Alnaser, W. E., et. al., Journal of the Association of Arab Universities for Basic and Applied Sciences, Vol. 1, 2005, 1-27

Survey of Low Background Radiation in the Kingdom of Bahrain

Alnaser, W. E., Aldallal, S.M.S, M.M.Zein+ and Alnaser,Y. E*.
Department of Physics, College of Science, P.O. Box 32038, University of Bahrain,
Kingdom of Bahrain.
*Prime Minister Court,P.O.Box 1000, Kingdom of Bahrain., +Deceaced

ABSTRACT

A survey of the α (Alpha) and β (Beta)low background radiation level (LBRL) at the Kingdom of Bahrain is reported herein.2 grams samples were collected from the soil at the surface and at a certain depth of terrestrial and coastal areas. The possibility of the existence of nuclear pollution or radioactive sources is investigated.

The weighted average for α - LBRL was 22.63 pCi, for samples taken from the terrestrial surface, and 21.21 pCi, for samples taken from a certain depth. For the coastal areas the LBRL was 14.17 pCi and 10.86 pCi, respectively. The weighted average for β- LBRL was 51.63pCi, for samples taken from the terrestrial surface and 47.10 pCi, for samples taken from a certain depth. For samples taken from the coastal areas it was 32.7 pCi and 28.47 pCi, respectively.

The unweighted average of α -LBRL was 25.78 pCi, for samples taken from the terrestrial surface, and 23.85 pCi, for samples taken from a certain depth; For β-LBRL the average values were 55.56 and 51.30 pCi, respectively.

Isa Town region had the highest average measured terrestrial α- LBRL (68.36 pCi for surface samples and 78.97 pCi at a certain depth), while the lowest was in Sitra (12.98 pCi and 12.75pCi, respectively). Meanwhile, the highest terrestrial average β- LBRL was measured in Isa Town (123.48 pCi for surface samples and 137 pCi for samples taken from a certain depth), while the lowest was in Sitra (30.42 pCi and 28.67pCi, respectively).

The highest measured coastal α- LBRL was in Hidd beach (27.98pCi for surface samples and 18.21 pCi for samples taken from a certain depth), while the lowest was in Belajaljazair (4.99 and 6.38pCi ,respectively).The highest measured coastal β- LBRL was in Hidd region (52.14pCi for surface samples), but the highest for samples taken at a certain depth was in Manama port(55.18pCi).The lowest coastal average β- LBRL was in Halat Alsalath (5.33pCi for samples taken from surface), while its in Hidd for samples taken from a certain depth(0.236 pCi).

The ratio of αsur to α dep as well as βsur to βdep in terrestrial region in Bahrain was found equal to 1.08 for both, when it was unweighted and 1.06 and 1.09 respectively, when they are weighted. This indicates that no major nuclear fallout on the kingdom or no nuclear emission from underground.

KEY WORDS: α and β Beta low background radiation l, Bahrain, Nuclear pollution, pCi

INTRODCTION

The Natural Background Radiation originates from external and internal sources. The external sources include cosmic radiation which arises from the sun and the other stars. The energetic cosmic radiation entering the atmosphere is called Primary Cosmic Rays and consists of high energy protons, as well as alpha particles, atomic nuclei, high energy electrons and photons. As this radiation encounters the earth's atmosphere, it interacts with its atoms and produces another type of radiation known as Secondary Cosmic Rays. They consist mainly of mesons, electrons and Gamma rays (Selman, 1977). Most detected radiation in the laboratory are of the secondary type. They are so penetrating that they have the capability of passing through lead a few meters thick. The atmosphere acts as a shield and reduces the amount of cosmic radiation reaching the earth's surface considerably. The Carbon-14 diffuses to the lower atmosphere as a result of interaction of cosmic rays (neutron, n) with nitrogen (^{14}N) in the upper atmospheres. This source may become incorporated in the living matter ($^{14}N(n,p)^{14}C$)[Martin and Harbiston (1979), Martin and Harbiston(1986) ,Selman (1977)].

Any sensitive radiation detector, such as G-M counter, will indicate the presence of environmental ionizing radiation even in the absence of any artificial or natural radioactive sources. This environmental radiation is called Natural Background and all the matter, living and non-living, is continuously exposed to it (Turk and Turk, 1983). It appears though that this Background Radiation cannot be controlled by mankind.

Another source of external background radiation is the natural radioactive minerals (radiation from terrestrial sources). This occurs in minute amounts almost everywhere in the earth's crust, including building materials, and in larger amounts where the minerals of Uranium, ^{238}U, Thorium, ^{232}Th and their daughter's products are deposited. The concentration of these elements varies considerably; depending upon the type of rock formation. For example, in Sandstone and Limestone regions, the concentration is much lower than in Granite (Martin and Harbiston, 1986).

Internal Background radiation is also an important source of radiation. The sources of this radiation include radioactive nuclides incorporated in the tissues of the body. The main naturally radioactive nuclides are the Carbon–14, Pottasium-40 and Strontium-90. The Carbon–14 originates, as mentioned earlier, in the lower part of the atmosphere. Significant contributions to the radioactivity in the body are Radon and Thoron, which are the products of U and Th, respectively.

Artificial (man-made) Background Radiation is another source of radiation arising from fallouts of weapons testing, radioactive waste occupational exposure, use of radioisotopes and therapeutic radiology (McGraw-Hill, 1980). This type of background radiation can be controlled by mankind.

Indeed, many countries give attention to measuring this background radiation from time to time, in order to study any environmental changes. For example, the total dose of background (natural) radiation in the British Isles was reported to be 1250 μSv/year in 1982, however, this figure increased to 1880 μSv/year in 1986 (Martin and Harbiston(1986)..

It was found that the increment in the total dose was due to an increase in the diffused Radon and Thoron gases from the soil and rocks to the atmosphere. Therefore, it is the purpose of this study is to examine the background radiation by testing the soil, so that any future changes in the background radiation can be detected by comparing these results with the updated ones.

EXPERIMENTAL TECHNIQUE

(a) Experimental Set-up

Alpha and beta background radiation is measured using TENNELC's LB 1500 series-low level counting system. The system is based on a time-tested proportional detector and shielding equipment. Up to 50 samples can be measured automatically by a programmable changer-controller which features a sample search mode. The three major parts of the system include: detector assembly, the changer and the electronic assembly. The detector assembly consists of a gas flow proportional sample and cosmic guard detectors surrounded by 4 inches of low background lead and oxygen-free high conductivity copper. The sample changer assembly incorporates the fewest possible number of moving parts to ensure low wear and high reliability. The basic mechanism consists of two precision lead screwdrivers by D.C. Motors. A NIM electronics analyses the information from the low background detector. Alpha and Beta counts for each sample are shown on a LCD display and are printed out with the counting time.

(b) Detection System

The sample counting rate is a function of the adsorption of the detector window, the geometric relationship of the sample to the detector, the detection probability, scattering effects, and the detector area. The detector window of a low background counting system has been made very thin to maximize unit efficiency. The adsorption at the window is a function of the energy of the radiation and the thickness of the window. The LB 1500 has a standard Mylar window of 500 g/cm^2 which can be used for beta emitters above approximately 0.3MeV. Since the radiation emitted from a point source is isotropic, the ideal relationship between the sample and the detector would be one in which the detector is spherical. Since this is not a feasible approach, therefore, this is achieved by making the sample holder diameter slightly less than the diameter of the window, and then reducing to a minimum the air space between the sample and the window. The factors affecting the detection probability are the ionization potential of the gas, the pressure of the gas, the energy of the particles, the path that the particles will travel and the electric field distributions in the detector. In general, the detection probability is normally close to unity, and the only factor that requires attention is the electric field distribution. Poor plateau slopes might tend to give a lower probability. Slopes of 1-

2% per 100 Volts will generally give probabilities in excess of 99%. The sample counting rate is proportional to the square of the detector area. Therefore, it is essential to match the detector diameter to the size of the sample.

