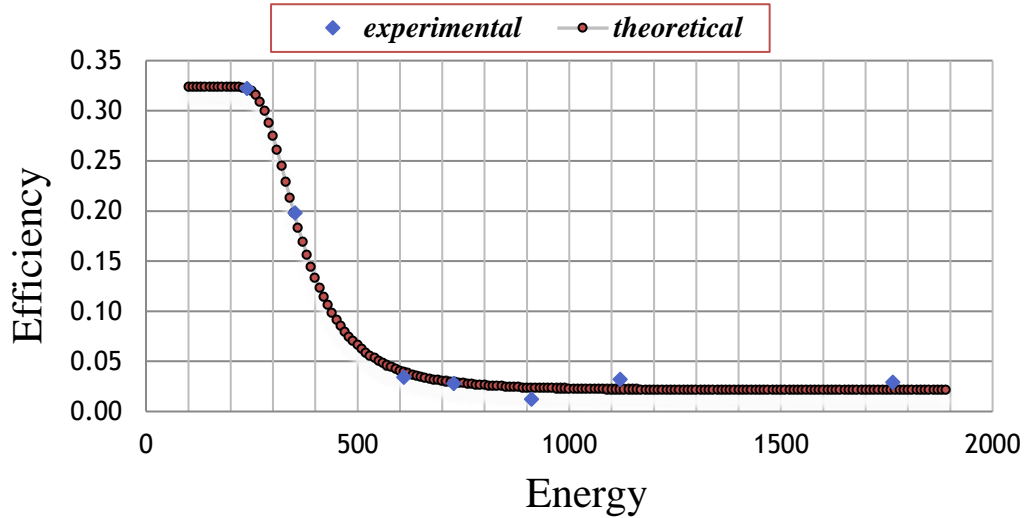


Fig 2.16: Full energy peak efficiency as a function of gamma ray energy for a typical NaI (TI) detector for standard source (IAEA-314) which have known activity of ^{226}Ra (732 Bqkg^{-1}) and ^{232}Th (17.8 ppm)

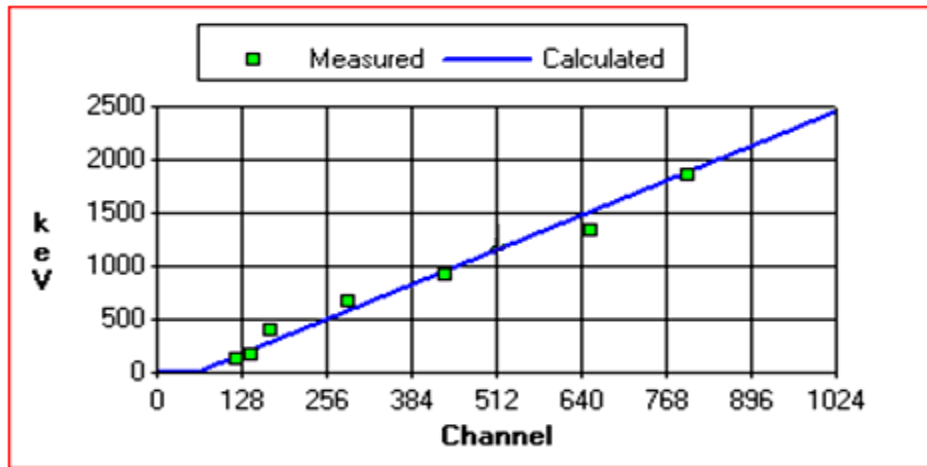


Fig 2.17: Energy and shape calibration curves using (IAEA-314) standard source

8 The Uncertainty of Efficiency:

The combined standard uncertainty of absolute efficiency $u(\text{EFF})$ (Uosif and El-Taher, 2005), is consists of $u(N_p)$, $u(I_\gamma)$, $u(\text{TOC})$ and $u(A_{\text{BOC}})$ so,

$$\left[\frac{u(EFF)}{EFF} \right]^2 = \left[\frac{u(N_p)}{N_p} \right]^2 + \left[\frac{u(I_\gamma)}{I_\gamma} \right]^2 + \left[\frac{u(TOC)}{TOC} \right]^2 + \left[\frac{u(A_{BOC})}{A_{BOC}} \right]^2 \quad (19)$$

Because of $u(BOC) \ll TOC$, we neglected $u(BOC)$, while $u(A_{BOC})$ was calculated by

$$\left[\frac{u(A_{BOC})}{A_{BOC}} \right]^2 = \left[\frac{u(A_{DOC})}{A_{DOC}} \right]^2 + (BOC - DOC)^2 \cdot u^2(\lambda) \quad (20)$$

We got $u(N_p)$ from the code Genie 2000 from Canberra) while $u(\lambda)$ and $u(I_\gamma)$ were taken from the compilation of (Reuss and Westmeier, 1983).

