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Environmental Impacts of Radon and Heavy Metals in Water Wells and Grasses from Wadi Sahu, South Westren Sinai, Egypt

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ABSTRACT

Wadi Sahu as a part of southwestern Sinai is inhabited by Bedouins which used natural materials in their living system. Also, there is manganese mining activities in this region that cause significant environmental and occupational radiological impacts. The present work aims to estimate ^{222}Rn gas concentration and heavy metals within soil, water wells and plants in the investigated area. Water samples were collected from various public water sources used in Wadi Sahu. Then radon gas concentration has been measured by Alpha Spectroscopy (SARAD RTM 1688) along three times for each sample. The obtained results showed that, the average radon concentration in central well water (83± 0.18 Bq/m3) is lower than the maximum contaminant level (MCL) of (11.1 k Bq m-3) for public water supplies, while the concentration of cadmium (1.51 mg/l) was higher than the permissible limit in drinking water (0.01 mg/l), which represents toxic impacts to humans. Also, the recorded concentration of lead (0.29 mg/l) was higher than the permissible limit in drinking water (0.05 mg/l). From the present data we can conclude that the central water well in Wadi Sahu is not safe for drinking or irrigation where it contains high levels of lead and cadmium that represent hazard effects to humans, animals and plants. The soil to plant transfer factor data obtained from this study possibly used as a natural bio-indicator for radioactive contamination.

KEYWORDS

Wadi Sahu; radiological impacts; Alpha Spectroscopy; transfer factor.

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INTRODUCTION

Components of natural environment such as soils, rocks, sediments, vegetation, air and water include some naturally occurring radioactive materials (NORM). These materials may contain ^{238}U, ^{235}U, ^{232}Th and their radioactive daughters and the radioactive isotope ^{40}K. These radionuclide's give rise to internal and external radiation exposures both indoor and outdoor. Soil and water are important environmental materials used in growing plants and feeding animals and humans. Radon indicates the presence of radium and its ultimate precursor's uranium in the ground. The vast variation in radon exposure depends on location considered.

Radon gas is soluble in water, but the solubility decreases with increasing in temperature. Groundwater which are encased in radium bearing rock formations can have concentrations of Rn-222 greater than 50,000 pCi/ L. The radon gas quickly transfer to the air when heated or when aerated as in a shower, a faucet aerator, or appliances (Somashekar and Ravikumar, 2010) Although the majority of radon present in groundwater will decay prior to its arrival at the surface, groundwater is nevertheless considered the second most prominent source of environmental radon and has been estimated to contribute approximately $5x10^8$Ci radon-222 per year to the atmosphere (Todorovic *et al.,* 2012). The plant in a soil contains radionuclide's may absorb a part of this radioactivity and the radionuclide may transfer to the plant through its root that immersed in the soil.

GEOLOGIC SETTING

Wadi Sahu lies in southwestern Sinai, Egypt and limited by the latitudes 28º 58` 00" and 28º 58` 50" N and the longitudes 33º 22` 30" and 33º 24` 20" E (Fig.1).The area covered by the Paleozoic sedimentary succession, includes the following rock units starting from the oldest; Adedia Formation. This formation is upwards followed unconformably by Um Bogma Formation which unconformably overlain by Abu Thora Formation (Figs. 1 & 2). Uranium mineralizations are mainly associated with topmost Adedia Formation (sandstone) and Um Bogma Formation. The different lithological units of Um Bogma Formation are arranged as follows:

1- Lower dolostone, siltstone, claystone member. It is mainly composed of dolostone, silt and clay beds manganese-iron concretions and lenses, sandstone and conglomeratic sandstone intercalation. Occasionally the sandstone grade into silty or conglomeratic size.

2- Middle marl, dolostone member. It is composed mainly of fossiliferous marly dolostone and shale. The dolostone is highly fractured and fissured with copper mineralization along fissures. It is grey to dark grey with Mn concretions. It is medium hard with caves near the base, which are often due to pre existing Mn-Fe concretions or karstification processes, i.e dissolution features of carbonates (El sharkawy, 1990). It is green with dark patches, contains green copper mineralization and is highly radioactive. The uranium mineralization are mainly associated with the middle member of Um Bogma Formation (Aita, 1996 and Ashami, 2003). Yellow secondary uranium minerals and green copper-uranium mineral torbernite have been detected in the silt of this member (Dabbour and Mahdy, 1988).