(c) Theory of Operation

Figure (1) shows a typical block diagram of the LB 1500 system. It has two basic sections – the detector/shielding section and the electronic section.

i) Detector /shielding:

The detectors are proportional counters, consisting basically of a gas filled chamber with electrodes. Ionization produced in the filling gas (usually 10% methane with 90% argon) is collected on the anode and cathode under the influence of the electrostatic field. When a particle, or ray, passes through the window and ionizes the gas, a pulse is generated. This is very fast and produces a rise in signal voltage measured in nanoseconds. The positive ions moving away from the anode wire produce a pulse whish is initially fast, and then slows down as the ion velocity in the lower field region diminishes.

ii) Alpha/beta analysis:

In a radioactive decay scheme, where alpha and beta disintegrations are occurring simultaneously, the problem becomes how to differentiate between the pulses generated by the alphas and those generated by the betas. As the particles, with their large mass and relatively high energy levels, ionize many gas molecules, the electron multiplication process will be great. As a result, the attendant pulse generated will have a large peak height, or higher voltage pulse. An alpha discriminator and logic circuitry are used to distinguish between the alpha and beta particles (Hoppin and yderg, 1980).

(d) Sample Preparation

To ensure a good counting efficiency, it is obvious that the preparation of the counting sample must be done with care and must be reproducible if several samples are to be compared. Alpha-emitters can be counted efficiently from solid samples if the sample is very thin so that self adsorption is eliminated (Hoppin and yderg, 1980).

For alpha-spectrometry we have used a surface density of less than $0.08 g/cm^2$. However, counting of solid samples of beta-emitters is less critical. Attention was paid to making our samples as flat and uniform as possible. The same sample was used for simultaneous measurement of both alpha and beta counting.

METHODS OF STATISTICAL ANALYSIS

The number of particles or counts N in a given time, t, will fluctuate about an average value. The standard deviation s, is a measure or the scatter of a set of observations about their average value. For a count rate to be accurate, the counting period, t, must be long enough. This can be understood from the following equation [Friedlander et al 1981)]

$$S= \sqrt{N/t} \tag{1}$$

In this research t was always taken to be 50 minutes.

The standard deviation, s, for counting rate S due to a source (the specimen) superimposed on a background counting rate (^{90}Sr, ^{210}Po and container) was calculated by using the following equation [1, 2, 7 and 8]

$$S = \frac{N}{t_1} - \frac{B}{t_2} \pm s \tag{2}$$

where,

$$s = \sqrt{s_1^{\ 2} + s_2^{\ 2}} \tag{3}$$

s_1 is the standard deviation for the count rate of the specimen and s_2 is the standard deviation for the counts of the background. Therefore, substituting (1) in (3)

$$s = \sqrt{\frac{N}{t_1^2} + \frac{B}{t_2^2}} \tag{4}$$

N represents the counts from the specimen in a time t_1 and B represents the counts from the background source in a time t_2.

The highest accuracy is achieved when,

$$\frac{t1}{t2} = \sqrt{\frac{(S+B)}{B}} \tag{5}$$

Since we are collecting specimens from different areas in Bahrain in order to make a survey, it is necessary, therefore, to calculate the sampling error, the confidence interval and the true mean of population. The statistics are useful to examine the coverage of the reflected samples in order to be representative for all the geographical regions in Bahrain.

In order to calculate the sampling error (S.E), we must first know the sampling variance ($\hat{V}$), which is a measure of the distribution of the observed results about $\bar{X}$ (the average radiation deviation activity).

$$\hat{V} = \frac{1}{N_0 - 1} \sum_{i=1}^{N_0} \left(X_i - \bar{X} \right)^2 \quad , \tag{6}$$

where N_0 is the total number of readings and X_i is the value of pico Curies(pCi) to be averaged for each area. The square root of $\hat{V}$ is called the standard deviation (s).

The sample error (S.E) is known to be equal to:

$$\text{S.E} = \frac{s}{\sqrt{N_0}} \tag{7}$$

The confidence interval, when s is known for each area, is (Rickmers and Hollis 1967)

$$(\bar{X} - \bar{t}_{v,\bar{a}} \frac{s}{\sqrt{N_o}}) \langle \mu \langle (\bar{X} + \bar{t}_{v,\bar{a}} \frac{s}{\sqrt{N_o}}) \tag{8}$$

The form $\bar{t}_{v,\bar{a}}$ is called the formula for confidence limits. The subscript ν signifies the number of degrees of freedom, (which equal to N_0-1)while the subscript $\bar{\alpha}$ is equal to 0.05, if we wish to use a 95 percent confidence level ,and 0.10 if we are satisfied with 90 percent confidence. In this research $\bar{\alpha}$ is chosen to be 0.05. The confidence limit using two tail $\bar{t}$ distributions can be found from Rickmers and Hollis 1967, where afterwards the true mean of population μ can be calculated. Equations 6, 7 and 8 are used when the coastal regions is considered. However, when talking about regions, the area of each region is one of the parameters involved in knowing the average background radiation activity. Therefore, we introduced the weighted average, i .e.,

$$\bar{\bar{X}}_W = \sum_{i=1}^{\bar{N}_0} A_i \bar{X}_i \Big/ \sum_{i=1}^{\bar{N}_0} \mathrm{A}_i \quad , \tag{9}$$

where A_i is the area of region i ,and the weighted variance becomes:

$$\hat{V}_W = \frac{\sum A_i \bar{x}^2 - \bar{x}_W^2 \sum A}{\sum A} \tag{10}$$

where $\overline{N}_0$ is the total number of points of the average for different areas (in this research $\overline{N}_0$ = 11, see Fig.2). Afterwards, one can work out the weighted standard deviation $\bar{s}_w$, and hence, the true weighted mean of population $\bar{\mu}_w$, i.e,

$$(\bar{\bar{X}} - \bar{t}_{v,\bar{a}} \frac{\bar{s}_W}{\sum A}) \langle \mu \langle (\bar{\bar{X}} + \bar{t}_{v,\bar{a}} \frac{\bar{s}_W}{\sum A}) \tag{11}$$

In fact, if $\bar{\bar{X}}_W, \hat{V}_W, \bar{s}_W$ and $\bar{\mu}_w$ are found to be comparable to $\bar{\bar{X}}$, $\bar{\hat{V}}, \bar{s}$ and $\bar{\mu}$, then our survey is acceptable, where $\bar{\bar{X}}_W, \hat{V}_W, \bar{s}_W$ and $\bar{\mu}$ represents the average background radiation activity in Bahrain for α and β, and $\bar{X}_W, \hat{V}_W, \bar{s}_w$ and $\bar{\mu}_w$ belong to the weighted average background activity in Bahrain for α and β radiation as well, i.e.

$$\left(\bar{\bar{x}} - t_{\sum A-1,\bar{x}} \frac{\bar{s}_W}{\sum A}\right) \langle \bar{\mu} \langle \left(\bar{\bar{x}} - t_{\sum A-1,\bar{2}} \frac{\bar{s}_w}{\sum A}\right) \qquad (12)$$

In order to investigate that there is no significant difference between the unweighted $\bar{\bar{x}}$ and the weighted means $\bar{\bar{x}}_w$, we must use the table of $\bar{t}$ distribution at 0.05 levels of confidence and compare it with $\bar{\bar{t}}$ which is the difference between the weighted mean and the unweighted mean, where,

$$\bar{\bar{t}} = \frac{\bar{\bar{X}} - \bar{\bar{X}}_w}{\sqrt{\frac{\hat{v}}{N_o} + \frac{V_w}{\sum A}}} \qquad (13)$$

If $\bar{\bar{t}}$ becomes much smaller than $\bar{t}$ ($\bar{t}_{2\bar{N}_0-2,0.05}$,) then we can say that there is no significant difference between the unweighted and the weighted means.

RESULTS

The results of the background radiation activity of the collected specimens from different terrestrial areas of Bahrain were tabulated according to the official classification of the regions in the Kingdom of Bahrain (Statistical Abstract, 1986). The summery of the results is presented in Tables 1 - 11. These tables includes the recorded number of counts of α and β radiation for samples collected from the surface, α_{sur} and β_{sur}, and specimens collected from a certain depth, α_{dep} and β_{dep}.These can be distinguished in the tables by referring to the first column, where the first 3 characters identify our personal numbering of the reigon.The other characters stands for the sample number followed by letter "s" for surface and "d" for depth (usually taken as not less than 20 cm). The count rate S was calculated by using equation 2 and the standard deviation s was calculated by using equation 4, as mentioned below. The activity of the radiation was recorded by the low background radiation detection machine in units of pico Curies (10^{-12} Curie).