9 Determination of Detection Limits

The smallest measurable activity that can be detected using γ -ray counting with a certain degree of confidence is called the lower limit of detection (LLD). The activity of each radionuclide and the lower limit of detection (LLD) were calculated according to IAEA directions (IAEA International Atomic Energy Agency, 1989) and are given by Eq. (21) and Eq. (22), respectively:

$$A = \frac{N_p}{\epsilon I_\gamma m t} \quad 21$$

$$LLd = \frac{446\sqrt{F_c}}{\epsilon I_\gamma m t} \quad 22$$

Where A is the sample activity concentration in $Bqkg^{-1}$; N_p is the net counts measured under the photopeak; ϵ is the system detection efficiency; I_γ is the absolute transition probability by gamma decay; m is the sample mass in kilograms; t is the counting time in seconds; and F_c is the Compton background in the region of the selected gamma line in the sample spectrum. The lower limits of detection (L_d) were $6.79 Bqkg^{-1}$ for ^{40}K , $1.63 Bqkg^{-1}$ for ^{226}Ra and $0.64 Bqkg^{-1}$ for ^{232}Th .

10 Measuring Activity of NORM Nuclides

Naturally Occurring Radioactive Material, (NORM) is potentially includes all radioactive elements found in the environment. However, the term is used more specifically for all naturally occurring radioactive materials where human activities have increased the potential for exposure compared with the unaltered situation. NORM is produced when radionuclides that occur naturally in ores, soils, water, or other natural materials are concentrated or exposed to the environment by activities, such as uranium mining or sewage treatment. Long-lived radioactive elements such as uranium, (^{238}U), thorium (^{232}Th) and potassium (^{40}K) and any of their decay products, such as radium (^{226}Ra) and radon (^{222}Rn) are examples of NORM. These elements have always been present in the Earth's crust and atmosphere, and are concentrated in some places, such as uranium ore., which may be mined.

The term NORM exists also to distinguish ‘natural radioactive material’ from anthropogenic sources of radioactive material, such as those produced by nuclear power and used in nuclear medicine, where incidentally the radioactive properties of a material maybe what make it useful. However from the perspective of radiation doses to people, such a distinction is completely arbitrary.

For measuring NORM nuclides in our investigated samples, we put each sample on the shielded NaI (Tl) detector and counted for an accumulating period of twelve hours (43200 s). The ²²⁶Ra radionuclide was estimated from the 351.9 keV (36.7%) gamma peak of ²¹⁴Pb and 609.3 keV (46.1%), 1120.3 keV (15%) and 1764 keV (15.9%) γ -peak of ²¹⁴Bi. The 186 keV photon peak of ²²⁶Ra was not used because of the interfering peak of ²³⁵U with energy of 185.7 keV. ²³²Th radionuclide was estimated from the 911.2 keV (29%) γ -peak of ²²⁸Ac and 238.6 keV (43.6%) γ -peak of ²¹²Pb. ⁴⁰K radionuclide was estimated using 1,461 keV (10.7%) γ -peak from ⁴⁰K itself (Shams Issa, et al 2014 and Uosif et al., 2012). The activity concentration in Bqkg⁻¹ (A) in the environmental samples was calculated as follows (Noorddin, 1999).

$$A = \frac{N_p}{I\gamma \times \eta \times m} \quad (23)$$

Where N_p is the count per second (cps), $I\gamma$ is the abundance of the γ -peak; η is the measured efficiency for each gamma line observed for the same number of channels for either the sample or the background, and m is sample mass in kilograms.

11 Uncertainty of Activity:

Uncertainty is the quantitative estimation of error present in data; all measurements contain some uncertainty generated through systematic error and/or random error. Acknowledging the uncertainty of data is an important component of reporting the results of scientific investigation.