Upper dolostone member: It is composed mainly of dark grey to black sandy dolostone. It is composed of coarse-grained, sometimes sugary dolomite crystals, containing variable amounts of silt-and sand-sized quartz grains to form sandy/silty dolostones and dolomitic sandstones.

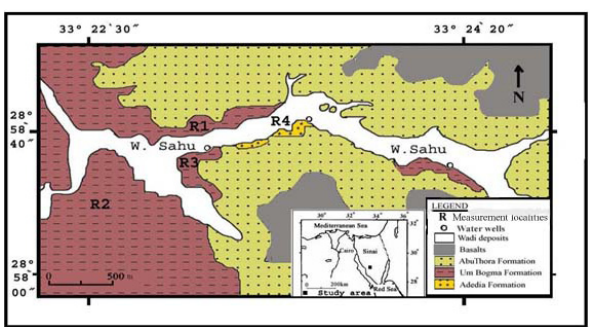

Fig.(1): Location and geological map of the study area.

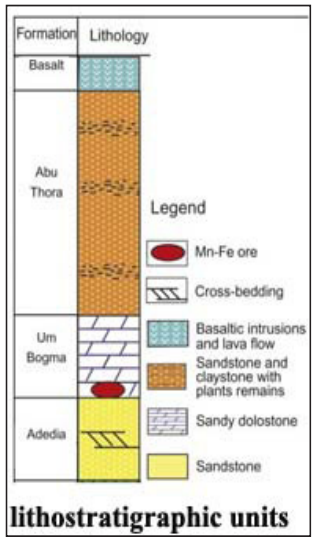

Fig.(2): Lithostratigraphy and photograph show Adedia Formation overlain by Um Bogma and Abu Thora Formation in the studied area.

EXPERIMENTAL TECHNIQUES AND METHODOLOGIES

As shown in the geological map (Fig.1),Wadi Sahu is divided into four loclities R1, R2, R3.and R4 .The distribution of measurements take place as the following;

1. Determination of Radon Concentration Levels in three water wells, eastern, central and western (Fig 1).
2. Calculation of radiological effects owing to ingestion of dissolved radon in these wells.
3. Analysis of Environmental Pollutants by Atomic Absorption Spectrophotometer.
4. Gamma spectroscopy measurements for U, Th, K concentrations in some plant samples collected from the area around these wells.

Determination of Radon concentration levels in well water;

Nine water samples were collected from the three wells (Three from each well)

Radon concentration in water was measured using a professional radon monitor Alpha Spectroscopy (SARAD RTM 1688). This is an ionization chamber designed for measuring radon in air, water and soil. It is suitable for continuous measurements of radon and has a measurement range of 2-2000000 Bq m^{-3} (0.054–54054.05 pCi l^{-1}) with a sensitivity of 5 cpm for 100 Bq m^{-3} (3 pCi l^{-1}). For radon water measurements, additional equipment called Aqua KIT was used. Figure (3) shows the set-up for radon measurements in water samples.

In a closed gas cycle, radon was expelled from the water samples (placed in a de-gassing vessel) using an air bubbling flask. The bubbling flask has to be connected to the radon monitor to create a closed air loop. The air volume of the system circulates through the loop drawn by the internal pump of the radon monitor. The small bubbles will transfer the radon very efficient because of the large resulting surface of the junction between water and air.