DISCUSSION

The results shown in table 12 and 13, especially when we concentrate on the values of the true mean population, indicate that our sampling is acceptable and the survey is meaningful, except Hidd's Town and Jidhaf's result, where the sampling is not adequate. In fact, the best sampling for a definite area is one which its standard deviation and sampling error is the smallest and that it's true mean of population does not fluctuate remarkably between maximum and minimum. From our results, the best average sampling and consistent measurements was that belonging to region 9 followed by regions 6, 10, 2, 7, 3, 12 and 5, while the worst was for region 8 (Isa Town). This is because that one area of this region has a remarkably high background radiation level comparing to the other areas in Isa Town. This area is opposite the flats of the Ministry of Housing and in front of the Ministry of Labour and Social Affairs. We dealt with this area statistically by excluding it from the total results of this region and found that the sampling error was very large. This can be attributed to the results of R9-16S and R9-17d. From the table we can see that the value of α_{sur} (the background alpha radiation activity of specimens collected from the surface) is a little bit larger than α_{dep} (the background alpha radiation activity of specimens collected from a certain depth from the surface). The ratio of $\alpha_{surl} / \alpha_{dep}$ is equal, on average, to 1.31 with a standard deviation of 0.35 for regions 3, 2, 11, 5, 6, and 9. The highest ratio of $\alpha_{surl} / \alpha_{dep}$ was 0.94. However, for β radiation, β_{sur} is larger than β_{dep} by nearly, on average, a factor of 1.24 and a standard deviation of 0.32 for region 2, 3, 5, 6, 7, 9 and 11. The highest ratio of $\beta_{sur} / \beta_{dep}$ is for region 5, where it has a value of 1.83. Furthermore, the smallest ratio is for regions 8 and 10, which are nearly equal.The results are consistent with each other and indicate that these regions may be, were subjected to a fallout rather than emission of radiation from underground. The results in table 14 show how the standard deviation $\bar{s}$ and $\bar{s}_w$, $\bar{S.E}$ and $\bar{S.E}_w$ and μ and $\bar{\mu}_W$ are comparable with each other, which indicates the validity of our sampling strategy.

Finally, equation 12 was used to find the difference between the weighted and unweighted means. We found that t was 0.367, 0.2315, 0.2890 and 0.2435 for α_{sur}, β_{sur}, α_{dep} and β_{dep}, respectively. These are encouraging figures, since $\bar{t}_{2\bar{N}_0-2,0.05}$ is equal to 2.806(much larger the obtained t values)- using table 17- which indicates that there is no significant difference between the unweighted and the weighted means(the best sampling was for β_{sur}).

The ratio of α_{sur} to α_{dep} as well as β_{sur} to β_{dep} for unweighted and weighted average, from table 14, was found 1.08, for both unweighted averages but 1.06 and 1.09 for the weighted averages, respectively.

The same statistical methods were applied when we studied coastal low background radiation level of the coast of most areas of Bahrain. The results of α_{sur}, β_{sur}, α_{dep} and β_{dep} of the collected samples from Bahrain's coasts are shown in table 15. It can be seen from this table that the sampling error is quite small for the two types of radiations, α and β, emerging from both specimens; those collected from the surface (α_{sur} and β_{sur}) and from a certain depth (α_{dep} and β_{dep}). The lowest sampling error was for α_{dep}. The ratio of $\alpha_{sur} / \alpha_{dep}$

was equal to 1.31 and the ratio of $\beta_{sur} / \beta_{dep}$ was equal to 0.74. The results in table 16 are rather inconsistent and asystematic; it prevents us to draw a conclusion about which coast is most polluted by α and β radiation. Since the highest figure for the average background radiation level was 32.7 pCi, which is nearly equal to the standard low background radiation, we can say that there is no nuclear pollution in the Kingdom of Bahrain's coasts.

ACKNOWLEDGEMENTS

We would like Mrs. A. A. Agab for producing the figures and the tables..

REFERENCES

1. Martin A and Harbison S A (1979) An Introduction to Radiation Protection, second edition, Chapman and Hall Publication, London.
2. Martin A and Harbison S A(1986) An Introduction to Radiation Protection, third edition, Arrowsmith Ltd., Bristol.U.K.
3. Selman J(1977) The Fundamentals of X-ray and Radium Physics, sixth edition, Charles C Thomas Publication , Illinois, USA.
4. Turk J and Turk A(1983) Environmental Science, third edition, Saunders College Publishing, USA.
5. McGraw-Hill Encyclopedia of Environmental Sciences, 1980, second edition, edited by Sybil P Parker, McGraw-Hill Book Publishing Company.UK.
6. Hoppin, G R and Ryderg J(1980) Nuclear Chemistry Theory and Application, Pergamon Press,New York..
7. Statistical Abstract (1985), December 1986, State of Bahrain, Central Statistics Organisastion.
8. Friedlander G, Kennedy J W, Macias E S and Miller J M(1981) Nuclear and Radio chemistry, third edition, John Wiley and Sons, Inc.New York.
9. Rickmers A D and Hollis N T(1967) Statistics in Introduction, McGraw-Hill Publication, Inc.,UK.
10. Pearson E S(1941) *Biometrika*, 32 : , 1941 168-181.

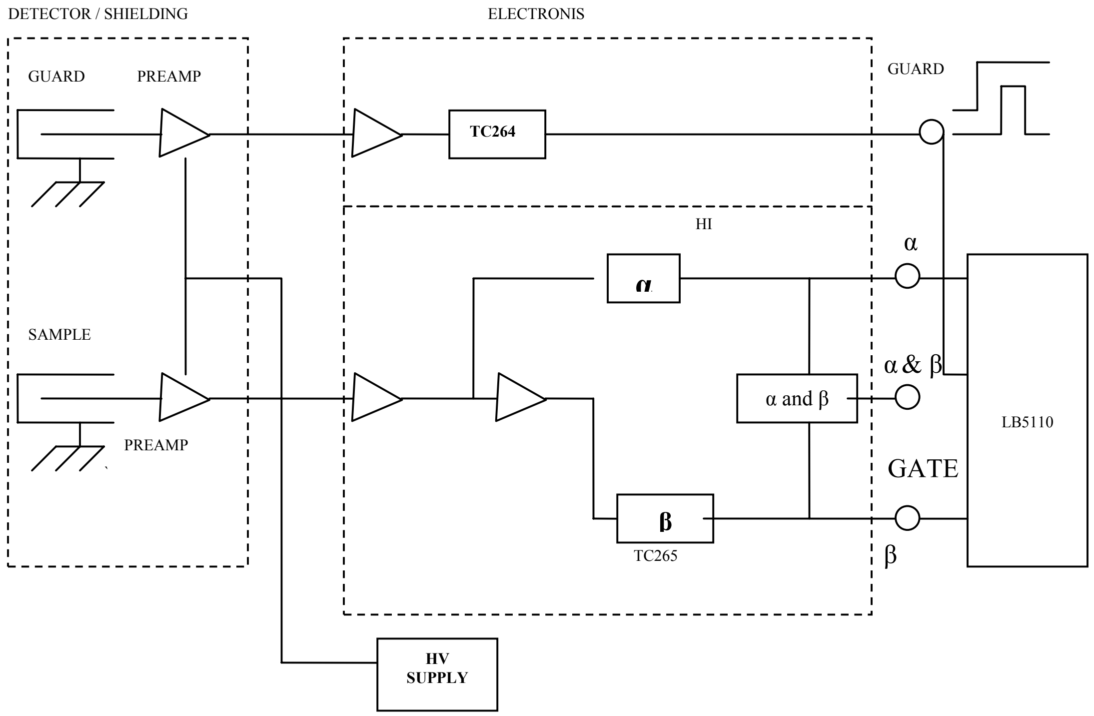

Figure 1: Typical block diagram of the LB 1500 system.

