

Concentrations of natural radioactivity and their contribution to the absorbed dose from water samples from the Western Province, Saudi Arabia

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Abstract. Twenty five samples of drinking water were collected from different areas of the Western province of the Kingdom of Saudi Arabia, from Tabouk north to Abha south, nineteen of wells as well as six samples of bottled and tap water locally used in Jeddah. The collected samples were analyzed for the content of the following elements, in ppm or ppb; Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Iron (Fe), Aluminum (Al), Bismuth (Bi), Cesium (Cs), Mercury (Hg), Lead (Pb) and Uranium (U) by atomic absorption spectrometer. Also gamma spectrometer based on HPGe crystal was applied to determine concentrations in Bq/l of the natural radio nuclides: Uranium-238, Radium-226 and Thorium-232 series also Potassium-40 in addition to man-made Cesium-137. Results were compared with limits given by the World Health Organization (WHO) to identify samples which are acceptable to be used for drinking purposes, to that needs chemical treatment to be acceptable. The annual absorbed doses were estimated for: ≤ 1 y, 1-2 y, 2-7 y, 7-10 y and > 17 y categories from U-238, Ra-226 and Ra-228 in mSv/y.

The results showed that, most of the estimated annual dose from samples exceeded the annual limit of the dose allowed by WHO (0.1 mSv/y) for all radio nuclides in drinking water.

Keywords: drinking water, radio nuclides, radioactivity, annual dose, HPGe, atomic absorption, gamma spectroscopy

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Introduction

The presence of naturally occurring radionuclides as well as some elements provides important informations about the quality of drinking water.

Al-Saleh and Al-Doush^[1] 1998 and Al-Saleh^[2] analyzed samples from household and bottled drinking water for the concentrations of trace elements (Cd, Cr, Be, Cu, Fe, Mg, Mn, Hg, Ni, Se, V and Zn) using ICP-Mass Spectrometer (Inductively Coupled Plasma Spectrometer) in Riyadh, Saudi Arabia. Salih *et al.*^[3] studied the uranium and thorium series radionuclides concentrations in drinking water, from drilled bedrock wells, correlated to geology for bedrock radioactivity by HPGe spectrometer. They estimated the dose in Lokiping, Sweden from the radionuclides concentrations. Desideri *et al.*^[4] studied the concentrations of radionuclides series (gross alpha and beta) after chemical analysis, for bottled water used in Italy. Also they estimated the absorbed dose for categories less than 1 year old to adults. Also Jia and Torri⁵ estimated the radioactive dose for the population in Italy from the drinking water. Fatima *et al.*^[6] measured the natural radioactivity in bottled drinking water in Pakistan by HPGe spectrometer also they studied concentrations of some stable dose from the radionuclides concentrations of some stable elements and chemical compounds (Ca, K, Mn, Na, Cl, F, NO₃, SO₄, HCO₃), they estimated the consequent dose from radionuclides concentrations.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)^[7] estimated that exposure to natural radionuclides contributes around 70 % of population radiation dose. The global average human exposure to natural sources is 2.4 mSv/y from both food and drinking water.

The aim of this study is to obtain a representative estimate of the concentration levels of natural radionuclides in well water and bottled drinking water from the Western Province, Saudi Arabia, also estimate the corresponding radiation doses for people consuming this water. Doses were determined from ²²⁶Ra, ²²⁸Ra, ²³⁸U for the following age groups: ≤ 1y, 1-2 y, 2-7 y, 7-10 y and >17 y.

Experimental

Sampling and Sample Preparation

Twenty-five samples from well, tap water and bottled drinking water were collected from Tabuk north to Abha south from the western region of Saudi Arabia, Fig.1.