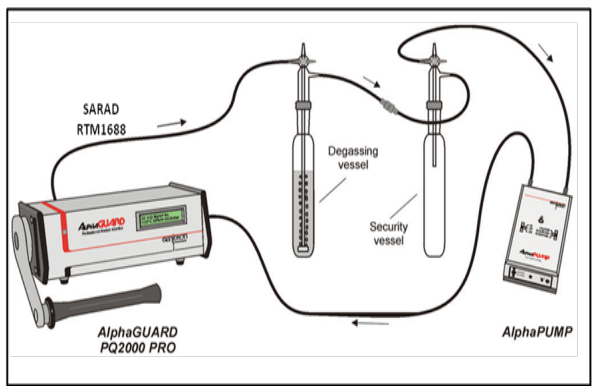

Fig.(3): Schematic view of the experimental set-up for radon measurement.

All connection tubes and the optional protection flask have to be flushed with fresh air for at least 15 minutes. The equilibrium state between the air and the water activity concentration is given after approximately 30 minutes.

Therefore, the measurement can be at the earliest after 30 minutes of bubbling.

After that, the water was injected into the degassing vessel, and the Alpha PUMP was switched on. After 10 min, the pump was switched off and the Alpha spectrometry remained switched on for another 20 min; so the radon measurement was continued. This cycle was repeated three times in order to obtain better precision. The radon concentration in the water samples was determined with the Alpha spectrometry. The measured value by Alpha spectrometry is not the radon concentration in the water sample since the radon driven out had been diluted in air within the measurement setup, and a small part determined by the partition coefficient of the radon remained diluted in the aqueous phase. For quantifying the dilution effect, the exact interior volume in the measurement set-up (V system) is required.

The RTM1688 is the most recommended solution for radon in water analysis. The unit offers a high sensitivity of more than 3 cpm/(kBq/m³) (Fast Mode) obtained from a very small internal volume of only 130 ml.

Calculation of radiological effects owing to ingestion of dissolved radon in drinking water

The radiological effects were defined in terms of effective radiation dose received by the population during habitual consumption of water. The annual effective dose to an individual consumer due to intake of radon from drinking water is evaluated using the relationship (Johns, 1969)

$$D_W = C_W C_{RW} D_{CW} \quad (1)$$

where D*w* is the annual effective dose (Sv y^{-1}) due to ingestion of radionuclide from the consumption of water, C*w* concentration of ^{222}Rn in the ingested drinking water (Bq L^{-1}), C_{Rw} annual intake of drinking water (L y^{-1}), D_{cw} is the ingested dose conversion factor for ^{222}Rn (Sv Bq^{-1}). For calculation of effective dose, a dose conversion factor of 5×10^{-9} Sv Bq^{-1} suggested by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has been used Annual effective dose due to intake of ^{222}Rn from drinking water has been calculated considering that an adult (Age18 year) on average, takes 730 L water annually (ICRP, 1991.Bosco *et al*., 2005),

Analysis of Environmental Pollutants by Atomic Absorption Spectrophotometer

i) **Materials:**Samples were taken from 3 different wells.

ii) **Chemicals**: a) Nitric Acid b) well water samples c) Standard solution of Cd ,Zn and Pb.

iii) **Apparatus:** Polyethylene cans of 2 L capacity were made use for collection of water samples. These polythene cans were first washed with tap water, soaked in chromic acid solution for about 10-15 minutes to remove any impurities, again washed with tap water. Finally, they were rinsed with de-ionized distilled water. Then the polythene cans were taken for sample collection. Acids, alkalis, indicator, buffer reagents, mineral salts *etc*. used in the analysis were of analytical grade of high purity. Hence they were directly used without any purification.

iv) **Instrument:** Atomic Absorption Spectrophotometer model GBC 932**,** Appropriate physical and chemical methods were applied for the determination of various parameters. So, the samples under test were subjected to trace metal analysis. The trace metals are zinc, cadmium, lead.

Gamma spectroscopy measurements for U, Th, K Concentrations;

Plant samples were collected from an area of 1 m^2 from the same site where the soils were collected and cut at stubble height of about 2 cm above soil surface to avoid collecting soil with plant.