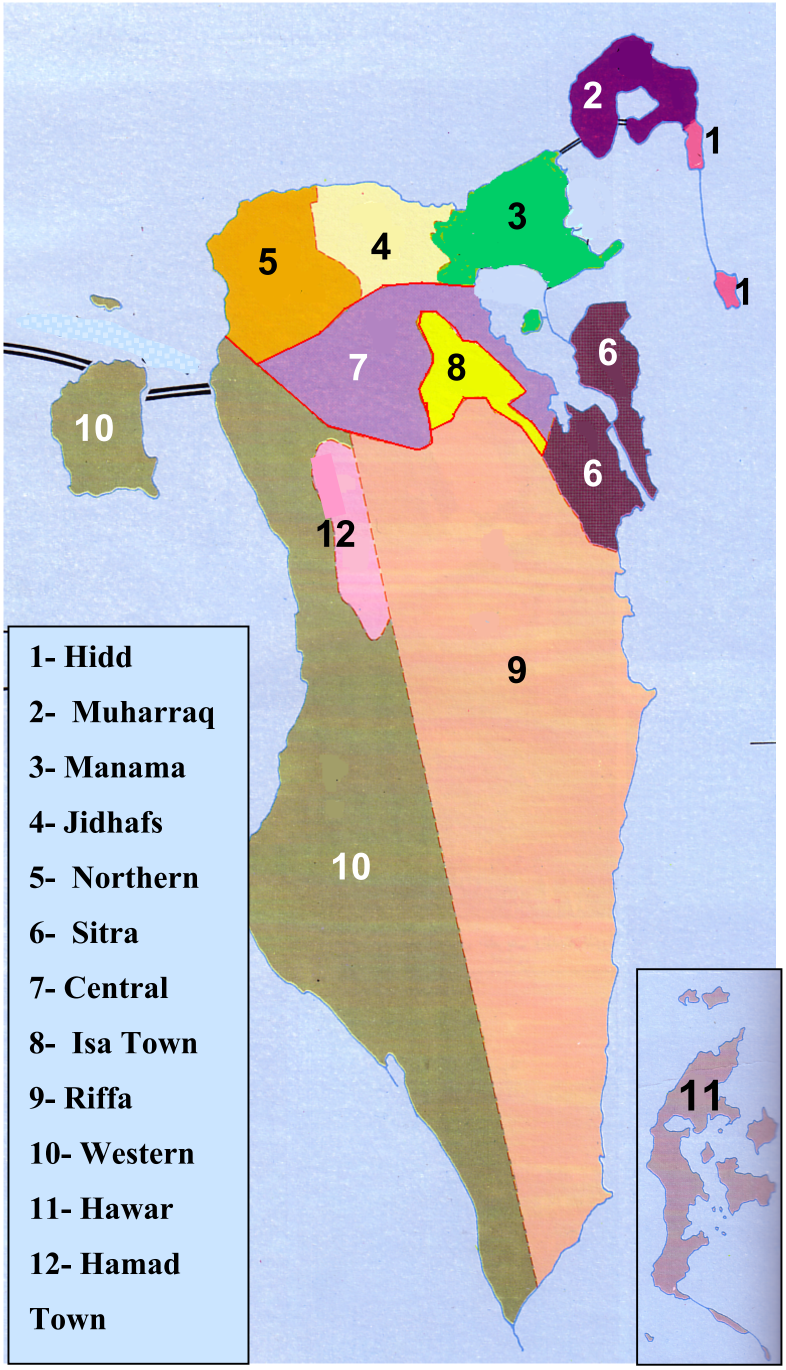

Figure 2: The distributions of the regions in the kingdom of Bahrain

Table 1: Experimental results of Low Background Radiation in Hidd (region 1)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β-Activity pCi	s(α)	s(β)
R13-32s	66	1.07	280	4.93	13.08	33.00	0.177	0.354
R13-33d	72	1.19	275	4.83	14.54	32.33	0.184	0.351

Table 2: Experimental results of Low Background Radiation in Muharraq (region 2)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R12-28s	75	1.30	302	5.27	15.07	35.3	0.184	0.463
R12-29d	71	1.22	320	5.63	14.14	37.7	0.180	0.379
R12-26s	80	1.4	263	4.49	16.23	30.07	0.190	0.347
R12-27d	45	1.70	156	2.35	8.12	15.74	0.148	0.279
R12-16s	73	1.27	240	4.03	14.61	27.0	0.182	0.334
R12-17d	56	0.92	286	4.95	10.67	33.16	0.163	0.360
R12-18s	94	1.68	281	4.85	19.48	32.49	0.204	0.358
R12-19d	51	0.82	169	2.61	9.51	17.48	0.156	0.288
R12-20d	77	0.34	358	6.39	15.54	42.81	0.187	0.398
R12-21d	94	1.68	387	6.97	19.48	46.69	0.204	0413
R12-22s	104	1.88	385	6.93	21.8	46.42	0.214	0.412
R12-23d	94	1168	360	6.43	19.48	43.07	0.204	0.399

Table 3: Experimental results of Low Background Radiation in Manama (region 3)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R9-4s	67	1.19	384	7.17	13.8	48.04	0.173	0.405
R9-5d	76	1.37	281	5.11	15.89	34.24	0.183	0.350
R9-6s	69	1.23	350	6.49	14.27	43.48	0.175	0.387
R9-7d	87	1.59	335	6.19	18.44	41.47	0.194	0.379
R13-26s	87	1.49	307	5.47	18.21	36.61	0.199	0.369
R9-10s	208	4.01	1017	19.83	46.52	132.86	0.293	0.645
R9-11d	73	1.31	305	5.59	15.20	37.45	0.179	0.363
R9-12s	105	1.95	418	7.85	22.62	52.6	0.212	0.421
R9-13d	82	1.63	421	7.91	18.91	53.16	53.16	0.422
R9-14s	89	1.19	384	7.17	13.8	48.04	0.173	0.405
R9-15d	84	1.53	331	6.11	17.75	40.94	0.191	0.377
R8-24s	96	1.65	362	6.43	19.14	43.08	0.209	0.401
R8-25d	75	1.23	257	4.33	14.27	29.09	0.188	0.345

Table 4: Experimental results of Low Background Radiation in Jidhafs (region 4)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R12 – 46s	98	1.76	363	6.49	20.41	43.48	0.208	0.401
R12 – 47d	102	1.84	410	7.43	21..34	49.77	0.212	0.424

Table 5: Experimental results of Low Background Radiation in Northern (region 5)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R11 – 16s	137	2.51	558	10.48	29.12	70.22	0.244	0.487
R11 – 17d	122	2.21	536	10.04	25.64	67.29	0.231	0.478
R11 – 18s	145	2.67	685	13.02	39.70	87.23	0.250	0.536
R11 – 19d	123	2.23	398	7.28	25.87	48.78	0.232	0.416
R11 – 14s	232	4.41	839	16.1	51.16	107.87	0.312	0.591
R11 – 15d	52	0.81	248	4.28	9.4	28.68	0.159	0.336

Table 6: Experimental results of Low Background Radiation in Sitra (region 6)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R13 – 6s	73	1.21	306	5.45	14.79	46.48	0.184	0.369
R13 – 7s	98	1.71	364	6.61	20.9	44.24	0.210	0.399
R13 – 8d	94	1.63	261	4.55	19.92	30.45	0.206	0.526
R13 – 9s	81	1.37	308	5.49	16.74	36.75	0.193	0.370
R13 – 10s	93	1.61	342	6.17	19.67	41.3	0.205	0.388
R13 – 12s	65	1.05	197	3.27	12.83	21.89	0.176	0.304
R13 – 13d	97	1.69	316	5.65	20.65	37.82	0.209	0.375
R13 – 14s	83	1.41	303	5.39	17.23	36.08	0.195	0.364
R13 – 15d	64	1.03	223	3.79	12.59	25.37	0.175	0.320
R8 – 6s	43	0.59	101	1.21	6.84	8.10	0.150	0.238
R8 – 7d	31	0.35	129	1.77	4.06	11.86	0.133	0.260
R8 – 8s	38	0.49	176	2.71	5.69	18.16	0.144	0.294
R8 – 9d	33	0.39	147	2.13	4.52	14.27	0.136	0.274
R8 – 10s	91	1.55	352	6.23	17.98	41.74	0.204	0.396
R8 – 11d	51	0.75	203	3.25	8.7	21.78	0.160	0.312
R8 – 12s	98	1.69	400	7.19	19.6	48.17	0.210	0.418
R8 – 13d	98	1.69	345	6.09	19.6	40.8	0.210	0.392
R8 – 14s	60	0.93	229	3.77	10.79	25.26	0.170	0.328
R8 – 15d	58	0.89	228	3.75	10.32	25.13	0.169	0.327
R8 – 15s	37	0.47	189	2.91	5.45	19.50	0.142	0.301
R8 – 17d	36	0.45	125	1.69	5.22	11.32	0.141	0.257
R8 – 18s	35	0.43	200	3.19	4.98	21.37	0.139	0.310
R8 – 19d	55	0.83	251	4.21	9.63	28.21	0.166	0.341
R8 – 20s	80	1.33	327	5.73	15.43	38.39	0.193	0.383
R8 – 21d	127	2.27	518	9.55	26.3	63.99	0.237	0.473
R8 – 28s	68	1.09	194	3.07	12.65	20.57	0.181	0.306
R8 – 29d	63	0.99	287	4.93	11.48	33.03	0.175	0.362
R8 – 26s	65	1.03	278	4.69	11.95	31.42	0.177	0.357
R8 – 27s	44	0.61	173	2.65	7.076	17.76	0.152	0.292

