AVALIAÇÃO DA DOSE EFETIVA COMPROMETIDA DE GÁS RADÔNIO EM ÁGUA POTÁVEL NA PROVÍNCIA DE AL-QADISIYAH, IRAQUE

EVALUATION OF COMMITTED EFFECTIVE DOSE OF RADON GAS IN DRINKING WATER IN AL-QADISIYAH PROVINCE, IRAQ

تقييم الجرعة الفعالة من غاز الرادون في مياه الشرب في محافظة القادسية، العراق

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RESUMO

A pesquisa científica está dando interesse em determinar as concentrações de Radônio na água potável e em sedimentos, devido à ocorrência de doenças graves relacionadas a este elemento químico. A solubilidade do Radônio em água (potável e subterrânea) permite a percolação em solos e rochas. As concentrações de radioatividade natural do Radônio foram medidas na água potável e sedimentos na estação de tratamento (Al-Diwaniyah, Iraque) usando detector de traços RAD7 e CR-39 (câmara de difusão, Landauer). A amostragem foi realizada em 20 amostras (10 de água potável e 10 de sedimento). Os resultados de radioatividade mostraram que a concentração de ²²²Rn na água potável variam de 0,05 a 0,47 Bq/L com média de 0,24 Bq/L. No entanto, as concentrações de ²²²Rn no sedimento variam de 29,16 a 60,52 Bq/m³ com uma média de 42,43 Bq/m³. A partir dos resultados foi possível calcular a contribuição do Radônio na água potável associado a idade. As doses anuais ficaram abaixo dos limites recomendados. As concentrações de Radônio na água potável e no sedimento apresentaram altos níveis de radioatividade quando comparadas ao limite natural. No entanto, os mesmos resultados indicaram baixos níveis de radioatividade quando comparados ao Comitê Científico das Nações Unidas sobre o Efeito da Radiação Atômica e à Organização Mundial da Saúde. Desta forma, toda a água potável nessa estação é segura para uso.

Palavras-chave: Água potável; radônio; RAD7, sedimento; CR-39; dose efetiva comprometida.

ABSTRACT

Scientific research is giving interest in determining the concentrations of Radon in drinking water and sediments due to the occurrence of serious diseases related to this chemical element. The solubility of Radon in water (potable and underground) allows percolation in soils and rocks. The concentrations of Radon natural radioactivity were measured in drinking water and sediment at a wastewater treatment plant (Al-Diwaniyah, Iraq) using trace detector RAD7 and CR-39 (diffusion chamber, Landauer). Sampling was carried out at 20 samples (10 of drinking water and 10 of sediment). The results of radioactivity showed that the concentration of ²²²Rn in drinking water varies from 0.05 to 0.47 Bq/L, with an average of 0.24 Bq/L. However, the ²²²Rn concentrations in the sediment vary from 29.16 to 60.52 Bq/m³, with an average of 42.43 Bq/m³. From the results, it was possible to calculate the contribution of Radon to drinking water associated with age. The effective annual doses were found below the recommended limit. Radon concentrations in drinking water and sediment showed high levels of radioactivity compared to the natural limit. However, the same results indicated low radioactivity levels compared to the United Nations Scientific Committee on the Effects of Atomic Radiation and the World Health Organization. In this way, all drinking water at these stations is safe to use.

Keywords: Drinking water; Radon; RAD7, sediment; CR-39; committed effective dose.