Samples preparation:

Twelve plant samples represents different type of

plants from the studied four localities were collected from each site as shown in Table (1). Samples were cleaned from soil residues to avoid radionuclide contribution from the soils but were not washed in order to provide an actual assessment of the total amount of radionuclides, be it from root uptake and/or from plant surface deposition on the plant. Each plant sample was weighed, dried at 105 ^{0}C for 24 hours or until completely dry (i.e. fixed weight is observed for two successive weighting times), mechanically crushed, and passed through at a 2 mm size. A representative plant sample was put on circular plastic containers of 10 cm diameter and 3 cm height. Every sample was then pressed manually in its container till it was completely filled and tightly closed. The prepared samples were stored for sealing about one month to accumulate free radon and reach the state of radioactive equilibrium**.**

Table (1) *The scientific and Arabic names for the plants used from the studied area.*

Sample no.	Scientific Name	Vernacular Name
1	**Compositae** *Achillea fragrantissimum*	Qaysoom
2	**Amaranthaceae** *Aerva javanica*	Taraf
3	**Leguminosae** *Acacia Arabica*	Talah
4	**Ephedraceae** *Ephedra aphylla*	Algan

Procedures of Radiometric Measurement:

The radiometric measurement of the radionuclides was carried out through four energy regions of interests (ROIs). Since uranium and thorium are not gamma-emitters, they were measured indirectly through the gamma-ray photons emitted from their daughters,Th-234 (81- 108 keV) for U-238, Pb-212 (221-273 keV) for Th-232 and radium was measured from the gamma-ray photon emitted by Pb- 214 (327-390 keV) whereas potassium was measured directly from the gamma-ray photon emitted by K-40 (1319- 1471 keV). Consequently, they are expressed as equivalent uranium (eU) and equivalent thorium (eTh).

Values of eU, eTh as well as K, in %, were converted to activity concentration, Bq kg^{-1}, using the conversion factors given by Polish Central Laboratory for Radiological Protection (Malczewski *et al*., 2004).

The specific parent activity of a sample containing 1 ppm, by weight, of U is 12.35 Bq kg^{-1}, 1 ppm of Th is 4.06 Bq kg^{-1} and 1% of ^{40}K is 313 Bq kg^{-1}. These data were used for calculation of some radiological parameters to estimate the environmental radioactivity impacts of the radionuclides.

RESULTS AND DISCUSSION

Radon Measurements in Groundwater

The results of radon concentration in the collected groundwater samples (9 samples) were illustrated in Table (2). Each water type was represented by three samples and the average value was obtained.

Table (2) *The activity concentrations of ^{222}Rn in drinking water samples collected from different locations in Wadi Sahu area.*

Water samples	Average of radon concentration (Bq/m^3)	Average of radon concentration (Bq/l)	Average of radon concentration (pCi/l)	Average of effective Dose Rate (m Sv/y)
1- Eastern well	67 ± 0.2	0.067± 0.0002	1.8 ± 0.005	0.24×10^{-3}
2- Central well	83 ± 0.18	0.083 ±0.0001	2.24 ± 0.004	0.3×10^{-3}
3- Western well	110 ± 016.	0.11 ± 0.0001	2.97 ± 0.004	0.4×10^{-3}

From the obtained activity concentration values of radon we can find that, the highest value was recorded in the western well samples**,** but is still smaller than the world average value. The US Environmental Protection Agency (EPA) has previously proposed a standard for radon contamination in drinking water known as the maximum contaminant level (MCL) of 11.1 Bq L^{-1}(300 pCi L^{-1} or 11.1 k Bq m^{-3}) for public water supplies. The EPA was considered as alternative waterborne ^{222}Rn standard of 4000 pCi/l for communities that make a concerted effort to reduce indoor ^{222}Rn gas concentration.

The annual effective dose calculated using equation (3.1) for eastern well samples was 0.24×10^{-3} mSv/y, for western well samples was 0.4×10^{-3} mSv/y and for central well samples was 0.3×10^{-3} mSv/y that were significantly lower than the UNSCEAR(2000) and(WHO,1998) recommended limits for members of the public of 1 mSv y^{-1}.

The trace elements concentration within the studied different groundwater samples were illustrated in Table (3).