Table 7: Experimental results of Low Background Radiation in Central (region 7)

Specimen No.	α	s_α	β	s_β	α-Activity	β -Activity	s(α)	s(β)
	Counts	CPM	Counts	CPM	pCi	pCi		
R13 – 16s	178	3.31	673	12.79	40.45	85.60	0.276	0.532
R13 – 17d	269	5.13	816	15.65	62.69	104.75	0.336	0.583
R13 – 18s	82	1.39	338	6.09	16.99	40.76	0.194	0.386
R13 – 19d	84	1.43	227	4.87	17.60	32.60	0.197	0.352
R13 – 20s	92	1.59	297	5.27	19.43	53.27	0.204	0.364
R13 – 21d	102	1.79	355	6.43	21.87	43.04	0.214	0.394
R11 – 22s	104	1.85	401	7.34	21.46	49.18	0.215	0.417
R11 – 23d	69	1.15	275	4.82	13.34	32.29	0.179	0.352
R11 – 24s	61	0.99	167	2.66	13.34	32.30	0.170	0.284
R11 – 25d	71	1.19	301	5.34	13.81	35.78	0.182	0.366
R11 – 26s	119	2.15	446	8.3	24.94	55.61	0.228	0.438
R11 – 27d	78	1.33	306	5.44	15.93	36.45	0.189	0.369
R11 – 28s	66	1.09	266	4.64	12.65	31.45	0.176	0.346
R11 – 29d	69	1.15	292	5.16	13.34	34.57	0.179	0361
R11 – 30s	78	1.33	280	4.92	15.43	32.97	0.189	0.354
R11 – 31d	45	0.67	255	4.42	7.77	29.61	0.15	0.34
R12 – 10s	78	1.36	348	6.19	15.77	41.47	0.188	0.393
R12 – 11d	84	1.48	317	5.57	17.16	37.31	0.270	0.379
R12 – 6s	76	1.32	339	6.01	15.30	40.26	0.186	0.389
R12 – 7d	119	2.18	459	8.41	25.28	56.34	0.227	0.446
R12 – 8s	156	2.92	693	13.09	33.86	87.69	0.344	0.541
R12 – 9d	177	3.34	627	11.77	38.73	78.85	0.387	0.516
R12 – 30s	85	1.50	321	5.65	17.39	37.85	0.195	0.379
R12 – 31s	74	1.28	283	4.89	14.84	32.76	0.183	0.359
R12 – 32s	147	2.74	592	11.07	31.77	74.16	0.251	0.502
R12 – 33s	93	1.66	396	7.15	19.25	47.9	0.203	0.417
R12 – 34s	82	1.44	305	5.33	16.70	35.71	0.192	0.371
R12 – 35s	69	1.81	278	4.79	13.68	32.09	0.178	0.354
R12 – 36s	129	2.38	467	8.57	27.6	57.41	0.226	0.450
R12 – 37	154	2.88	563	10.49	33.39	70.27	0.256	0.491
R6 – 4s	90	1.45	410	7.64	16.82	52.0	0.21	0.418

R6 – 5d	91	1.47	384	7.12	17.05	47.71	0.208	0.406
R6 – 6s	118	2.01	509	9.62	23.3	64.46	0.232	0.463
R6 – 7d	101	1.67	488	9.2	19.64	61.64	0.218	0.454
R6 – 8s	51	0.83	515	9.74	9.63	0.175	0.175	0.651
R6 – 9d	187	3.39	410	7.64	39.32	51.19	0.286	0.418
R6 – 10d	53	0.71	182	3.08	8.24	20.64	0.168	0.290
R6 – 11s	60	0.85	266	4.76	9.86	31.89	0.176	0.343
R6 – 12s	79	1.23	300	5.44	14.27	36.45	0.196	0.362
R6 – 13d	66	0.97	239	4.22	11.25	28.27	0.182	0.327
R6 – 14s	57	0.79	218	3.8	9.16	25.46	0.173	0.313
R6 – 15d	47	0.59	253	4.54	6.84	30.42	0.161	0.335
R9 – 38s	62	109	179	3.07	12.65	20.57	0.167	0.286
R9 – 39d	85	1.55	294	5.37	17.98	35.98	0.192	0.357
R9 – 40s	85	1.55	314	5.77	17.98	38.66	0.192	0.368
R11 – 32s	94	1.65	397	7.25	19.14	48.64	0.205	0.415
R11 – 33d	60	0.97	206	3.44	11.25	23.05	0.169	0.310

Table 8: Experimental results of Low Background Radiation in Isa Town (region 8)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R12 – 38s	233	4.46	732	13.87	51.7	92.92	0.312	0.555
R12 – 39d	188	3.56	661	12.45	41.28	83.40	0.281	0.529
R6 – 48s	78	1.21	272	4.88	14.04	32.67	0.196	0.346
R13 – 28s	185	3.45	607	11.4	42.16	76.77	0.281	0.506
R13 – 29d	733	1.21	281	4.95	14.78	33.13	0.185	0.354
R11 – 34s	110	5.92	330	1.97	22.85	39.66	0.220	0.382
R11 – 35d	66	1.09	201	3.34	12.67	22.38	0.176	0.307
R11 – 36s	162	3.01	517	9.66	34.92	64.72	0.263	0.469
R11 – 37d	184	3.45	503	9.36	40.02	62.71	0.280	0.463
R11 – 38s	437	8.51	1308	25.48	98.72	170.72	0.424	0.733
R11 – 39d	559	10.95	1656	32.44	127	217.35	0.478	0.822
R11 – 40s	97	1.17	387	7.06	19.84	47.3	0.208	0.410
R11 – 41d	85	1.47	401	7.42	17.05	49.72	0.196	0.417
R11 – 42s	287	5.51	932	17.96	63.92	120.33	0.345	0.622
R11 – 43d	358	6.93	1129	21.9	80.39	146.73	0.384	0.682
R11 – 44s	200	3.77	606	11.44	43.7	76.65	0.291	0.506
R11 – 45d	156	2.89	406	9.04	33.52	60.57	0.259	0.456
R11 – 46s	141	2.59	472	8.76	30.04	58.69	0.257	0.450
R11 – 47d	77	1.31	337	6.06	15.20	50.6	0.188	0.385
R12 – 40s	904	17.88	2867	56.57	207.32	378.97	0.604	1.078
R12 – 41d	977	19.34	3054	10.31	224.25	404.02	0.628	1.112
R12 – 42s	622	12.24	1937	37.97	141.92	254.36	0.503	0.889
R12 – 43d	1260	25	3307	65.37	289.87	437.92	0.717	1.338
R9 – 16s	991	10.13	1455	28.59	117.51	191.55	0.63	1.16
R9 – 17d	514	4.46	732	13.87	51.7	92.92	0.457	0.862

Table 9: Experimental results of Low Background Radiation in Riffa (region 9)