Five liters were collected in polyethylene container, then acidified by 10 cc concentrated HNO₃ acid (69-72 %, unvolatile impurities 0.01%, HCl 0.005%, H₂SO₄ 0.01%, Ar 0.0001%, Fe 0.005% and Pb 0.0005%). These values of the impurities concentrations were subtracted from that measured by both atomic absorption and HPGe analysis. Sample and sample preparation has been done obeying the report by the methodology sub-group to the Radioactivity Research and Environmental Monitoring Committee (RADREM)^[8]. Ten cc from the acidified samples as well as distilled water acidified by HNO₃ with the same concentration of HNO₃ were analyzed by the ICP-MS spectrometer. ICP-atomic absorption spectrometer of the model (A Analyst 700 from Perkin Elmer, OPTIMA 4000 DV Series) was used for the concentrations of (Ca, Na, Mg, K, Fe, Al, Cs, Hg, Bi, Pb and U) in ppm or ppb.

For gamma measurements, 640 cc of each sample in Marenelli beakers were used. The samples were sealed and stores for 1 month to reach secular equilibrium between U-238- Ra-226 and Th-232 series and their progenies. HPGe (Tennelec Model no. CPVD 530-15200) was used for the measurements of concentrations of U-238 and Th-232 series and Potassium-40 concentrations in Bq/l.

Eu-152 in water as well as natural KCl solutions with different concentrations in 640 cc polyethylene Marenelli beakers were used for the absolute efficiency calibration in the energy range from 121.78 to 1460.8 keV. The same Marenelli beakers were used for gamma measurements. The efficiency curve was extended to 2447.9 keV using Ra-226 point source normalized to the same volume.

For the Uranium-238_Radium-226 series concentrations, gamma transitions of: [351.9 (0.383) keV] Pb-214 and [609.3 (0.499), 1120.27 (0.162), 1764.49 (0.160) keV] Bi-214 were used considering Ra-226 in secular equilibrium with its progenies Bi-214 and Pb-214, as the samples were stored for more than one month. For the Th-232_Ra-228 series concentrations gamma transitions of:[338.42 (0.130), 911.16 (0.303),

964.6+968.97 (0.057+0.183) keV] Ac-228, [727.25 (0.081) keV] Pb-212 and [583.02(0.332) keV] Tl-208 were used calculated considering Ra-228 and Ac-228 are in secular equilibrium with Bi-212 and Pb-212. The 1460.8(0.107) keV gamma transition was used for the determination of K-40 concentration. The Cs-137 concentrations were lower than the detection limit (LDL) in most samples (0.08±0.03 Bq/l). Each sample was detected for about 24 hours.

Dose Estimation

For concentration calculations, the equation used:

$$C = \frac{Net\ Area/sec}{\beta \epsilon x \epsilon V} (Bq/l) \quad (1)$$

Where: C is Concentration; *Net Area/sec* is under the peak area per sec; ϵ is the absolute efficiency for energy; β is the branching ratio at this energy; V is the volume of the sample per liter.

For the annual dose estimation, the equation used^[4]

$$E=KGCT \quad (2)$$

Where: E is the dose *via* ingestion (Sv); K is the ingesting dose conversion factor of the specific radionuclide (Sv/Bq); G is the water consumption per day for every group; C is the concentration of the specific radionuclide (Bq/l) and T is the duration of consumption, taken 365 days.

The annual doses were calculated to check the quality of drinking water for radioactive content. Doses were determined from ²²⁶Ra, ²²⁸Ra, ²³⁸U for the following age groups: ≤ 1y, 1-2 y, 2-7 y, 7-10 y and >17 y.

Table 1 gives the conversion factors for ²³⁸U, ²²⁶Ra, ²²⁸Ra in SvBq⁻¹, and water consumption per day (G) for every age group. (Desideri *et al.* 2007)⁴

No estimation of ²³²Th as thorium is not soluble in water.

Table 1. Dose conversion factors for ^{238}U , ^{226}Ra , ^{228}Ra in SvBq^{-1} and water consumption per day.**(G) for every group.**

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}
Water Consumption (L day⁻¹)	0.7	1	1	1	2

Results and Discussion

The results of elemental concentrations by the Atomic Absorption Spectrometer were shown in Table 2.