Table (3) *Average trace elements concentration (ppm).within the studied water samples.*

Water samples	Cd (ppm)	Zn (ppm)	Pb (ppm)
1- Eastern well	N.D	0.0312	N.D
2- Central well	1.5127	0.1796	0.2879
3- Western well	0.0689	0.1748	N.D

N.D = Not detected

In the water treatment, heavy metals refer to the heavy dense and metallic elements that could be found only at the trace levels in water. Nonetheless, these constituents are very toxic and tend to accumulate in the body in a long period of time. Heavy metals such as Pb, Cd and Hg mercury are micro-pollutants and of special interest as they have both health and environmental significance due to their persistence, high toxicity and bioaccumulation characteristics. We must note that cadmium origin includes electroplating, erosion of natural deposits, discharges from metal and plastic refineries, battery and paint waste, mining as well as sewage. It occurs mostly in association with Zn and gets into the water from the corrosion of Zn-coated galvanized pipes and fittings. It penetrates body via food eaten and water drank. Cd can cause kidney disease and injures the renal, pulmonary, skeletal and testicular, in addition, is been recognized as a carcinogen. Renal failure tends to be the fatal due to the sensitive nature of the kidneys if there is a concentration of Cd. Lead is common heavy metal, its poisoning has been recognized as an occupational illness for centuries. It gets into the water from the corrosion of plumbing materials. Sources including paint, mining wastes, incinerator ash, automobile exhaust, water from Pb pipes and solder that are used to join Cu pipes, in fittings and faucets are made from brass. Intake of Pb causes delay in physical or mental development for infants and children. Whereby for adults, it may causes damage to kidneys, brain, and nervous system.

From Table (3), we can conclude that:

Eastern well samples**:** Results of analysis demonstrate that cadmium (Cd) and lead (Pb) are under limits of detection. The concentration of zinc in the sample was with value of 0.0312 mg/l. Since the recommendations for the domestic water supplies are 5 mg/l (WHO, 1998) .The levels of zinc in the groundwater are safe enough for drinking and other domestic purposes where zinc is an essential element for both animals and man. It is necessary for the functioning of various enzyme systems, deficiency of which leads to growth retardation. Low intake of zinc results in retardation of growth, immaturity and anemia condition known as zinc deficiency syndrome.

Western well samples: Results of analysis demonstrate that lead (Pb) is under limits of detection. The concentration of cadmium (0.0688 mg/l) was higher than the permissible limit for cadmium in drinking water (0.01 mg/l) that present hazards to humans. The concentration of zinc was 0.1746 mg/l. Since the recommendations for the domestic water supplies are 5 mg/l (WHO, 1998) the levels of zinc in the groundwater are safe enough for drinking and other domestic purposes.

***Central well samples*:** Results of analysis demonstrate that there was cadmium (Cd), zinc (Zn) and lead (Pb) metals. The concentration of cadmium was (1.5127 mg/l) which is higher than the permissible limit in drinking water (0.01 mg/l) (WHO, 1998). The concentration of zinc in this water was 0.17 mg/l. Since the recommendations for the domestic water supplies are 5 mg/l the level of zinc in the groundwater is safe enough for drinking and other domestic purposes. The concentration of lead was (0.28 mg/l) which is higher than the permissible limit in drinking water (0.05 mg/l) (WHO, 1998). The lead content in the groundwater of the study area cannot be safely used as a source of drinking water supplies. The contamination in the groundwater may be related to the water recharged for the central and western wells, while the recharge is come from many wadis crosscutting Um Bogma Formation. Also, the high concentration of iron oxide in the ferruginous sandstone aquifer of central and western wells is higher than the eastern well. It is considered as a barrier for mobile uranium and other elements, while uranium and other elements can be adsorbed on iron oxides crystal surfaces.

