Concentrations of natural and man-made radioactivity soil and ground water in Al-Madinah Al-Monawarah

Afaf A. Fakeha[1] (sabrytaha2000@yahoo.com), Safiah Q. Hamidalddin (safiahqh@yahoo.com) Nuha Abdul-Hameed Al-Turkestany (alturki28@hotmail),

Ahlam M.A. Al-Amri (ahlam1403@hotmail.com),and NAGDYA M.IBRAHEIM(NUCLEAR SAFETY CENTRE)EAEA.

Department of Physics, Faculty of Science for Girls, King Abdulaziz university, Jeddah, Saudi

ABSTRACT

Al-Madinah Al-Monawarah lies around latitude 39˚36'00" , longitude 24˚28'00" , altitude 624 m . Ten surface soil samples were collected from Al-Madinah Al-Monawarh province with a template 30×30×15 cm. Samples were analyzed by atomic absorption spectrometer for Aluminum (Al) , Iron (Fe) and Calcium (Ca) concentrations in percent, Lead (Pb) and Arsenic (As) in ppm. The concentrations range for Al from (4.48 -7.65%), Fe from (3.08 -4.92 5%) , Ca from (1.66 -10.60 %) , Pb from (14 -27 ppm) and As from (10.5 -30.7 ppm) . Also XRD spectrometry was applied for the chemical and mineral composition, the major and minor composition is ALBITE , CALCITE , CLINOCHLORE , MICROCLINE , QUARTZ . Gamma-ray spectrometer based on HPGe crystal was applied for the concentrations in Bq/kg dry weight , for (^{238}U and ^{226}Ra series) from 7.01 to 15.55 Bq/kg, (^{232}Th and ^{228}Ra series) from 5.23 to 21.8Bq/kg, ^{40}K concentrations range from (64.6 to 754.2 Bq/kg). The man-made ^{137}Cs was observed in some samples. The radium equivalent Bq/kg was calculated , and the absorbed dose rate nGy/h for each sample was calculated one meter above the earth. It is found that the values of the absorbed dose are in the accepted range put by EPA (Environmental Protection Association).

Four underground water samples from the study area Al-Khief (Western province of Saudi Arabia) were analyzed by both an atomic absorption spectrometer for the ; Ca , Na , Mg , K , Fe , Al , Cs , Hg , Bi , Pb and U concentrations, and a HPGe gamma-ray spectrometer system for the concentrations of radioactive nuclides of the ^{226}Ra and ^{232}Th series and ^{40}K from the absorbed dose which calculated for the age categories ; <1y , 1-2y , 2-7 y, 7-10y and > 17y.

Key words; atomic absorption, gamma-ray spectrometry ,natural radioactivity, absorbed dose.

[1]Corresponding author. Tel.: +966505546949

Afa Fakeha E-mail address:sabrytaha2000@yahoo.com

1. INTRODUCTION

Study of radioactivity levels and concentrations of natural and man-made radionuclides have been done all over the world . In Egypt (Ibrahiem et al 1993) gave a base map for the radioactivity in the Delta and middle Egypt, by HPGe gamma-ray system they measured the absorbed dose one meter above the ground in each point. Also (Ibrahiem et al 1995) studied sediments and surface area of Naser lake area by both neutron activation analysis and gamma-ray spectroscopy techniques. Amaral, 2000, in Portogal studied gamma-ray spectrum and dose rate In Situ, also studied the type and composition of the different rocks, as well as the mechanical, chemical and biological properties for each type of soil. Melo et al 2000; studied the severe internal dose in Brazil from the high radioactivity concentrations due to the concentrations of uranium and thorium in this area. Morton et al, 2006, measured the natural radioactivity concentrations $^{232}Th, ^{238}U$ and ^{226}Ra series and ^{40} K , as well as the man made ^{137}Cs . Also they studied the salinity level in the soil from the series of the black plateau resulting from the flood of Virgin River, south-east of Nevada state USA. They analyzed the samples by EDS electron dispersion spectrometer in addition XRD diffraction spectrometer for the soil composition. Wu,2006 studied the accumulation of radioactive concentrations owing to the long period of irrigation according to the Yucca Mountain program of

Nevada state USA to point out , time needed to reach equilibrium , the suitable time for irrigation, study of agricultural areas irrigated for long time and the change of concentrations of radioactive nuclides in water.