In well water the average values for Ca, Na, Mg, K and Fe are 112.81, 118.50, 34.81, 9.53, and 0.97 ppm, respectively. In bottled water the average values for the corresponding elements were, 6.93, 8.63, 1.93, 0.23 and <0.1 ppm. In tap water the average values for the corresponding elements were, 12.73, 46.20, 2.80, 2.80, 0.17 ppm respectively. With respect to Al, Cs, Hg, Bi, Pb and U elements the average values in well water are, 124.60, 0.47, <0.1, <0.1, 1.72, and 2.30 ppb, the corresponding elements in bottled water were, 19.16, <0.1, <0.1, <0.1, 0.70, and <0.1 ppb respectively, the corresponding elements in tap water were 28.31, <0.1, <0.1, <0.1, 0.53, and <0.1 ppm.

Table 2. Element concentrations in ppm or ppb.

Elements	Ca	Na	Mg	K	Fe	Al	Cs	Hg	Bi	Pb	U
DL.	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Units	Ppm	Ppm	ppm	ppm	ppm	ppb	ppb	ppb	ppb	ppb	ppb
* (Distilled Water)	2.0	1.9	0.2	<0.20	<0.1	16.19	<0.1	<0.1	<0.1	29.96	<0.1
Jeddah* (1-6)	176.25	313.53	76.45	8.88	0.47	96.02	<0.1	0.13	<0.1	1.85	5.42
Makkah* (7-11)	148.85	139.8	12.61	3.76	0.26	42.21	<0.1	<0.1	<0.1	1.99	5.34
Al-Leath* (12-13)	250.0	293.5	0.6	30.3	0.2	100.01	6.5	<0.1	<0.1	1.96	<0.1
Madinah* (14-17)	120.8	80.4	33.5	6.43	0.91	677.36	0.17	<0.1	<0.1	1.83	0.93
Abha* (18)	57.3	11.1	9.1	2.1	0.1	55.3	<0.1	<0.1	<0.1	2.03	0.28
Tabuk* (19)	66.1	30.7	21.8	5.0	<0.1	23.11	0.10	<0.1	<0.1	1.25	1.70
Jeddah*** (20-22)	6.93	8.63	1.93	0.23	<0.1	19.16	<0.1	<0.1	<0.1	0.70	<0.1
Jeddah*** (23-25)	12.73	46.20	2.80	2.80	0.17	28.31	<0.1	<0.1	<0.1	0.53	<0.1

Note: Number of samples in parentheses, * well water, ** bottled water, *** tap water.

Table.3. represents comparison between the element concentrations obtained by atomic absorption spectrometer in this work and some previous results as well as the values established by the TSE-266, EPA, WHO and EC. For Ca the range is from 1.6 to 430.9 ppm, the permissible value given by TSE-266 in mg/l for the allowed value is 200, so all the samples are in the accepted range except samples (05 and 06) from Jeddah. For Na the range is from 0.7 to 613.4 ppm, the value given by TSE-266 is 175 mg/l and the value given by WHO is 200 mg/l so all the samples except samples no. (04, 05, 06, 16, 12 and 13) need chemical treatment before using for drinking purposes. For Mg the range is from 0.9 to 210 ppm while the value given by TSE-226 is 50, samples 05, 06, 07, 08, 09, 11 and 17 are out of the permissible value, so they need chemical treatment. For the concentrations of K the range is from <0.1 to 31.9 ppm and the value given by TSE is 12 mg/l, so the samples 12 and 13 only are out of range.

Table 3. Comparison between the element concentrations obtained by atomic absorption spectrometer in this work and some previous results as well as the values established by the TSE-266, EPA, WHO, EC.

Elements	Ca	Na	Mg	K	Fe	Al	Hg
TSE-266 ^a mg/l	200	175	50	12	0.2	---	---
EPA ^a mg/l	---	---	---	---	0.3	---	---
WHO ^{a & b} Ppm	---	200	---	---	0.3	0.05	0.001
EC ^a Ppm	---	200	---	---	0.2	0.05	0.001
Turkey ^a mg/l	(2.6±0.5)- (4.9±1.6)	(112±22)- (226±18)	(70±19)- (136±15)	(5.7±0.6)- (10.6±1.8)	(0.12±0.03)- (0.43±0.11)	---	---
Saudi Arabia ^b µg/l	---	---	---	---	5.79- 264.29	0-106.8	---
Saudi Arabia ^c µg/l	---	---	0.95-10.16 (9.88)	---	LDL-24.7 (20.36)	---	LDL-4.0 (2.58)
The Present Work	1.6-430.9 Ppm	0.7-613.4 ppm	0.5- 210.6 ppm	<0.2-31.9 ppm	<0.1-3.08 ppm	18.15- 2268.17 Ppb	<0.1- 0.17 ppb