Specimen No.	α Counts	s_α CPM	β Counts	s_β CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R6 – 36s	129	2.23	526	9.96	25.87	66.73	0.242	0.471
R6 – 37d	86	1.37	354	6.25	15.89	43.68	0.208	0.391
R6 – 38s	77	1.19	284	5.12	13.80	34.3	0.194	0.353
R6 – 39d	75	1.15	310	5.64	13.34	37.79	0.192	0.368
R6 – 46s	100	1165	592	9.28	19.14	62.18	0.217	0.456
R6 – 47d	89	1.43	370	6.84	16.59	45.83	0.206	0.399
R6 – 44s	58	0.81	252	4.48	9.40	30.02	0.174	0.334
R6 – 45d	149	2.63	623	11.9	30.51	79.73	0.258	0.510
R6 – 16s	78	1.21	248	4.4	14.04	29.48	0.195	0.332
R6 – 17d	53	0.71	204	3.52	8.24	23.59	0.168	0.305
R6 – 18s	65	0.95	238	4.2	11.02	28.14	0182	0.326
R6 – 19d	53	0.71	196	3.36	8.24	22.51	0.168	0299
R6 – 20s	92	1.49	433	8.1	17.28	54.27	0.210	0.429
R6 – 21d	54	0.37	182	3.08	8.47	20.64	0.169	0.290
R6 – 22s	127	2.19	540	10.24	25.40	68.6	0.240	0.47
R6 – 23d	62	0.89	281	5.06	10.32	33.9	0.178	0.352
R9 – 18s	120	2.25	433	8.15	26.1	54.6	0.226	0.428
R9 – 19d	165	3.15	522	9.93	36.54	66.53	0.263	0.468
R9 – 20s	127	2.39	462	8.73	27.57	58.49	0.232	0.441
R9 – 21d	191	3.67	574	10.97	42.57	73.50	0.282	0.489
R9 – 22s	126	2.37	528	10.05	27.49	67.34	0.231	0.470
R11 – 10s	116	2.09	390	7.12	24.24	47.71	0.226	0.412
R11 – 11d	102	1.81	433	7.98	21.8	53.47	0.213	0.432
R11 – 12s	74	1.25	259	4.5	14.5	30.15	0.185	0.342
R11 – 13d	104	1.85	463	4.58	12.4	57.49	0.275	0.446
R10 – 24s	108	1.9	340	6.01	22.04	40.27	0.22	0.39
R10 – 25d	81	1.36	333	5.87	15.78	39.33	0194	0.386
R10 – 26s	99	1.72	501	9.23	19.95	61.84	0.212	0.465
R10 – 27d	107	1.88	591	11.03	21.81	73.90	0.219	0.502
R10 – 28s	133	2.4	586	10.93	27.84	73.23	0.242	0.500
R10 – 29d	127	2.28	575	10.71	26.45	71.76	0.237	0.496

R10 – 30s	121	2.16	538	9.97	25.06		66.80		0.232	0.481
R10 – 31d	130	2.34	587	10.95	27.15		73.37		0.239	0.501
R10 – 32s	155	2.84	619	11.59	32.94		77.65		0.259	0.513
R10 – 33d	149	2.72	584	10.89	31.55		72.96		0.266	0.499
R10 – 34s	73	1.2	276	4.73	13.92		31.69		0.186	0.355
R10 – 35d	62	0.98	228	3.77	11.37		25.26		0.185	0.327
R10 – 36s	96	1.66	356	6.33	19.26		42.41		0.205	0.398
R10 – 37d	60	0.94	281	4.83	10.90		32.36		0.171	0.358
R10 – 38s	91	1.56	390	7.01	18.10		46.97		0.204	0.414
R10 – 39d	49	0.72	248	4.17	8.35		27.94		0.158	0.339
R10 – 40s	63	1	261	4.43	11.6		29.68		0.174	0.347
R10 – 41d	41	0.56	157	2.35	6.5		15.75		0.147	0.280
R10 – 42s	49	0.72	234	3.89	8.35		26.06		0.158	0.331
R10 – 43d	126	2.26	494	9.09	26.22		60.9		0.236	0.462
R10 – 44s	26	0.26	128	1.77	3.02		11.86		0.125	0.259
R10 – 45d	126	2.26	55	10.39	26.22		69.61		0.236	0.489
R10 – 47d	101	1.76	438	7.97	20.42		53.4		0.214	0.437
R10 – 48s	86	1.46	455	8.31	16.94		55.68		0.199	0.445
R10 – 49d	98	1.7	383	6.87	19.72		46.03		0.211	0.411
R6 – 26s	90	1.45	452	8.48	16.8		56.82		0.207	0.438
R6 – 27d	100	1.65	515	9.74	19.14		65.26		0.217	0.466
R6 – 28s	62	0.89	330	6.04	10.32		40.47		0.178	0.378
R6 – 29d	59	0.83	238	4.20	9.63		28.14		0.175	0.326
R6 – 30s	89	1.43	381	7.06	16.59		47.30		0.206	0.404
R6 – 31d	90	1.45	299	5.42	16.82		36.31		0.207	0.362
R6 –32s	86	1.37	322	5.89	15.89		39.4		0.203	0.374
R6 –33d	76	1.17	322	5.88	13.57		39.4		0.194	0.374
R6 –34s	105	1.75	421	7.86	20.3		52.66		0.221	0.424
R6 –35d	153	2.71	530	10.04	31.44		67.27		0.261	0.470
R9 –23d	171	3.27	568	10.85	37.93		72.70		0.267	0.487
R9 –24s	85	1.55	363	6.75	17.98		45.23		0.192	0.394
R9 –25d	70	1.25	230	4.09	14.5		27.40		0.176	0.319
R9 –26s	129	2.43	300	7.29	28.19		48.84		0.234	0.407
R9 –27d	115	2.15	379	7.07	24.94		47.37		0.221	0.402
R9 –28s	167	3.19	582	11.13	37.0		74.57		0.264	0.493

R9 –29d	214	4.13	688	13.25	47.9	88.78	0.297	0.534
R9 –30s	100	1.85	355	6.59	21.46	44.15	0.207	0.390
R9 –31d	188	3.61	578	10.95	41.88	73.37	0.280	0.489
R9 –32s	94	1.73	402	7.53	20.07	50.45	0.201	0.413
R9 –33d	111	2.02	302	5.53	25.01	37.05	0.218	0.362
R9 –34s	110	2.05	310	5.69	23.78	38.12	0.217	0.366
R9 –35d	89	1.63	321	5.91	18.91	39.6	0.196	0.372
R9 –36s	102	1.89	318	5.85	21.92	39.20	0.209	0.371
R9 –37d	114	2.13	328	6.05	24.71	40.54	0.220	0.376
R9 –42s	99	1.63	375	6.94	18.9	46.50	0.216	0.401
R9 –43d	79	1.23	316	5.76	14.27	38.59	0.196	0.371
R9 –44s	124	2.33	426	8.01	27.03	53.67	0.229	0.425
R9 –45d	149	2.83	497	9.43	32.83	63.18	0.250	0.457
R10 – 4s	125	2.24	390	7.01	25.99	46.97	0.235	0.415
R10 – 4d	83	1.4	280	4.81	16.24	32.23	0.196	0.358
R13 – 11s	104	1.83	400	7.33	22.36	49.06	0.216	0.416
R9 –42s	128	2.41	457	8.63	27.96	57.82	0.329	0.439
R9 –43d	28	0.41	126	2.01	4.756	13.47	0.119	0.246
R10 – 10s	100	1.74	371	6.63	20.18	44.42	0.215	0.405
R10 – 11d	91	1.56	346	6.13	18.09	41.07	0.213	0.393
R10 – 12s	117	2.08	400	7.21	24.13	48.31	0.228	0.419
R10 – 13d	69	1.12	249	4.19	13.0	28.07	0.181	0.340
R6 – 40s	83	1.31	328	6.02	15.2	40.33	0.200	0.378
R6 – 41s	137	2.39	489	9.22	27.73	61.77	0.248	0.455

Table 10: Experimental results of Low Background Radiation in Manama (region 10)

Specimen No.	α Counts	s_{α} CPM	β Counts	s_{β} CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R11 – 5d	65	1.07	235	4.02	12.41	26.93	0.175	0.328
R11 – 6s	99	1.75	438	8.08	20.3	54.14	0.210	0.434
R11 – 7d	127	2.31	441	8.14	26.80	26.80	0.235	0.436
R11 – 8s	159	2.95	588	11.08	34.22	74.24	0.261	0.499
R11 – 9d	141	2.56	529	9.9	29.70	66.33	0.247	0.475