Table (4) *Radioelement's content in the collected grasses from the four localities of Wadi Sahu area.*

Sample No.	Radionuclide's	Radionuclide Concentration (ppm)	Specific Activity (Bq/kg)
Sample(1) *Achillea fragrantissimum*	^{238}U	2.43	30.10
	^{232}Th	1.58	6.38
	^{40}K	1.25%	392.03
Sample(2) *Aerva javanica*	^{238}U	1.35	16.73
	^{232}Th	3.13	12.65
	^{40}K	0.38%	120.30
Sample(3) *Acacia Arabica*	^{238}U	6.86	85.06
	^{232}Th	0.69	2.78
	^{40}K	0.73%	229.03
Sample(4) *Ephedra aphylla*	^{238}U	3.31	40.99
	^{232}Th	0.79	3.19
	^{40}K	1.05%	329.92

Radiometric Measurements in Grasses:

The release of radionuclides into the environment can result in contamination of grasses, so that different types of grasses were collected from the study area. The concentrations of the naturally occurring radionuclides ^{238}U, ^{232}Th and ^{40}K were determined in grasses as indicated in Table (4).

The radionuclide activity concentrations of ^{238}U ranged between 16.73Bq kg^{-1} in sample (2) and reach up to 85.06 Bq kg^{-1} in sample (3), from 2.78Bq kg^{-1} in sample (3) up to 12.65Bq kg^{-1} in sample (2) for ^{232}Th, and from 120.30Bq kg^{-1} in sample (2) up to

392.03Bq kg^{-1} in sample (1) for ^{40}K.

For all types of grass samples, a relatively large variability in radionuclide concentration values was found.

The higher concentrations obtained in the present work may be due to the high uranium content in soil of Wadi Sahu which increase the uptake of ^{238}U from soils to grass. The levels detected for ^{40}K are higher than the range reported (40-240 Bq/kg) in different parts of the world (**Maul and O'Hara, 1989**).

The levels detected for ^{238}U in plant samples are higher than the range (< DL to 2.11± 0.01Bq kg−1) in Alexandria region, Egypt (**Saleh *et al*., 2007**).

Leafy plants seem to absorb more potassium than other crops or the potassium are concentrated in leaves more than any other parts of the plant (Badran *et al.*, 2003). However, the concentrations of ^{40}K in the studied plants were higher than both world range and reported Egyptian range

The Transfer and accumulation of uranium from one environmental compartment to another, through root uptake in biological systems such as plants, clearly depend upon the availability of the nuclides in soil, and also on the rate of loss from the internal structure of leaves after translocation**.**

Soil –To-Plant Transfer Factors:

The plant -to-soil concentration ratio (CR) has been used to predict the transport of radionuclides and other elements of interest through the food chain (Simon and Brahmin, 1987).

^{226}Ra is one of the most important alpha emitting radionuclides in the ^{238}U decay chain, and is retained primarily in bone, due to metabolic similarities to calcium. The reference value for annual intake of ^{226}Ra in diet (food and water) has been estimated to be 22 Bq, corresponding to an annual effective dose of 6.3 µSv for adults (UNSCEAR, 2000).

Table (5) *The soil to plant concentration ratio (CR) of 238U for the studied plants in Wadi Sahu area.*

Scientific Name of plants	^{238}U Activity concentration (Bq/Kg) in drayed grass	Soil type	^{238}U Activity concentration (Bq/Kg) in dried soil	C.R
Composite Achilles Fragrantissimum	**30.10**	**Variegated Shale-middle Um Bogma.**	**587.86**	**0.05**
Amaranthaceae *Aervajavanica*	**16.73**	**Middle Member of Um Bogma (Marl)**	**334.99**	**0.05**
Leguminosae *Acacia Arabica*	**85.06**	**Variegated shale + white gibbsite L. Um Bogma and Variegated Shale-middle Um Bogma**	**467.75**	**0.18**
Ephedraceae *Ephedra aphylla*	**40.99**	**Gibbsite, L. Um Bogma**	**133.79**	**0.3**

There were several reasons to study and assess their natural and anthropogenic radionuclides contents**.**

First, to assess any possible transfer of specific radionuclide from soil to the corresponding vegetation to get some actual field study data about the transfer behavior of these radionuclides.

Second, using the soil to plant transfer factor data obtained from this study, vegetables could be used as a natural bio-indicator for radioactive contamination in cases of accidents of unplanned releases of radioactivity to the environment.