^b (Al-Saleh, 1996)^[2] ^c (Al-Saleh and Al-Doush, 1998)^[1]

For Fe the given range is from <0.1 to 3.02 ppm and the permissible value given by TSE-226 is 0.2 ppm and that given by both EPA and WHO are 0.3 ppm, so samples no. (01, 02, 03, 07 and 17) needs chemical treatment.

For Al it ranged from 18 to 2268 ppb and the value given by WHO is 0.05 ppm, so samples (04, 05, 06, 13, 14, 15 and 17) are out of the

permissible value and need chemical treatment. For Hg the measured values range from <0.1 to 0.7 ppb and the allowed value given by WHO is 0.001 ppm, so all the samples are in the acceptable range.

Thorium is insoluble, so the Th-232 concentrations were measured from the Ra-228 series while Uranium is soluble in water so it was measured by both ICP-AA and HPGe, the estimated dose were measured for U-238 and Ra-226 and Ra-228 concentrations. The Cs-137 concentrations were lower than detection limit (LDL) in most samples.

Table 4 gives the concentrations of U-238 (total uranium is measured by atomic absorption spectrometer), Ra-226, Ra-228 series and K-40 in Bq/l (measured by HPGe). The measured concentrations of U-238 ranged from <0.001 to 0.17 Bq/l, with an average of 3.5 ppb. Ra-226 series values ranged from LDL to 2.5 Bq/l, Ra-228 ranged from LDL to 3.3 Bq/l and K-40 ranged from LDL to 339.2 Bq/l.

Table 4. Concentration of radionuclides in water samples in Bq/l.

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 - 01	0.112	1.4 ± 0.1	0.50 ± 0.07	LDL
Sample - 02	0.116	0.70 ± 0.05	0.7 ± 0.1	LDL
Sample - 03	0.105	LDL	LDL	10.4 ± 0.1
Sample - 04	0.023	2.8 ± 0.3	LDL	9.20 ± 0.14
Sample - 05	0.022	2.50 ± 0.13	3.3 ± 0.4	33.7 ± 0.4
Sample - 06	0.026	0.70 ± 0.07	1.9 ± 0.2	LDL
Sample - 07	0.020	1.9 ± 0.1	3.1 ± 0.3	LDL
Sample - 08	0.014	1.9 ± 0.2	1.4 ± 0.2	LDL
Sample - 09	0.013	1.4 ± 0.1	3.3 ± 0.4	LDL
Sample - 10	0.098	LDL	LDL	LDL
Sample - 11	0.168	1.2 ± 0.1	LDL	LDL
Sample - 12	<0.001	1.13 ± 0.08	0.30 ± 0.04	LDL
Sample - 13	<0.001	LDL	0.60 ± 0.16	LDL
Sample - 14	0.001	2.02 ± 0.20	LDL	13.6 ± 0.2
Sample - 15	0.015	1.5 ± 0.1	2.2 ± 0.2	33.8 ± 0.4
Sample - 16	0.016	11.0 ± 0.6	8.5 ± 0.6	339.2 ± 3.0
Sample - 17	0.014	1.4 ± 0.2	LDL	LDL
Sample - 18	0.003	2.1 ± 0.1	0.97 ± 0.09	LDL
Sample - 19	0.021	1.2 ± 0.1	1.8 ± 0.3	LDL
Sample - 20	<0.001	3.0 ± 0.3	LDL	LDL
Sample - 21	<0.001	1.0 ± 0.1	2.3 ± 0.2	LDL
Sample - 22	<0.001	1.50 ± 0.08	1.9 ± 0.2	LDL
Sample - 23	<0.001	1.8 ± 0.1	2.4 ± 0.4	LDL
Sample - 24	0.001	1.5 ± 0.1	0.30 ± 0.05	LDL
Sample - 25	<0.001	1.6 ± 0.1	1.30 ± 0.14	LDL
Range	<0.001 - 0.17	LDL - 2.5	LDL - 3.3	LDL - 339.2

LDL: Lower than Detection Limit.