Flrou et al, 2007; studied the effect of the external dose intake for areas of high radioactivity levels in three islands from Greece of volcanic origin. In these areas many geothermal springs gives gases as carbon mono-oxide, carbon dioxide as well as radon. Study was done by In Situ NaI(Tl) spectrometer, concentrations of natural radionuclides in soil, spring water, sea water and sediments, they calculated the dose rate and the external risk also the quality assurance of the ecosystem. Baykara and Dogru, 2008, studied 72 soil samples from the northern and eastern regions of Anadool of Turkey, by NaI(Tl) for the concentrations of radioactivity and dose rate. Santos et al 2009 analyzed 78 soil samples by HPGe gamma-ray system for the concentrations of ^{226}Ra and ^{228}Ra. Jankovic Mandic et al studied the distribution of natural radionuclides in Belgrad province, Serbia, they compared the results with some published work. Saidou et al ,2011 studied site for uranium mining in Cameron to plot a base line map for Poli province, they found that the concentrations of radionuclides and the absorbed dose are slightly higher the world average.

The aim of this work is to make base line map for the study area, to be compared with future studies for any environmental or geological changes. Study of the relation between type of soil and the radioactivity level, measurements of dose rate for population in this area, also $relation$ between the geological composition of the soil and the dose rate.

2. Geology of the study area

The study area lies east of the Red sea between 24° 22' 27" and 24° 32'16" latitude north and 39° 31' 36" and 39° 43' 11" longitude east and elevation 625m above the sea level . 430km from Mekka, 220km from Yanboa the nearest port to Al-Madina Almonawra, 150km from the Red Sea , and 980km from Al-Reyad . Mountain Ohod from the north, mountain Salaa north- west, Harrat Waqem and Wabara from the south. (Badr , 1993) .

Rock types in the study area are :

1-Volcanic rocks , Silicic volcanic rocks , pyroclastic rocks andr hyollitic tuff . 2-Sandy rocks.

3-Sedimentary rocks , from the erosion of volcanic rocks .

4-Breccia Andesitic. -5Basalt. 6-Sandy regions. 7-Sandstone.

8-Harrat areas , Harrat Khyber and Harrat Hirmah .

Al-Madina also contains vales from sand and clay, and sediments from granite , (Saudi Geological Survey , 2010).

9-Felsic rocks . 10-Quaternary deposits.

3.Sampling and sample preparation

The study area was divided to 10 parts, a sample was collected from each part.Sampling were done from 0 to 15 cm by a template 30x30x15 cm. Samples were collected in a polyethylene bags, then labeled. Remains of plants, weeds and rocks were removed, then soil samples were grinded, sieved with a 1mmx1mm mesh sieve, mixed for homogeneity. Samples were dried to 80 ℃ not to lose the volatile ^{137}Cs or the natural polonium. A 640 cc of the dried sample were weighed then stored for one month in a polyethylene Marinelli beaker, for gamma-ray spectrometry, to reach secular equilibrium between $^{226}Ra\ and\ ^{226}Th$ and their progeny. A 10 gm of the dried sample were used for the analysis by atomic absorption for the K , Al , Bi , Pb and Th concentrations. Also 10 gm for XRD for the chemical and mineral composition .

Sampling was done obeying methods adopted by Her Majesty's Office, the UK Atomic Energy Authority and UK Nirex Ltd, (RADREM , 1980).

4.Measurements

An X-ray diffraction spectrometer model Burker XRD D8 Advance was applied for the chemical and mineral composition. Also an inductively coupled plasma atomic absorption spectrometer of A-Analyst 700 model Perkin Elmer OPTIMA 4000 DV series, was used for the concentrations of Pb and As ppm and Al , Fe and Ca %.

A gamma ray spectrometer based on a HP Ge crystal of the vertical type Canberra model number GC2520, cryostat Canberra model 7500SL, FWHM 1.06 keV for the transition 122 keV ^{57}Co and 2.0 keV for the transition 1332.5 keV of ^{60}Co, peak to Compton ratio 53:1, relative efficiency 27.1%, were applied

for the concentrations of the natural ^{232}Th and ^{226}Ra series and ^{40}K and the manmade ^{137}Cs.