يهدف البحث العلمي بتحديد تراكيز غاز الرادون في مياه الشرب والرواسب نتيجة الإصابة بأمراض خطيرة مرتبطة بهذا العنصر الكيميائي. تسمح قابلية ذوبان الرادون في المياه (الصالحة للشرب وتحت الأرض) بالتسرب في التربة والصخور. تم قياس تراكيز النشاط الإشعاعي الطبيعي للرادون في مياه الشرب والرواسب في محطة معالجة مياه الصرف الصحي (الديوانية، العراق) باستخدام كاشف التتبع RAD7 و CR-39 (غرفة الانتشار، لاندور). العينات المأخوذة للدراسة 20 عينة (10 من مياه الشرب و 10 من الرواسب). أظهرت نتائج النشاط الإشعاعي أن تركيز ^{222}Rn في مياه الشرب يتراوح بين 0.05 و 0.47 بيكريل / لتر بمتوسط 0.24 بيكريل / لتر. ومع ذلك، فإن تراكيز ^{222}Rn في الرواسب تتراوح من 29.16 إلى 60.52 بيكريل / م³ بمتوسط 42.43 بيكريل / م³. من النتائج، كان من الممكن حساب مساهمة الرادون في مياه الشرب المرتبطة بالعمر. تم العثور على الجرعات السنوية الفعالة أقل من الحد الموصى به. أظهرت تراكيز الرادون في مياه الشرب والرواسب مستويات عالية من النشاط الإشعاعي مقارنة بالحد الطبيعي. ومع ذلك، أشارت النتائج نفسها إلى انخفاض مستويات النشاط الإشعاعي مقارنة بلجنة الأمم المتحدة العلمية المعنية بآثار الإشعاع الذري ومنظمة الصحة العالمية. بهذه الطريقة، تكون جميع مياه الشرب في هذه المحطات آمنة للاستخدام.

الكلمات المفتاحية: مياه الشرب؛ رادون RAD7؛ الرواسب؛ CR-39؛ جرعة فعالة المترسبة.

1. INTRODUCTION

The aquatic environment is the final destination of many potentially toxic and radioactive industrial residues that hinder the growth of biota, causing irreversible ecological damage (Shannoun, 2015; Cho *et al.*, 2019). The determination of radionuclide concentrations in aquatic systems is fundamental mainly in two aspects: i) protection of human health (drinking water consumption) and ii) control of environmental pollution. Thus, Radon determination has become a public health concern due to its dangerous nature regarding its exposure (Al-Fifi *et al.*, 2012; Alshahri *et al.*, 2019). Radon is a product of the disintegration of radium (atomic number 88), a highly radioactive element, as well as thorium (atomic number 90), where the name of one of its isotopes, toron, with a half-life ($t_{1/2}$) of 55 seconds and atomic mass 220. The ^{219}Rn isotope is called actinon, it is a product of the disintegration of actin and has a half-life of 4 seconds. In addition to these, Radon has 22 artificial isotopes, produced in nuclear reactions by artificial transmutation in a cyclotron and linear accelerators (AS-Subaihi *et al.*, 2020; Binesh *et al.*, 2012). The most stable isotope is ^{222}Rn , the most abundant, with a half-life of 3.8 days and a disintegration of ^{226}Ra . When emitting alpha particles, it becomes an isotope of the polonium element (Shannoun, 2015; Somlai *et al.*, 2007; Al-Nafiey *et al.*, 2014).

Radionuclides are naturally present in all environmental elements. They are found in atmospheric air, water, sand, plants, animals, soils, rocks, and in the human body itself in varying amounts (Shannoun, 2015; Al-Alawy *et al.*, 2018). The presence of radionuclides in the environment is responsible for significant exposure to radiation for humanity (Shannoun, 2015). Radionuclides can emit alpha or beta particles and can be ingested or inhaled by the body. ^{222}Rn gas is one of the most dangerous

nuclides for humans (Gruber *et al.*, 2009).

Inhalation and ingestion of ^{222}Rn correspond to 54% of registered deaths, and about 10% is due to exposure in closed rooms or caves causing lung cancer (Al-Mosuwai and Subber, 2013; Chanyotha *et al.*, 2016; Atallah *et al.*, 2001). Radon is present in rocks that make up the earth's crust, and for this reason, there is a percolation of this chemical element through porous cavities reaching the groundwater. This phenomenon also occurs in sediments by physical and biological processes through leaching of sediment and water (Shannoun, 2015; Showard and Aswood, 2019; Todorovic *et al.*, 2012; Jobbágy *et al.*, 2017). Radon is a radioactive gaseous element belonging to the group of noble gases. (Appleton, 2007; Divya *et al.*, 2019; Martins *et al.*, 2020). The risk of Radon being ingested is generally small when compared to inhaled Radon (Gruber *et al.*, 2009).