Table 11: Experimental results of Low Background Radiation in Hamad Town (region 12)

Specimen No.	α Counts	s_{α} CPM	β Counts	s_{β} CPM	α-Activity pCi	β -Activity pCi	s(α)	s(β)
R12 – 4s	106	1.92	384	6.91	22.26	46.29	0.215	0.411
R12 – 5d	99	1.78	424	7.71	20.64	51.65	0.209	0.42
R10 – 20s	136	2.46	499	9.91	28.54	61.57	0.244	0.464
R10 – 21d	93	1.58	418	7.57	18.33	50.72	0.205	0.428
R10 – 22s	199	3.72	672	12.65	43.15	84.76	0.291	0.533
R10 – 23d	176	3.26	689	12.99	37.82	87.03	0.275	0.540
R10 – 16s	123	2.2	416	7.53	25.52	50.45	0.233	0.427
R10 – 17d	92	1.58	415	7.51	18.33	50.32	0.205	0.426
R10 – 18s	122	2.18	467	8.55	25.29	57.29	0.232	0.449
R10 – 19d	103	1.8	468	8.57	20.88	57.42	0.215	0.451

Table 12: Statistical results of alpha background radiation level in different terrestrial regions in the kingdom of Bahrain.

REGION	**α – RADIATION (Surface)**				**α – RADIATION (Depth)**			
	$\bar{X}$ *PCi*	*S*	*S.E*	$< \mu >$ *PCi*	$\bar{X}$ *PCi*	**S**	**S.E**	$< \mu >$ *PCi*
1. HIDD	*13.08*	-	-	-	*14.54*	-	-	-
2.MUHARRAQ	*17.44*	*3.09*	*1.383*	*13.57 , 21.31*	*13.85*	4.62	1.75	9.58 , 18.12
3. MANAMA	*21.92*	*11.26*	*4.26*	*11.51 , 32.33*	*16.47*	1.61	0.66	14.84 , 18.08
4. JIDHAFS	*20.41*	-	-	-	*21.34*	-	-	-
5. NORTHERN	*39.99*	*11.02*	*6.36*	*33.63 , 67.35*	*20.30*	9.44	5.45	3.15 , 43.75
6. SITRA	*12.98*	*5.42*	*1.31*	*10.20 , 15.76*	*12.75*	7.249	2.09	8.15 , 17.35
7. CENTRAL	*19.18*	*7.9*	*1.49*	*16.12 , 22.24*	*19.69*	13.35	2.98	13.44 , 25.94
8. ISA TOWN	*68.36*	*57.45*	*15.94*	*33.66 , 92.15*	*78.97*	90.48	26.12	21.48 , 136.46
9. RIFFA	*22.11*	*6.22*	*1.20*	*19.65 , 24.57*	*21.86*	12.4	2.531.63-	16.63 , 27.09
10. WESTERN	*19.14*	*7.72*	*1.65*	*15.71 , 22.57*	*19.39*	7.80	3.69	16.01 , 22.77
11. HAWAR	-	-	-	-	-	-		-
12.HAMAD TOWN	*28.95*	*8.24*	*3.68*	*18.73 , 39.17*	*23.20*	8.26		12.96 , 33.44

Table 13: Statistical results of beta background radiation level in different terrestrial regions in the kingdom of Bahrain.

REGION	**β – RADIATION (Surface)**				**β – RADIATION (Depth)**			
	$\bar{X}\ PCi$	***s***	***S.E***	$<\mu>PCi$	$\bar{X}\ PCi$	**S**	**S.E**	$<\mu>PCi$
1. HIDD	33	-	-	-	32.33	-	-	-
2.MUHARRAQ	34.26	7.46	3.33	25.02 , 43.50	33.81	12.52	4.73	22.23, 45.39
3. MANAMA	53.55	33.28	12.58	27.77 , 89.33	37.69	5.26	2.15	32.17 , 43.21
4. JIDHAFS	43.48	-	-	-	49.77	-	-	-
5. NORTHERN	88.44	18.85	10.89	41.64 , 135.24	48.25	19.31	11.15	0.27 , 96.23
6. SITRA	30.42	12.13	2.94	24.19 , 36.65	28.67	14.66	4.23	19.36, 37.98
7. CENTRAL	46.57	17.62	3.33	39.74 , 53.40	42.21	20.52	4.59	32.61, 51.81
8. ISA TOWN	123.48	101.37	28.39	62.23 , 184.73	137.6	143.15	41.32	46.7 , 228.5
9. RIFFA	49.76	12.4	2.39	44.82 , 54.67	45.46	20.81	4.25	36.67 , 54.25
10. WESTERN	48.2	16.77	3.58	40.77 , 55.63	49.13	19.12	3.99	40.86 , 57.4
11. HAWAR	-	-	-	-	-	-	-	-
12.HAMAD TOWN	60.00	15.02	6.72	41.35 , 78.65	59.43	15.69	7.02	39.94 , 78.92

Table 14: Comparison between unweighted and weighted statistical parameters of α and β low background radiation level.

TYPE OF RADIATION	UNWEIGHTED PARAMETERS				WEIGHTED PARAMETERS			
	$\overline{\overline{X}}PCi$	$\overline{S}$	$\overline{S.E}$	$<\overline{\mu}> PCi$	$\overline{\overline{X}}_W\ PCi$	S_W	$\overline{S.E}_W$	$<\overline{\mu}_W> PCi$
α (Surface)	*25.78*	*16.01*	*4.76*	*(15,16,36,37)*	*22.63*	8.25	2.49	(6.52 , 38.4)
α (Depth)	*23.85*	*18.61*	*5.61*	*(11,35,36,35)*	*21.29*	8.45	2.55	(6.015 , 36.56)
β (Surface)	*55.56*	*27.62*	*8.33*	*(37,44,74,55)*	*51.63*	14.75	4.46	(15.87, 87.73)
β (Depth)	*51.30*	*30.02*	*9.05*	*(31,13,71,46)*	*47.10*	13.78	4.16	(14.39,79.8)

The areas used in obtaining the weighted statistical parameters are as follows (statistical abstract1985)

REGION	1	2	3	4	5	6	7	8	9	10	11	12
AREA (km^2)	5.23	15.22	25.38	21.58	36.84	28.57	35.20	12.36	291.6	156.0	49.96	13.12

Table 15: Average low background radiation activity $\bar{X}$ in pCi for α and β radiation collected from surface and at certain depth in some coastal regions in the kingdom of Bahrain.

NAME OF THE AREAS	$\bar{X}(\alpha)_{sur}$	$\bar{X}(\alpha)_{dep}$	$\bar{X}(\beta)_{sur}$	$\bar{X}(\beta)_{dep}$
AL JUFFAIR	*19.79*	*14.55*	*39.49*	*40.89*
BELALJALJAZAIR	*4.99*	*6.38*	*25.86*	*24.79*
ALNABEG SALEH	*24.24*	*18.21*	*48.98*	*39.06*
ALHIDD	*27.98*	*18.21*	*52.14*	*0.236*
GALALI	*18.45*	*16.25*	*43.30*	*45.58*
ALDAIR	*12.1*	*16.01*	*33.53*	*27.11*
ALDARAZ	*16.82*	*10.32*	*43.28*	*20.5*
ALOKOR	*11.95*	*7.08*	*31.42*	*17.76*
HALAT ALSALATH	*5.33*	*3.25*	*9.85*	*10.11*
JAWW	*12.99*	*7.42*	*23.12*	*20.03*
ALDOR	*8.35*	*4.64*	*23.12*	*16.261*
ALBUDYYA	*12.87*	*14.03*	*30.81*	*45.21*
SITRAH	*7.98*	*9.44*	*25.1*	*17.61*
ALMANAMA PORT	*8.47*	*8.24*	*16.01*	*55.18*
ALMOHARRAQ	*10.2*	*8.11*	*24.58*	*20.7*
ASKAR	*25.98*	*16.24*	*46.97*	*32.24*

Table 16: Statistical data related to the α and β low background radiation level in samples collected from certain coast of Bahrain, for specimens collected from the surface of the coast and at a certain depth.