The uncertainty of activity $u(A)$ was calculated by the following equation (Uosif and El-Taher, 2007):

$$u(A) = \sqrt{[u(N_p)/(N_p)]^2 + [u(\eta)/(\eta)]^2 + [u(m)/(m)]^2} \quad (24)$$

The uncertainty of each single net-peak area is determined by the spectrum-evaluation code (GENIE-2000). It takes into account the Poisson uncertainties of the counts in the individual channels as well as the uncertainty of the background determination. Sometimes a peak cannot be attributed unambiguously to a single nuclide. If it seems that the contributions of other nuclides to a peak are very small no correction was applied. Due to this procedure, we think that we have to assume a maximum in accuracy of 2% due to contributions of other nuclides but it must be pointed out that in average this uncertainty should be smaller. By repeated

measurements it could be verified that the total uncertainty of the efficiency calibration was 5% (Uosif and El-Taher, 2007).

12 Background Measurement

The background of the detector system is mainly due to natural background radioactivity: uranium and thorium daughters, and Potassium-40. Measurement of the background is important since it effects the detection limit and the accuracy of measurements. The background differs from one place to another: it depends on the type of the detector, size, type of shield used for the detector and the material used in shielding. Also the background may increase due to the interaction of the primary gamma radiation with the structural and shielding material around the detector.

To reduce gamma ray background, a cylindrical lead shield with a fixed bottom and movable cover shielded the detector. The lead shield contained an inner concentric cylinder of copper (0.3 mm thick). The soft component of cosmic rays, consisting of photons and electrons is reduced to a very low level by 100 mm of lead shielding. The X-ray (73.9 keV) emitted from lead by its interaction with external radiation is suppressed by the copper layer. In order to determine the background distribution in the environment around the detector, an empty sealed beaker was counted in the same manner and in the same geometry as the samples. The background spectra were used to correct the net peak area of gamma rays of measured isotopes (Abbady et al., 2005). The offline analysis of each measured γ -ray spectrum has been carried out by a dedicated software program Genie 2000.

13 Radiological Hazards Indices:

Radiological hazards arising from exposure to gamma rays emitted by radioactive elements naturally (^{226}Ra , ^{232}Th and ^{40}K) were calculated and estimated by the follow factors:

13.1 Radium Equivalent Dose (Ra_{eq})

The distribution of ^{226}Ra , ^{232}Th and ^{40}K in soil is not uniform. Uniformity with respect to exposure to radiation has been defined in terms of radium equivalent activity (Ra_{eq}) in Bqkg^{-1} to compare the specific activity of materials containing different amounts of ^{226}Ra , ^{232}Th and ^{40}K . It is calculated through the following relation (Yu et al, 1992)

$$\text{Ra}_{\text{eq}} = A_{\text{Ra}} + 1.43 A_{\text{Th}} + 0.077A_{\text{K}} \quad (25)$$

Where A_{Ra} , A_{Th} and A_{K} represent the activity concentrations in (Bqkg^{-1}) of ^{226}Ra , ^{232}Th and ^{40}K , respectively.

Radium equivalent activity (Ra_{eq}) is used to assess the hazards associated with materials that contain ^{226}Ra , ^{232}Th and ^{40}K in Bqkg^{-1} , which is, determined by assuming that 370 Bqkg^{-1} of ^{226}Ra or 260 Bqkg^{-1} of ^{232}Th or 4810 Bqkg^{-1} of ^{40}K produce the same γ dose rate This

value measures in (Bqkg-1) The published maximal admissible (permissible) Ra_{eq} is 370 Bqkg-1 (UNSCEAR, 2000).

13.2 Absorbed Gamma Dose Rate (D)

The absorbed dose rates due to gamma radiations in air at 1 m above the ground surface for the uniform distribution of the naturally occurring radionuclides (226Ra, 232Th and 40K) were calculated based on guidelines provided by UNSCEAR (2000). The conversion factors used to compute absorbed gamma dose rate (D) in air per unit activity concentration in Bq kg-1 (dry weight) corresponds to 0.462 nGyh-1 for 226Ra, 0.604 nGyh-1 for 232Th and 0.042 nGyh-1 for 40K. Therefore, D (in nGyh-1) in the outdoor air can be calculated as follows equation:

$$D = 0.462A_{Ra} + 0.604A_{Th} + 0.0417A_k \quad (26)$$

Where A_{Ra}, A_{Th} and A_K are the activity concentrations in (Bqkg-1) for 226Ra, 232Th and 40K, respectively. The world average value of D is 57 nGyh-1 (UNSCEAR, 2000).