Radon is a completely inert, tasteless, and odorless gas. Within the radionuclides descending from ^{238}U , ^{226}Ra stands out, which has a half-life of 1600 years and which, by alpha emission, forms ^{222}Rn , Radon, with a half-life of 3.82 days (Fares, 2017). Their descendants are ^{218}Po , ^{214}Pb , ^{214}Bi , and ^{214}Po , all with a very short half-life. ^{222}Rn is an inert gas with accumulated property in closed environments such as homes, caves, mines, and tunnels (Nikolopoulos and Louizi, 2008; Subber *et al.*, 2011). Therefore, together with their parents ^{218}Po and ^{214}Po , they are responsible for approximately 50% of the equivalent effective dose produced by natural ionizing radiation (Subber *et al.*, 2017). In the ^{232}Th series, a similar process occurs with ^{220}Rn , also called toron, with a half-life of 55 seconds and with its descendants ^{216}Po , ^{212}Pb , ^{212}Bi , ^{208}Tl , and ^{212}Po (Jaber *et al.*, 2015; Kiat *et al.*, 2008).

Radon consists of several isotopes; however, only three are naturally occurring: Radon (^{222}Rn), actinon (^{219}Rn), and toron (^{220}Rn).

These radionuclides come from the series of decay originated from ^{238}U , ^{235}U , and ^{232}Th , respectively. Despite being produced continuously in rocks and minerals by the α decay of ^{226}Ra , ^{224}Ra and ^{223}Ra , these radionuclides do not form chemical compounds (Henshaw *et al.*, 1993; Kurnaz and Çetiner, 2016). In practice, only ^{222}Rn and ^{220}Rn isotopes are relevant from the point of view of radiological protection or environmental and geological interest (Lopes, 2005). ^{219}Rn is rarely found in nature due to its very short half-life of 4 seconds and the isotopic abundance of its parent ^{235}U of only 0.72%. ^{222}Rn has a half-life of 3.83 days, which allows its mobility significant to escape the rock on which it was generated (Nasir and Shah, 2012; Wallner and Steininger, 2007). ^{220}Rn is of concern from the point of view of radiological protection only if high concentrations of ^{232}Th are present in the minerals. The emission of ionizing radiation by rocks and soils depends on their content of U, Th, and K; Radon contents will depend mainly on the concentration of uranium.

A widely used device to detect the presence of Radon in water is RAD7 (DurrIDGE Company Inc.) (Al-Nafiey *et al.*, 2014; Zalewski *et al.*, 2001; Fard *et al.*, 2020). RAD7 is a solid-state detector composed of a semiconductor material (usually silicon) that converts alpha radiation directly into an electrical signal. During the Radon decay, the alpha particle is 50 percent likely to penetrate the detector and produce an electrical signal (Wang *et al.*, 2011; Wong *et al.*, 1992). Therefore, to detect the concentrations of Radon in sediments, the widely used equipment is the CR-39 (Columbia Resin-39) composed of a polymer with optical properties similar to that of optical glass (Al-Nafiey *et al.*, 2014; Mustapha *et al.*, 2002; Xinwei, 2006; Muhammad *et al.*, 2012). This research aims to examine Radon exposure in drinking water and sediments, establishing an adequate intake.

2. MATERIALS AND METHODS

2.1. Samples collection

Samples of drinking water and sediment were obtained at drinking water stations in the city of Al-Diwaniya, in southern Iraq. Ten samples of drinking water were obtained and stored in polyethylene bottles. Based on the International Atomic Energy Agency (IAEA) requirements, the polyethylene bottles were rinsed with double distilled water at least five times with 1:1 $\text{HNO}_3\text{:H}_2\text{O}$. To avoid accumulating organic materials and minimizing radioactive material

loss, hydrochloric acid (HCl) was used. Ten samples of sediment were collected to determine the availability of radionuclides based on the International Atomic Energy Agency standards. The samples were removed by dredging stainless steel. From each location, 250 g of sediment were collected and deposited in polyethylene bags. The samples were identified and labeled with time, place, and date (Al-Alawy *et al.*, 2018).