Multichannel analyzer of 8K ADC (analogue to digital converter), Genie 2000 program, where used for spectrum analysis. ^{152}Eu in 640cc Marinilli beaker, the same type, volume and material of these used for measurements, were used for absolute calibration, and natural KCl with three different concentrations, as well as ^{226}Ra point source normalized to the same configuration .

Energies (keV) of 295.2 (20.1) and 351.9 (38.3) ^{214}Pb and 609.3 (49.9), 1120.3 (16.2) and 1764.5 (16.0) ^{214}Bi were used for the ^{226}Ra series. 338.4(13) ,911.16(30.3) and 968.97(18.3)^{228}Ac and 727.25 (8.1) ^{212}Bi, also 583.02(33.2) and 2614.48(35.9) ^{208}Tl for the ^{232}Th series (Saito & Moriuchi ;1985). 1460.8(10.7) for the ^{40}K and 661.65(89.9) for the ^{137}Cs (Holden ;2003).

5.Results and discussion

Table (1) represents XRD analysis results it shows the major and minor minerals. The major mineral is the quartz (SiO_2), the next is albite ($NaAlSi_3O_8$), then calcite ($CaCO_3$). The minor minerals are clinochlore ($(MgFe^{2+})17Si_{20}O_{54}(OH)_6$] ,and microline ($KAlSi_3O_8$).

Table (2) gives concentrations of Al, Fe and Ca % and Pb and As ppm by atomic absorption analysis. The stable lead (^{208}Pb, ^{206}Pb and ^{207}Pb) ranged from 14.00 to 27.00 ppm. Calcium, (^{40}Ca, ^{42}Ca, ^{43}Ca, ^{44}Ca, ^{46}Ca and ^{48}Ca), they are all stable, ranged from 1.66 to 10.60%. Arsenic (^{75}As) ranged from 10.50 to 30.70 ppm. Aluminum (^{27}Al) ranged from 4.5 to 7.7%. Iron (^{54}Fe,^{56}Fe,^{57}Fe and ^{58}Fe), ranged from 3.08 to 4.92% .

Table (3) represents concentrations of radionuclides for the natural $^{238}U - ^{226}Ra$ series and $^{232}Th - ^{228}Ra$ series and ^{40}K and the manmade ^{137}Cs, Bq/kg dry weight .

For the $^{238}U - ^{226}Ra$ series concentrations protactinium-234m (^{234m}Pa) ranged from LDL to 12.3, and the ^{226}Ra series from 7.01 to 1555. This shows disequilibrium in the series. For the $^{232}Th - ^{228}Ra$ series concentrations ranged from 5.23 to 21.8, disequilibrium can't be observed in the series. The main reasons for disequilibrium the difference in chemical and physical properties of the elements in the series, weathering , radon as a gas can escape from the sample, also the emission of beta or alpha particles may led the residual nucleus leaving the crystal .

^{40}K concentrations ranged from 62.6 (2.2%) to 754.2 (25.5%) this sample contains microlene ($KAlSi_3O_8$).

Figures (1, 2 and 3) show the relations between ^{226}Ra and ^{228}Ra , ^{40}K and ^{226}Ra and ^{40}K and ^{228}Ra .

^{137}Cs were found in four samples concentrations around 3.0 Bq/kg dry weight .

The Ra_{eq} is calculated from the equation (1) (Tufail et al 2006) :

$$Ra_{eq} = A_{Ra} + (A_{Th} \times 1.43) + (A_K \times 0.077) \quad (1)$$

Where; A_{Ra}, A_{Th} and A_K are concentrations Bq/kg for radium , thorium and potassium respectively .

The absorbed dose nGy/ h is given by the equation (2) (Quindos et al , 2004):

$$D = C_{Ra} A_{Ra} + C_{Th} A_{Th} + C_K A_K \quad (2)$$

Where: C_{Ra} , C_{Th} and C_K are the conversion factors Bq/kg to nGy/h for radium , thorium and potassium (Quindos et al 2004) .

Table (4) represents the values of the Ra_{eq} and the absorbed dose. The Ra_{eq} Bq/kg dry weight ranged from 22 to 104.9, less than 370 adopted by EPA for the permissible value. Using the conversion factors from Bq/kg to nGy/y (Qunidos et al ,2004) the adsorbed dose one meter above the ground, ranged from 10 nGy/h (>1mmGy/y) to 52.2 nGy/h (o.46 mGy/y), it is within the permissible value given by EPA and UNSCEAR .