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

Table 5 gives a comparison of U-238, Ra-226 and Ra-228 concentrations in mBq/l in drinking water in some countries and the world average^[7] and the present work.

The high concentrations of Ra-226 & Ra- 228 refer to the bottom sediment from well and the rain passage through the soil.

Table 5. ²³⁸U, ²²⁶Ra & ²²⁸Ra concentrations in drinking water in mBq/l I some countries in the world compared to the present work.

Region/Country	Concentration (mBq l ⁻¹)		
	²³⁸ U	²²⁶ Ra	²²⁸ Ra
North America			
U. S.	0.3 – 77	0.4 – 1.8	0 – 0.5
Asia			
China	0.1 – 700	0.2 – 120	
India	0.09 – 1.5		
Europe			
Finland	0.5 – 150,000	10 – 49,000	18 – 570
France	4.4 – 930	7 – 700	
Germany	0.4 – 600	1 – 1800	
Italy	0.5 – 130	0.2 – 1200	
Poland	7.3	1.7 – 4.5	
Romania	0.4 – 37	0.7 – 21	
Switzerland	0 – 1000	0 – 1500	0 – 200
Spain	3.7 – 4.4	< 20 – 4000	
U. K.		0 – 180	
Reference value	1	0.5	0.5
<i>The Present Work</i>	1 – 168	700 – 11000	300 – 8500

Table 6 shows the derived activity concentration in water (DWC) in Bq/l and critical concentrations for the most critical categories^[9].

Table 6. Derived activity concentration in water (DWC) in Bq l⁻¹ and critical concentrations for the most critical age.

Radio-Nuclide	Derived activity concentration in water (DWC)					Critical concentration Bq/l	Critical age y
	Bq/l						
	≤ 1 y	1-2 y	2-7 y	7-10 y	> 17 y		
⁴⁰ K	6.5×10 ⁰	6.8×10 ⁰	1.4×10 ¹	2.2×10 ¹	2.2×10 ¹	6.5×10 ⁰	≤ 1
¹³⁷ Cs	1.9×10 ¹	2.4×10 ¹	3.0×10 ¹	2.9×10 ¹	1.1×10 ¹	1.1×10 ¹	> 17
²²⁶ Ra	8.5×10 ⁻²	3.0×10 ⁻¹	4.6×10 ⁻¹	3.6×10 ⁻¹	4.9×10 ⁻¹	8.5×10 ⁻²	≤ 1
²²⁸ Ra	1.3×10 ⁻²	5.0×10 ⁻²	8.4×10 ⁻²	7.3×10 ⁻²	2.0×10 ⁻¹	1.3×10 ⁻²	≤ 1
²³⁸ U	1.2×10 ⁰	2.4×10 ⁰	3.6×10 ⁰	4.2×10 ⁰	3.0×10 ⁰	1.2×10 ⁰	≤ 1

The annual dose from K-40 was not calculated as potassium is uniformly distributed and controlled in the human body independent of

its concentration in the environment (EPA). Also the dose rate from K-40 can be measured directly by whole body counting, taking the potassium concentration is about 0.18% from the total weight for adults and about 0.20% for infants⁷.

Thorium is rarely soluble in water so the annual dose was calculated from the Ra-228 and Ac-228 concentration.

The increase of uranium concentration may be due to leaching effect. It has been proposed that some factors are likely to influence the uranium concentration in natural surface water and ground water¹¹ such factors are summarized as follows:

1. The uranium content of the source rocks, sediments or soils, and the case with which uranium may be leached.
2. The proximity of the water to uranium source.
3. The degree of hydraulic isolation of the water by fresher surfaces or ground waters.
4. The oxidation state of the water and.
- 5- The concentration of suitable complexing agents, which can be increased the solubility of uranium.

The concentrations obtained by both atomic absorption spectrometer and HPGe spectrometer showed that the majority of the samples need treatment to reduce concentrations of different elements, stable or radioactive.