13.3 Hazard indices:

Beretka and Mathew (1985) defined 2 indices that represent external and internal radiation hazards. The prime objective of these indices is to limit the radiation dose to a dose equivalent limit of 1 mSvy-1. The external hazard index (H_{ex}) is calculated using the given equation:

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad (27)$$

Where; A_{Ra}, A_{Th} and A_K are the activity concentrations for the series 238U, 232Th and 40K in (Bqkg-1) (UNSCEAR, 2000). The H_{ex} must not exceed the limit of unity for the radiation hazard to be negligible (Beretka, and Mathew, 1985)

On the other hand, the internal hazard index (H_{in}) gives the internal exposure to carcinogenic radon and its short-lived progeny, and it is given by the following formula:

$$H_{in} = \frac{A_{Ra}}{185} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (28)$$

Where; A_{Ra}, A_{Th} and A_K are the activity concentrations for the series 238U, 232Th and 40K in (Bqkg-1). The value internal hazard index (H_{in}) should also be less than unity to provide safe levels of radon and its short-lived daughters for the respiratory organs (UNSCEAR, 2000).

13.4 Annual Effective Dose:

In estimating the effective dose in any environment, the two factors of importance are the conversion factor from Gyh-1 to Sv-1 and the occupancy factor. The former gives the equivalent human dose in Sv-1 from the absorbed dose rate in air (Gyh-1) while the latter gives the fraction of the time that an individual is exposed to the outdoor radiation. In the UNSCEAR (1993, 2000) reports, a value of 0.7 was used for the conversion factor from absorbed dose in air to effective dose received by adults, and 0.8 for the indoor occupancy

factor, implying that 20% of time is spent outdoor, on average, around the world. Therefore, the annual effective doses outdoors in units of (μSvy^{-1}) received by adults can be estimated as follows:

$$\text{AEDE (outdoor)} = D \text{ (nGyh}^{-1}) \times 8760 \text{ h} \times 0.7 \text{ Sv.Gy}^{-1} \times 0.2 \times 10^{-3} \quad (29)$$

Where D is the calculated dose rate in (nGyh^{-1}), the annual effective doses for infants and children were calculated using equation 29, taken into account the numerical values, 0.9 and 0.8, of conversion factor for infants and children, respectively as reported in UNSCEAR (2000). The world average value of outdoor AEDE for infants, children and adults (90, 80 and 70 μSvy^{-1}), respectively. (Shams et al., 2013 & Wafaa Rashed, 2012)

13.5 Gamma index (I_γ)

In order to examine whether the samples meet these limits of dose criteria, another radiation hazard index, the representative level index, I_γ , used to estimate the level of gamma-radiation hazard associated with the natural radionuclides in specific investigated samples, is de-fined as (NEA-OECD, 1979), from the following equation:

$$I_\gamma = \frac{A_{Ra}}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad (30)$$

Where A_{Ra} , A_{Th} and A_K are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K , respectively, in Bqkg^{-1} . The numerical quantities in the denominator of these equation are also in units of Bqkg^{-1} , so that the gamma activity concentration index I_γ is a dimensionless quantity. For the activity concentration index, $I_\gamma \leq 2$ corresponding to dose criterion of 0.3 mSvy^{-1} , while $I_\gamma \leq 6$ corresponds to 1 mSvy^{-1} in the report of the (European Commission in 2000). Thus, the 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.

13.6 Excess Lifetime Cancer Risk (ELCR):

Excess lifetime cancer risk (ELCR) can be defined as the excess probability of developing cancer at a lifetime due to exposure level of human to radiation. Excess lifetime cancer risk is calculated using the equation (ICRP-60, 1991):

$$\text{ELCR} = \text{EDR} \times \text{DL} \times \text{RF} \quad (31)$$

Where EDR is the annual effective dose equivalent, DL is duration of life (30-70 year) and RF is risk factor (Sv^{-1}) fatal cancer risk per Sievert. For stochastic effects, ICRP 60 uses values of (RF = 0.05) for public. Natural radionuclide and radiological hazards have been evaluated for deposits samples from Red sea sediment.