Based on the literature (Simon and Brahmin, 1987) the ability of various plant species to absorb radionuclides from soils or other substrates is determined by CR and defined as:

CR= ^{238}U conc. (dried plant)/^{238}U conc. (dried soil)

Based on the assumption that the concentration of ^{2238} U in plants increased linearly with increasing ^{238} U concentration in soil. From table (5) it can be noted that the calculated soil to plant (CR) of ^{238} U for 4 different types of desert plants (leafy plants and trees) and different soil types showed nonlinearity which is coincide with (Simon and Brahmin, 1987).

CONCLUSION

Results of analysis demonstrate that cadmium (Cd) and lead (Pb) are under limits of detection, and the levels of zinc in the groundwater are safe enough for drinking and other domestic purposes

From the generated data and the foregoing discussion, it can be concluded that most of the groundwater samples in Wadi Sahu area (especially the central and western parts) are not suitable for drinking use and require treatment before being used. The levels detected for ^{238}U in plant samples are higher than the range (< DL to 2.11± 0.01Bq kg−1) in Alexandria region, Egypt. In general, no significant results for ^{238}U concentrations in foodstuffs reported in Egypt literature.

So, some precautions and recommendations should be follow and take into consideration for the public residences in this area especially region one.

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مجلة
التقنيات النووية
فى العلوم التطبيقية
مجلد 3 ، عدد 3 ، ص 145 : 155 ، (2015)

التأثيرات البيئية للرادون والعناصر الثقيلة في مياه الأبار والنباتات من وادي الصحو ،جنوب غرب سيناء، مصر.

سيد فهمي حسن سليمان[1] - عبد الستار محمد سلام[2] - محمود مصيلحي نصر[1] - ولاء صلاح محمد[1]

وادي الصحو كجزء من جنوب غرب سيناء ,مأهول بالسكان البدو الذين يستخدمون الموارد الطبيعية في نظام حياتهم . بلأضافة الي تواجد انشطة تعدين المنجنيز التي قد تسبب بقدر ما بعض الاضرار البيئية والتاثرات الاشعاعية المهنية.

هذه الدراسة تهدف الي تقدير تركيزات غاز الرادون و المعادن الثقيلة في التربة و ابار المياه والنباتات في المنطقة تحت الدراسة.

تم تجميع عينات المياه من ابار المياه العامة المستخدمة في الوادي وتم قياس تركيز غاز الرادون باستخدام مطياف الفا موديل (اس ايه ار ايه دي ار تي ام ١٦٨٨) ثلاثة مرات لكل عينة.

وقد اوضحت النتائج الاتي :

- تركيز غاز الرادون في مياه البئر الأوسط ٨٣± ٠,١٨) بكريل لكل متر مكعب) وهي اقل من القيمة العظمي لمستوي التلوث لمصادر المياه العامة ١١,١ كيلو بكريل لكل متر مكعب)
- تركيز الكادميوم ١,٥١ مللي جرام لكل لتر اكبر بكثير من الحدود المسموح بها لمياه الشرب ٠,٠١ مللي جرام لكل لتر و الذي يسبب تاثير سام للانسان
- تركيز الرصاص كان ٠,٢٩ مللي جرام لكل لتر وهو اكبر من الحدود المسموح بها بالنسبة لمياه الشرب (٠,٠٥ مللي جرام لكل لتر)

من النتائج السابقة يتضح ان البئر الاوسط في وادي الصحو غير امن الاستخدام في اغراض الشرب او الزراعة بسبب احتوءاه علي تركيزات عالية من الرصاص و الكادميوم و التي تسبب تأثير خطر علي الانسان و الحيوان

نتائج معامل الانتقال من التربة الي النبات التي تم الحصول عليها من هذه الدراسة يمكن استخدامها كمؤشر طبيعي حيوي علي التلوث الاشعاعي.

1. هيئة المواد النووية – المعادي – القاهرة – مصر.
2. قسم الفيزياء – كلية العلوم – جامعة عين شمس – القاهرة – مصر.