2.2. Experimental method

After the collection process, the samples were taken to the laboratory (Department of Physics, Faculty of Education), where the preparation process began. In this step, the RAD-7 and CR-39 techniques were used to measure the Radon concentration in the samples, as shown in Figure 1. The Radon concentration in drinking water were calculated according to the EPA protocol. The RAD7 detector (model 2890 - DurrIDGE Company) was exposed to a known concentration of Radon (or Thoron) during calibration. The detector was set up to perform counts of five minutes in five minutes, with four cycles for each sample (Divya *et al.*, 2019).

Therefore, for the sediment samples (250 g) were heated in an oven at 110 °C for about 24 hours to remove moisture and ground to obtain a homogeneous powder. To measure the Radon concentrations in the sediments, 10 g of the powder was stored inside the PVC tubes (Showard and Aswood, 2019). CR-39 detectors were installed on the bottom of the tube and stored for 60 days to ensure that the radionuclide reaches a steady-state, as shown in Figure 2 (Al-Alawy *et al.*, 2018). When the ionizing particle travels through the solid, an unseen latent path appears with the naked eye. The physical-chemical changes at the damage site depend on the chemical composition of the detection material and the atmosphere (temperature and pressure).

The CR-39 detector was then chemically attacked in a standard 6.25 N NaOH solution for 6 h at 70 °C. The tracks were captured with an Olympus optical microscope with 400 X magnification, as shown in Figure 3.

2.3. Calculation

The annual effective dose due to ingestion of ^{222}Rn in drinking water were calculated according to Equation 1 (Somlai *et al.*, 2007; Singh *et al.*, 2010):

$$E = K \cdot C_{W222Rn} \cdot KM \cdot t \quad \text{Eq. 1}$$

where:

E represents the effective ingestion dose (Sv - Sievert is the unit used to give an assessment of the impact of ionizing radiation on humans); K is the ingesting dose conversion factor of ^{222}Rn (1×10^{-8} Sv/Bq for adults and 2×10^{-8} Sv/Bq for children); C_{W222Rn} represent the Radon concentration in drinking water (Bq/L); KM is the water intake, and t is the duration of intake.

The indoor Radon was calculated in drinking water using Equation 2 (Zalewski *et al.*, 2001):

$$C_{A222Rn} = C_{W222Rn} \cdot W \cdot \frac{e}{V \cdot \lambda_c} \quad \text{Eq. 2}$$

where:

C_{A222Rn} is the indoor Radon; $C_{WRn-222}$ represent the Radon concentration in drinking water (Bq/L), W is the intake of water; V is the bulk of indoor room; e is the ratio of Radon transfer from indoor (water to air); λ_c is the air exchange (0.7/h) (Xinwei, 2006). On the other hand, Radon concentrations in sediment were calculated using Equation 3 (Showard and Aswood, 2019):

$$C_{S222Rn} = \frac{\rho}{K \cdot T} \quad \text{Eq. 3}$$

where:

C_{S222Rn} is the Radon concentrations in sediment (Bq/m³); K represents the calibration factor of the detector (0.024); T is the exposure time; ρ is the density of track that particle appears on the surface of detector CR-39. The density was determined using Equation 4 (Showard and Aswood, 2019).

$$\rho = \frac{N_t}{A} \quad \text{Eq. 4}$$

where:

N_t is the average of tracks number in grids area (8×8), and A is the visible area under the microscope.