	$\bar{X}(PC1)$	S	**S.E**	**< μ >**	**No**
α (sur)	14.17	6.92	1.51	11.02 , 17.32	21
β (sur)	32.7	12.47	2.72	27.03 , 38.37	21
α (dep)	10.86	5.17	1.186	8.37 , 13.35	21
β (dep)	28.47	12.69	2.91	22.35 , 34.59	21

Table 17: Critical values of $\bar{t}$ distribution (pearson 1941).

	Two – tail Critical Values						
	0.50	**0.25**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**
1	1.00000	2.4142	6.3138	12.706	25.452	63.657	127.62
2	0.81650	1.6036	2.9200	4.3027	6.2053	9.9248	14.089
3	0.76489	1.4226	2.3534	3.1825	4.1765	5.8409	7.4533
4	0.74070	1.3444	2.1318	2.7764	3.4954	4.6041	5.5976
5	0.72669	1.3009	2.0150	2.5706	3.1634	4.0321	4.7733
6	0.71756	1.2733	1.9432	2.4469	2.9687	3.7074	4.3168
7	0.7114	1.2543	1.8946	2.3646	2.8412	3.4995	4.0293
8	0.70639	1.2403	1.8595	2.3060	2.7515	3.3554	3.8325
9	0.70272	1.2297	1.8331	2.2622	2.6850	3.2498	3.6897
10	0.69981	1.2213	1.8125	2.2281	2.6338	3.1693	3.5814
11	0.69745	1.2145	1.7959	2.2010	2.5931	3.1058	3.4966
12	0.69548	1.2089	1.7823	2.1788	2.5600	3.0545	3.4284
13	0.69384	1.2041	1.7709	2.1604	2.5326	3.0123	3.3725
14	0.69242	1.2001	1.7613	2.1448	2.5096	2.9768	3.3257
15	0.69120	1.1967	1.7530	2.1315	2.4899	2.9467	3.2860
16	0.69013	1.1937	1.7459	2.1199	2.4729	2.9208	3.2520
17	0.68919	1.1910	1.7396	2.1098	2.4581	2.8982	3.2225
18	0.68837	1.1887	1.7341	2.1009	2.4450	2.8784	3.1966
19	0.68763	1.1866	1.7291	2.0930	2.4334	2.8609	3.1737
20	0.68696	1.1848	1.7247	2.0860	2.4231	2.8453	3.1534
21	0.68635	1.1831	1.7207	2.0796	2.4138	2.8314	3.1352
22	0.68580	1.1816	1.7171	2.0739	2.4055	2.8188	3.1188
23	0.68531	1.1802	1.7139	2.0687	2.3979	2.8073	3.1040
24	0.68485	1.1789	1.7109	2.0639	2.3910	2.7969	3.0905
25	0.68443	1.1777	1.7081	2.0595	2.3846	2.7874	3.0782
26	0.68405	1.1766	1.7056	2.0555	2.3788	2.7787	3.0669
27	0.68370	1.1757	1.7033	2.0518	2.3734	2.7707	3.0565
28	0.68335	1.1748	1.7011	2.0484	2.3685	2.7633	3.0469
29	0.68304	1.1739	1.6991	2.0452	2.3638	2.7564	3.0380
30	0.68276	1.1731	1.6973	2.0423	2.3596	2.7500	3.0298
40	0.68066	1.1673	1.6839	2.0211	2.3289	2.7045	2.9712
60	0.67862	1.1616	1.6707	2.0003	2.2991	2.6603	2.9146
120	0.67656	1.1559	1.6577	1.9799	2.2699	2.6174	2.8599
∞	0.67499	1.1503	1.6449	1.9600	2.2414	25758	2.8070
ν	0.25	0.125	0.05	0.025	0.0125	0.005	0.0025
α	One – tail Critical Values						

دراسة مسحية للأشعة النووية المتخلفة في مملكة البحرين

وهيب الناصر+، شوقي الدلال+، مازن زينx، ياسر الناصر*
+ قسم الفيزياء، كلية العلوم، جامعة البحرين، ص.ب.32038, مملكة البحرين
* ديوان مجلس الوزراء، ص.ب.1000, مملكة البحرين , x متوفى

ملخص

في هذا البحث تم إجراء مسح لقياس نسبة أشعة ألفا وجاما المتخلفة ذات المستوي المنخفض في مملكة البحرين. تم سحب 2 جرام من التربة من على سطح الأرض وكذلك على عمق معين من الأراضي الداخلية وكذلك الساحلية لغرض التحقق من وجود تلوث نووي أو وجود مواد مشعة.وأشارت النتائج أن نسبة المتوسط الموزون لأشعة ألفا المتخلفة هي 22.63 بيكوكيوري (pCi) للعينات المأخوذة من سطح الأراضي الداخلية و 0.21 بيكوكيوري من تلك المأخوذة من على عمق معين. أما بالنسبة للأراضي الساحلية فإن مستوى الإشعاع قد بلغ 14.17 بيكوكيوري و 10.86 بيكوكيوري، على الترتيب. أما متوسط أشعة جاما المتخلفة فقد كانت 23.85 بيكوكيوري للعينات المأخوذة من سطح الأراضي الداخلية و 47.10 بيكوكيوري لتلك المأخوذة من على عمق معين، بينما بلغ مستوى الإشعاع في التربة المأخوذة من الأراضي الساحلية 32.70 و 28.47 بيكوكيوري، على الترتيب.أما بالنسبة للمتوسط غير الموزون فإن نسبة إشعاع ألفا كانت 25.78 بيكوكيوري لعينات مأخوذة من سطح الأراضي الداخلية و 23.85 بيكوكيوري لعينات مأخوذة من على عمق معين، بينما كانت لأشعة بيتا 55.56 و 51.30 بيكوكيوري، على الترتيب.كما أشارت النتائج أن مدينة عيسى هي المنطقة التي بها أكثر إشعاع ألفا النووي (68.36 بيكوكيوري) لعينات مأخوذة من على سطح الأراضي الداخلية و 78.97 بيكوكيوري لعينات مأخوذة من على عمق معين، بينما كان أقل إشعاع ألفا النووي في سترة (12.98 و 12.75 بيكوكيوري، على الترتيب). كما أن أكثر إشعاع بيتا النووي كان كذلك في مدينة عيسى (123.48 بيكوكيوري) لعينات مأخوذة من على سطح الأراضي الداخلية و 137 بيكوكيوري من على عمق معين، أما أقل نسبة إشعاع بيتا فقد كانت في سترة كذلك حيث كانت 30.42 و 28.62 بيكوكيوري، على الترتيب.

أما أكثر إشعاع ألفا النووي لعينات مأخوذة من الأراضي الساحلية فقد كان في مدينة الحد (27.98 بيكوكيوري لتلك المأخوذة من على السطح و 18.21 بيكوكيوري لتلك المأخوذة من على عمق معين)، بينما أدنى نسبة إشعاع فقد كانت في بلاج الجزائر (4.94 و 6.38 بيكوكيوري، على الترتيب). أما أكثر إشعاع بيتا النووي في المناطق الساحلية فقد كان في مدينة الحد كذلك (52.14 بيكوكيوري) لعينات مأخوذة من على السطح، أما تلك العينات المأخوذة من على عمق فقد كان أكثر إشعاع بيتا النووي في ميناء المنامة (55.18 بيكوكيوري). أما أقل نسبة إشعاع بيتا النووي في المناطق الساحلية فقد كان في حالة السلطة في المحرق (5.33 بيكوكيوري لعينات مأخوذة من على السطح) بينما لتلك المأخوذة من على عمق فقد كانت في مدينة الحد.

وأشارت نتائج الدراسة أن النسبة بين أشعة ألفا في عينات مأخوذة من على السطح وتلك المأخوذة من على عمق، وكذلك الحال لأشعة بيتا، في الأراضي الداخلية كانت تساوي 1.08 عندما كانت غير موزونة إحصائيا بينما بلغت 1.06 و 1.09، على الترتيب عندما كانت موزونة إحصائيا، وهذا يشير إلى أنه ليس هناك تلوث نووي هام نتيجة هطول أشعة نووية على أراضي البحرين أو وجود مصادر مشعة في باطنها.