As a conclusion the collec ted samples show that the study area is safe for the radiological levels, for either to live or to cultivate if the type of soil is suitable.

Table (5) gives a comparison of the activity concentrations in the present work and some published values.

Table (6) represents elemental concentrations in ppm or ppb measured by ICP-Atomic

Absorption spectrometer for four samples from AL-Khief.

For Ca, the concentrations in ppm of the samples are in the accepted range. For Na, results show that samples have concentrations in ppm higher than the guideline value set by EPA, and need chemical treatment before using for drinking purposes. For K, the concentrations in pppm of the samples are less than the acceptable values per a day per person. For Fe, the concentrations in ppm are ranged from <0.1 to3.08. For Al, the concentrations in ppb of the samples ranged from 33.53 to 2268.17. For Cs, the concentrations in ppb of the samples ranged from <0.1 to 0.39, Hg and Bi, the concentrations in ppb are <0.1. For Pb, the concentrations in ppb are less than the guideline value set by EPA. For U, the concentrations in ppb of the samples are in the accepted range.

Table (7) Shows Concentration of radioactive nuclides in water for four samples in Bq/l measured by HPGe. The measured concentrations ranged from 0.001 to 0.016 for ^{238}U and from 1.4 ± 0.2 to 11.0 ± 0.6 for ^{226}Ra series and from LDL to 8.5 ± 0.6 for ^{232}Th series (^{228}Ra) and from LDL to 339.2 ± 3.0 and LDL for ^{37}Cs.

Table (8) represents dose conversion factors for ^{238}U, ^{226}Ra and ^{228}Ra in SvBq^{-1}.

Table (9) represents the annual dose measured from ^{238}U, ^{226}Ra and ^{228}Ra in mSv/y for age class $\leq$ 1 y (infants) to class >17 y (adults).

The results show that the samples exceededthe annual limit of dose allowed by WHO (o.1 mSv/y) for all radioactive nuclides in drinking water, so samples need chemical treatment.

4. TABLES

Table (1) XRD analysis results.

Sample No.	Major	Minor	Trace
SU-1	QUARTZ , ALBITE	MICROCLINE , CLNIOCHLORE , CALCITE	LUDLOKITE , BIOTITE AUGITE , MAGNETITE
SU-2	QUARTZ , ALBITE	CALCITE , CLINOCHLORE	GEIGERITE , MICROCLINE, REEVESITE , BIOTITE , MAGNETITE
SU-3	CALCITE , QUARTZ	ALBITE , CLINOCHLORE	MAGNETITE , TINAKSITE , DUNDASITE , GEIGERITE
SU-4	QUARTZ , ALBITE	……..	MICROCLINE , CALCITE , KAOLINITE FAUJASITE , AUGITE , MAGNETITE
SU-5	QUARTZ , ALBITE , MICROCLINE	CLINOCHLORE	CALCITE , VOLKOVSKITE , MAGNETITE
SU-6	QUARTZ , ALBITE	CLINOCHLORE	CALCITE , AUGITE , MAGNETITE , PARGASITE , BIOTITE, LUDLOKITE
SU-7	QUARTZ , ALBITE	CALCITE , CLINOCHLORE	REEVESITE , BIOTITE , MAGNETITE , PARGASITE
SU-8	QUARTZ , ALBITE	CLINOCHLORE , CALCITE	PARGASITE , AUGITE , BIOTITE, MAGNETITE
SU-9	QUARTZ , ALBITE	CALCITE , CLINOCHLORE	BIOTITE, AUGITE , PARGASITE , MICROCLINE
SU-10	QUARTZ , CALCITE , ALBITE	CLINOCHLORE	PARGASITE , BIOTITE, TUNISITE , OFFRETITE , MAGNETITE

able (2) Results of the atomic absorption analysis.