13.7 Annual Gonadal Dose Equivalent (AGDE)

It is a measure of the genetic significance of the yearly dose equivalent received by the population's reproductive organs (gonads) (Morsy et al., 2012). In the same context, the activity bone marrow and the bone surface cells are considered as the organs of interest by

UNSCEAR, (1988). Therefore, the annual gonadal dose equivalent (AGDE) due to the specific activities of ^{226}Ra , ^{232}Th and ^{40}K was calculated using the following formula (Mamont-Ciesla et al., 1982)

$$\text{AGDE } (\mu\text{SvY}^{-1}) = 3.09A_{\text{Ra}} + 4.18A_{\text{Th}} + 0.314A_{\text{K}} \quad (32)$$

Where A_{Ra} , A_{Th} and A_{K} are the activity concentrations of ^{226}Ra , ^{232}Th and ^{40}K , respectively, in Bqkg^{-1} .

Gamma radiation is only very weakly ionizing, but it's much more penetrating than α -particles and β -particles and so all the internal organs of the body are at risk, even from external sources. The results of interaction of γ -rays with tissue are very similar to those produced by α -particles and β -particles. Electrons are liberated from the atoms and molecules of tissue and cause abnormal chemical reactivity. Most of the external radiation received by ordinary men and women is γ -rays from natural sources, the radionuclides in the earth irradiating the whole body more or less uniformly. Since most building materials are either natural or derived from natural materials, they too are usually radioactive to some degree. Therefore, radiation is received indoor as well as in the open air.

We discussed in our study how we collected the samples and how we prepared it in the field and in our lab, and mentioned the techniques which we used in our study like GPS (Magellan) which use it to determine the sample's locations also mentioned how measured the total carbonate (TC) content and organic carbon and total organic matter (TOM) by Geochemical Analysis and we were used Golden Software Surfer (V.8) to draw the bottom profile and facies for all studied transects and we used sieves are 2.0, 1.0, 0.5, 0.25, 0.125 and 0.063 mm in addition to the ban to study Mechanical (Granulometric) Analysis and we measured the Concentrations of the metals; Mn, Zn, Cu, Pb, Ni, Co and Cd which were determined according to Chester et al. (1994) (Chester et al., 1994) by Atomic Absorption Spectrophotometry (AAS) using GBC-932ver.1.1 with detection limits of 0.01 ppm (National Institute of Oceanography and Fisheries, Red Sea Branch).

And Finlay The equipment used in gamma spectroscopy includes a detector, a multichannel analyzer, associated amplifiers and data readout. The spectrometer system used in this study consists of sodium iodide detector 3×3 inch (NaI (TI) model (802) with a 2048 multichannel analyzer (MCA). Its hermetically sealed assembly which includes a high resolution NaI (TI) crystal, photomultiplier tube, an internal magnetic/light shield, aluminum housing and a 14-pin connector, Preamplifier, main amplifier, analogue to digital convert and Canberra Multichannel Analyzer (MCA) with Genie 2000 software as shown in the block diagram in (fig. 2.18). The applied detector has the following specifications:

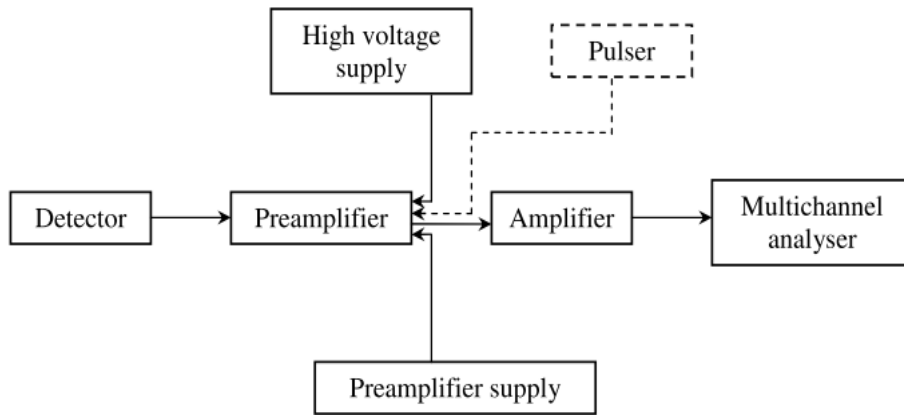


Fig 2.18: A simple schematic electronic system for gamma-ray spectrometry (Gilmore, 2008).