Table 7. represents the annual dose (mSv/y) calculated from the U-238,Ra-226 and Ra-228 concentration (Bq/l) for different age groups.

Areas	Ra-226 effective doses per year (mSv.y ⁻¹)				
	≤1y	1-2y	2-7y	7-10y	>17y
Jeddah [*] (1-6)	< 1.7	< 0.5	< 0.3	< 0.4	< 0.3
Makkah [*] (7-11)	< 1.6	< 0.5	< 0.3	< 0.4	< 0.3
Al-Aeath [*] (12-13)	< 0.9	< 0.3	< 0.2	< 0.2	< 0.2
Madinah [*] (14-17)	4.8	1.4	0.9	1.2	0.8
Abha [*] (18)	2.5	0.7	0.5	0.6	0.4
Tabuk ⁸ (19)	1.4	0.4	0.3	0.4	0.2
Jeddah ^{**} (20-22)	2.2	0.6	0.4	0.5	0.4
Jeddah ^{***} (23-25)	2.0	0.6	0.4	0.5	0.3

Table 7. continued

Areas	Ra-228 effective doses per year (mSv.y ⁻¹)				
	≤1y	1-2y	2-7y	7-10y	>17y
Jeddah*(1-6)	< 8.9	< 2.4	< 1.4	< 1.7	< 0.6
Makkah*(7-11)	< 12.9	< 3.5	< 2.1	< 2.4	< 0.8
Al-Aeath*(12-13)	3.4	0.9	0.6	0.6	0.2
Madinah*(14-17)	< 21.7	< 5.9	< 3.5	< 4.0	< 1.4
Abha*(18)	7.4	2.0	1.2	1.4	0.5
Tabuk ⁸ (19)	13.8	3.7	2.2	2.6	0.9
Jeddah**(20-22)	< 11.5	< 3.1	< 1.9	< 2.1	< 0.8
Jeddah*** (23-25)	10.2	2.8	1.7	1.9	0.7
Areas	Ra-228 effective doses per year (mSv.y ⁻¹)				
	≤1y	1-2y	2-7y	7-10y	>17y
Jeddah*(1-6)	< 8.9	< 2.4	< 1.4	< 1.7	< 0.6
Makkah*(7-11)	< 12.9	< 3.5	< 2.1	< 2.4	< 0.8
Al-Aeath*(12-13)	3.4	0.9	0.6	0.6	0.2
Madinah*(14-17)	< 21.7	< 5.9	< 3.5	< 4.0	< 1.4
Abha*(18)	7.4	2.0	1.2	1.4	0.5
Tabuk ⁸ (19)	13.8	3.7	2.2	2.6	0.9
Jeddah**(20-22)	< 11.5	< 3.1	< 1.9	< 2.1	< 0.8
Jeddah*** (23-25)	10.2	2.8	1.7	1.9	0.7
Areas	U-238 effective doses per year (mSv.y-1)				
	≤1y	1-2y	2-7y	7-10y	>17y
Jeddah*(1-6)	0.0058	0.0029	0.0020	0.0017	0.0022
Makkah*(7-11)	0.0054	0.0027	0.0018	0.0015	0.0020
Al-Aeath*(12-13)	< 0.0001	< 0.00005	< 0.00004	< 0.00003	< 0.00004
Madinah*(14-17)	0.0010	0.0005	0.00034	0.0003	0.00038
Abha*(18)	0.0003	0.0002	0.0001	0.00009	0.0001
Tabuk ⁸ (19)	0.0018	0.0009	0.0006	0.0005	0.0007
Jeddah**(20-22)	< 0.0001	< 0.00005	< 0.00004	< 0.00003	< 0.00004
Jeddah*** (23-25)	< 0.0001	< 0.00005	< 0.00004	< 0.00003	< 0.00004
Areas	Ra-226 + RA-228 + U-238 effective doses per year (mSv.y-1)				
	≤1y	1-2y	2-7y	7-10y	>17y
Jeddah*(1-6)	< 10.6	< 2.9	< 1.8	< 2.1	< 0.9
Makkah*(7-11)	< 14.5	< 4.0	< 2.4	< 2.8	< 1.1
Al-Aeath*(12-13)	< 4.4	< 1.2	< 0.7	< 0.9	< 0.4
Madinah*(14-17)	< 26.4	< 7.3	< 4.4	< 5.2	< 2.2
Abha*(18)	10.0	2.8	1.7	2.0	0.9
Tabuk ⁸ (19)	15.2	4.2	2.5	2.9	1.2
Jeddah**(20-22)	< 13.7	< 3.8	< 2.3	< 2.7	< 1.1
Jeddah*** (23-25)	< 12.2	< 3.3	< 2.0	< 2.4	< 1.0