Elements	Al	Fe	Ca	Pb	As
DL.	**0.25**	**0.05**	**0.05**	**1.00**	5.50
Units	**%**	**%**	**%**	**ppm**	ppm
SU - 1	6.98	4.72	3.75	19.00	10.50
SU - 2	7.65	4.68	4.98	18.00	12.30
SU - 3	4.48	3.08	10.60	14.00	29.10
SU - 4	6.18	4.60	2.78	16.00	30.70
SU - 5	6.84	3.08	1.60	16.00	17.26
SU - 6	6.61	4.60	3.48	16.00	17.30
SU - 7	6.79	4.68	3.51	19.00	13.41
SU - 8	6.73	4.92	3.28	15.00	12.20
SU - 9	6.80	4.32	5.04	27.00	15.70
SU - 10	6.04	4.14	8.00	25.00	28.60

Table (3) a represents concentrations of radionuclides for the natural $^{238}U - ^{226}Ra$ series and $^{232}Th - ^{228}Ra$ series and ^{40}K and the manmade ^{137}Cs, Bq/kg dry weight .

Sample code.	Concentration Bq/kg dry weight		
	U-Ra series		**Th series**
	^{214m}Pa	**Ra-226**	**Ra-228**
SU-1	**LDL**	**7.75 ±0.057**	**6.84 ±0.078**
SU-2	**12.1±0.56**	**10.54 ±0.051**	**13.95 ±0.09**
SU-3	**4.6±0.51**	**7.71±0.05**	**6.46 ±0.055**
SU-4	**3.56±0.29**	**10.08 ±0.044**	**18.79 ±0.13**
SU-5	**LDL**	**15.55 ±0.064**	**21.84 ±0.13**
SU-6	**11.42 ±0.52**	**7.01 ±0.037**	**8.21±0.054**
SU-7	**12.3±0.75**	**10.21 ±0.066**	**14.86 ±0.13**
SU-8	**LDL**	**8.45±0.063**	**8.02 ±0.099**
SU-9	**4.8±0.47**	**8.72±0.062**	**5.23 ±0.054**
SU-10	**9.7±0.7**	**7.60±0.045**	**6.16 ±0.058**

Table (3) b represents concentrations of radionuclides for the natural $^{238}U - ^{226}Ra$ series and $^{232}Th - ^{228}Ra$ series and ^{40}K and the manmade ^{137}Cs, Bq/kg dry weight .

Sample code.	Concentration Bq/kg dry weight		Concentration %
	K-40	**Cs-137**	Natural-K
SU-1	**262.69 ±1.42**	**0.94 ±0.078**	8.875 ±0.048
SU-2	**255.30 ±0.95**	**3.09 ±0.099**	8.63 ±0.032
SU-3	**64.64 ±0.033**	**3.6 ±0.16**	2.183 ±0.011
SU-4	**301.32 ±1.14**	**2.51 ±0.085**	10.18 ±0.039
SU-5	**754.21±2.31**	**1.7 ±0.06**	25.48 ±0.078
SU-6	**328.36 ±1.22**	**3.13 ±0.095**	11.093 ±0.041
SU-7	**312.40 ±1.57**	**3.181 ±0.133**	10.554 ±0.053
SU-8	**409.74 ±2.28**	**1.484 ±0.102**	13.842 ±0.077
SU-9	**265.92 ±1.42**	**0.91 ±0.071**	8.984 ±0.048
SU-10	**209.38 ±1.09**	**LDL**	7.074 ±0.037

LDL : Lower than Detection Limit

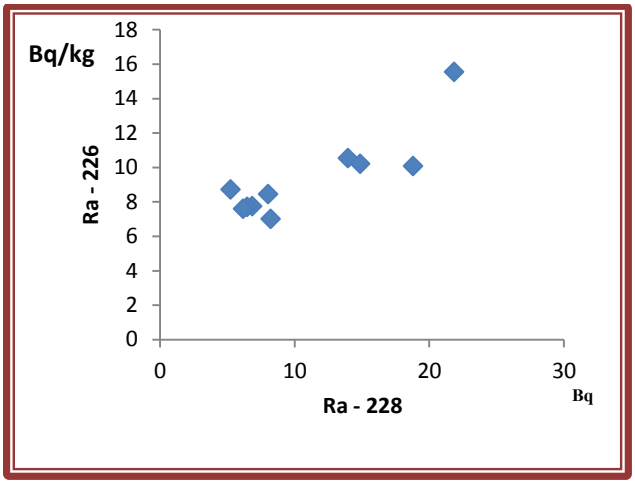

Fig. (1) Relative between ^{228}Ra and^{226}Ra per Bq/kg

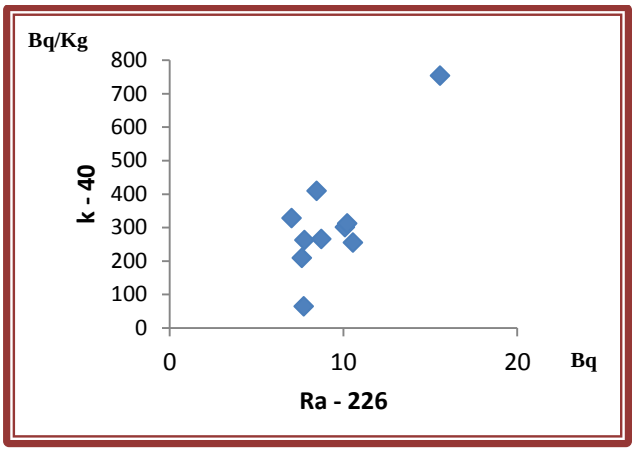

Fig. (2) Relative between ^{226}Ra &^{40}K per Bq/kg

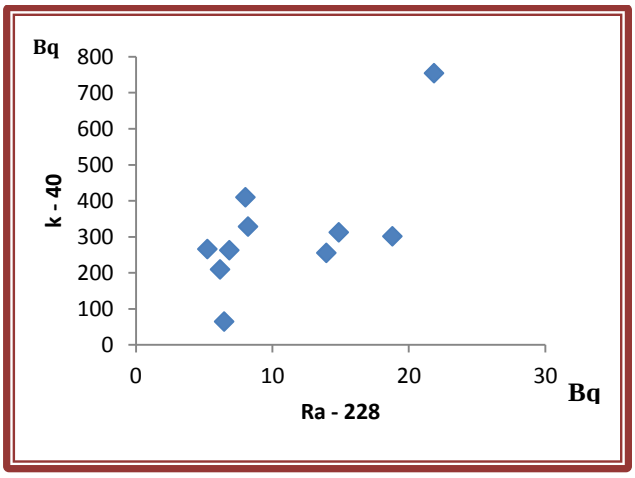

Fig. (3) Relative between ^{228}Ra &^{40}K per Bq/kg

Table (4) the radium equivalent Bq/kg and the absorbed dose nGy/h.

Sample Code	Ra_{eq} Bk/kg	Absorbed dose nGy/h
SU-1	**37.76**	18.79
SU-2	**50.15**	23.89
SU-3	**21.93**	10.05
SU-4	**60.15**	28.49
SU-5	**104.86**	52.17
SU-6	**44.03**	22.07
SU-7	**55.53**	26.72
SU-8	**51.47**	26.10
SU-9	**36.67**	18.43
SU-10	**32.53**	16.04

Table (5) Comparison of isotopes concentrations in Bq/kg dry weight concentrations in the present work and some published results.

Reference / **Nuclide-Series**	**Present work**	**Ibrahiem *etal.* 1993**	**Ibrahiem *etal.* , 2003**	**Al-Garni Z., 2008**
U-238−Ra-226	7.01-15.55	5.2-63.7	31-55	9.2-18.1
Th-232−Ra-228	5.23-21.8	2.5-95.6	2.4-3.2	9.5-22.6
K-40	64.6-754.2	29-653	65-1046	378.2-592.6

Table (6): Element concentrations in ppm or ppb measured by ICP-Atomic Absorption Analyzer in water samples.

Elements	DL	Sample-1	Sample-2	Sample-3	Sample-4
Ca(ppm)	0.2	72.1	152.6	78	180.5
Na(ppm)	0.2	28.4	96.1	254	171.7
Mg(ppm)	0.2	15.3	36.5	28.5	53.7
K(ppm)	0.2	5.9	10.2	3.4	6.2
Fe(ppm)	0.1	0.31	0.13	<0.1	3.08
Al(ppb)	0.1	296.07	111.68	33.53	2268.17
Cs(ppb)	0.1	<0.1	<0.1	0.39	0.1
Hg(ppb)	0.1	<0.1	<0.1	<0.1	<0.1
Bi(ppb)	0.1	0.15	<0.1	<0.1	<0.1
Pb(ppb)	0.1	1.66	0.98	1.33	3.36
U(ppb)	0.1	0.1	1.24	1.25	1.14

Table (7): Concentration of radionuclides in water samples in Bq/l measured by HPGe.