Note: Number of samples in parentheses, * well water, ** bottled water, *** tap water.

Conclusion

Most of the samples show higher concentrations for most elements than the permissible values given by EPA (environmental protection agency) and WHO for well water (samples from 1 to 19). Then, they need chemical treatments before being using as drinking water.

These measurements give primary estimation for the concentrations of radio nuclides in well water, bottled and tap water in some samples used in the western province in Saudi Arabia. It is recommend for continuous assessment and higher number of samples to estimate the dose for each category especially for the age from 10 to 17 years old, because of the lack of information about this category^[9].

The EC Council Directive 98/83/EC^[10] for the quality of drinking water gives the dose limit in drinking water to be 0.1 mSv/y excluding the level of ^3H which put to a limit of 100 Bq/l and K-40 which distribute uniformly in the body, also Rn and its progeny. So the measurements of the dose were measured only for the radio nuclides which is considered being of importance (Radium isotopes and uranium)^[11].



Fig. 1. Map of Saudi Arabia showing the sampling sites.

Acknowledgements

We express our gratitude to Prof. Nagdya M. Ibrahim for her fruitful discussions and advise also to King Abdul aziz City for Science and Technology (KACST) for the financial support, research no. GSP-15-74. Also, Saudi Geological Survey is gratefully acknowledged for the elemental analyses.

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تركيزات العناصر المشعة الطبيعية والجرعة الممتصة لعينات مياه من المنطقة الغربية من المملكة العربية السعودية

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المستخلص. تم تحليل خمسة وعشرين عينة مياه تم جمعها من غرب المملكة العربية السعودية من تبوك شمالاً إلى أبها جنوباً. تسعة عشر عينة من مياه الآبار، وست عينات من المياه المعبأة، ومياه الصنبور المستخدمة محلياً بمنطقة جدة.

تم تعيين تركيزات الكالسيوم والماغنسيوم والصوديوم واليوتاسيوم والحديد والألومنيوم والسيزيوم والزنك والرصاص والبيزموث واليورانيوم بالجزء في المليون أو الجزء في البليون، باستخدام مطياف الامتصاص الذري. كما تم تعيين تركيزات عناصر سلسلتى اليورانسيوم-٢٣٨- راديوم-٢٢٦ والثوريوم-٢٣٢، كذلك البوتاسيوم-٤٠ بالإضافة إلى السيزيوم-٣٧ بالبيكريل/كجم. تم مقارنة التركيزات بتلك المتبناة من منظمة الصحة العالمية للمياه الصالحة للشرب، لتحديد تلك الصالحة للشرب مباشرة من تلك التى يجب معالجتها كيميائياً. كما تم تقدير الجرعات الممتصة للمراحل السنوية [أقل من عام ومن عام إلى عامين ومن سنتين إلى سبع سنوات ومن سبع إلى عشر سنوات ثم البالغين (< من سبعة عشر سنة)] بالملي سيفرت/عام من تركيزات اليورانسيوم-٢٣٨ والراديوم-٢٢٦ وكذلك الراديوم-٢٢٨. وجد أن الجرعة الممتصة من معظم عينات المياه

أعلى من القيم المتبناه من منظمة الصحة العالمية. للمياه الصالحة للشرب لجميع الأنوية. وجد أن الجرعة الممتصة من معظم عينات المياه أعلى من القيم المتبناه من منظمة الصحة العالمية. للمياه الصالحة للشرب لجميع الأنوية.