Sample Code	Concentration in Bq/l			
	U-238 *	Ra-226 Series	Ra-228	K-40
DL.	**0.001**	**0.40 ± 0.07**	**0.30 ± 0.07**	**4.6 ± 0.5**
Sample – 1	**0.001**	**2.02±0.2**	**LDL**	**13.6±0.2**
Sample – 2	**0.015**	**1.5±0.1**	**2.2±0.2**	**33.8±0.4**
Sample – 3	**0.016**	**11.0±0.6**	**8.5±0.6**	**339.2±3.0**
Sample – 4	**0.014**	**1.4±0.2**	**LDL**	**LDL**

LDL: Lower than Detection Limit

***U-238 is measured as total uranium by atomic** absorption spectrometry.

Table (8) conversion dose Sv/Bq .

Radio-nuclide	Dose conversion factors (K) Sv/Bq				
	≤ 1 y	1-2 y	2-7 y	7-10 y	> 17 y
^{238}U	3.4×10^{-7}	1.2×10^{-7}	8.0×10^{-8}	6.8×10^{-8}	4.5×10^{-8}
^{226}Ra	4.7×10^{-6}	9.6×10^{-7}	6.2×10^{-7}	8.0×10^{-7}	2.8×10^{-7}
^{228}Ra	3.0×10^{-5}	5.7×10^{-6}	3.4×10^{-6}	3.9×10^{-6}	6.9×10^{-7}

Table (9) a The annual dose measured from ^{238}U, ^{226}Ra, ^{228}Ra in mSv/y for age class ≤ 1y.

Doses in mSv/y	Age Class <1y			
	Sample 1	Sample 2	Sample 3	Sample 4
^{238}U Dose	**0.0001**	**0.0013**	**0.0013**	**0.0012**
^{226}Ra Dose	**2.4**	**1.8**	**13.2**	**1.7**
^{228}Ra Dose	**<2.3**	**16.9**	**65.2**	**<2.3**
Annual Dose $^{238}U+^{226}R+^{228}R$	**<4.7**	**18.7**	**78.4**	**<4.0**

Table (9) b The annual dose measured from ^{238}U, ^{226}Ra, ^{228}Ra in mSv/y for age class 1-2y.

Doses in mSv/y	Age Class1-2y			
	Sample 1	Sample 2	Sample 3	Sample 4
^{238}U Dose	**0.00005**	**0.0007**	**0.0007**	**0.0006**
^{226}Ra Dose	**0.7**	**0.5**	**3.9**	**0.5**
^{228}Ra Dose	**0.6**	**4.6**	**17.7**	**0.6**
Annual Dose $^{238}U+^{226}R+^{228}R$	**<1.3**	**5.1**	**21.5**	**<1.1**

Table (9) c The annual dose measured from ^{238}U, ^{226}Ra, ^{228}Ra in mSv/y for age class 2-7y.

Doses in mSv/y	Age Class 2-7			
	Sample 1	Sample 2	Sample 3	Sample 4
^{238}U Dose	0.00004	0.0004	0.0005	0.0004
^{226}Ra Dose	0.5	0.3	2.5	0.3
^{228}Ra Dose	<0.4	2.7	10.5	<0.4
Annual Dose $^{238}U+^{226}R+^{228}R$	<0.8	3.1	13.0	<0.7

Table (9) d The annual dose measured from ^{238}U, ^{226}Ra, ^{228}Ra in mSv/y for age class 7-10y.

Doses in mSv/y	Age Class7-10			
	Sample 1	Sample 2	Sample 3	Sample 4
^{238}U Dose	0.00003	0.00038	0.00038	0.00035
^{226}Ra Dose	0.6	0.4	3.2	0.4
^{228}Ra Dose	<0.4	3.1	12.1	<0.4
Annual Dose $^{238}U+^{226}R+^{228}R$	<1.0	3.6	15.3	<0.8

Table (9) f The annual dose measured from ^{238}U, ^{226}Ra, ^{228}Ra in mSv/y for age class >17y.

Doses in mSv/y	Age Class7-10			
	Sample 1	Sample 2	Sample 3	Sample 4
^{238}U Dose	0.00003	0.00038	0.00038	0.00035
^{226}Ra Dose	0.6	0.4	3.2	0.4
^{228}Ra Dose	<0.4	3.1	12.1	<0.4
Annual Dose $^{238}U+^{226}R+^{228}R$	<1.0	3.6	15.3	<0.8

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