3. RESULTS AND DISCUSSION

The average Radon concentrations are expressed in Bq/L (for drinking water) and Bq/m³ for sediments. The samples were collected at the water treatment plant in different areas in Al-Diwaniyah, Iraq. Table 1 shows that the

concentrations of ^{222}Rn in drinking water vary from 0.05 Bq/L (sample W07) to 0.47 Bq/L (sample W05). In turn, the contribution of indoor Radon varied from 0.02 Bq/L (sample W07) to 0.19 Bq/L (sample W05). Therefore, for the sediment samples, the concentrations of ^{222}Rn varied from 29.16 Bq/m³ (sample S08) to 60.52 Bq/m³ (sample S05). The highest concentrations of ^{222}Rn were found in the Il-Hemad area due to the high levels of uranium in the region due to the Gulf War (a conflict that involved Kuwait, Iraq, and the United States in 1991).

Figure 4 shows the ratio between the average concentrations of Radon in samples of drinking water and sediments. We identified the highest proportion in Al-Shamiya (16%), while the lowest proportion was found in Al-Jazzier I (2%). This discrepancy in the ratio depends on the sorption potential of the sediments. The partition coefficient of ^{222}Rn in sediments decreases according to the pores of water entering the rock. Consequently, sediment irrigation rates change ^{222}Rn levels. Also, the sorption/desorption kinetics, taking into account the contact time in the water-sediment interaction, can impact the determination of the concentration of this radionuclide. A slow percolation between water and sediment can interfere with the determination of ^{222}Rn .

In turn, the results of the concentration of Radon in the sediment vary considerably due to the presence of uranium and radium. The amount of Radon in sediments and in the air changes over time. Other factors that need to be considered are atmospheric pressure, temperature, wind speed, and relative humidity. The granulometry and morphology of the sediments control the emanation of Radon in solid samples.

The United Nations Security and Energy Commission for Sustainable Development reports that the relationship between grain size and emanation of ^{222}Rn is inversely proportional. The uranium content in the samples led to the discrepancies observed in the concentrations of ^{222}Rn in the sediments. In any case, the levels of ^{222}Rn are below the limits recommended by the International Commission for Radiological Protection (200 to 600 Bq/m³).

The measures taken in this study are following environmental protection standards. The results indicate that the areas under study did not represent a risk to public health, thus allowing the reuse of these sediments in civil construction. The results obtained for the

effective dose of Radon intake in drinking water (Table 2), depending on the population's age group. Among children, there is a variation of 0.001×10^{-10} to 0.007×10^{-10} Sv/Bq and for the adult population from 0.001×10^{-10} to 0.004×10^{-10} Sv/Bq. When we compare the concentrations of ^{222}Rn in drinking water and sediments, we can identify a much greater tendency for particulate matter. This is due to the water filtration process, geological structure of the regions, and high rainfall. Thus, we can conclude that the Radon concentration in the samples, in general, is lower than the level reported by the Environmental Protection Agency (11.1 Bq/L (Khattak *et al.*, 2011)).

Considering the World Health Organization indicators, the safety limit for the concentration of ^{222}Rn is 100 Bq/L, being lower than the average concentrations observed in this study (0.24 Bq/L). The result clearly shows that the drinking water samples in the research areas are healthy and free from radiation. Generally, Radon levels in groundwater are higher than in drinking water samples due to high concentrations of uranium and radio (Mustapha *et al.*, 2002; Ahmad *et al.*, 2018). As for the effective dose of drinking water intake for children equal to twice the dose for adults (Figure 5). Tables 3 and 4 show the concentrations of ^{222}Rn in drinking water and sediments in other countries.

The values obtained in the present study were lower than the levels found in Pakistan, United Kingdom, Iran, Portugal, Malaysia, India, Austria, Giro, and Greece, except Iraq and Turkey. The same behavior is seen for the regions of Yemen, Iraq (Basra), Saudi Arabia (Jazan), Iraq (Arabian Gulf), Saudi Arabia (Arabian Gulf), and Jordan, except Egypt, Thailand, and China.

4. CONCLUSIONS

In the present work, ^{222}Rn levels were determined in a water treatment plant located in the city of Al-Diwaniya/Iraq. In a total of 20 samples (10 of drinking water and 10 of sediment), the RAD7 and CR-39 equipment were used in order to measure the concentrations of ^{222}Rn . With the aid of the RAD7 detector, the results for drinking water reveal that it can be used safely from the radiological point of view. Likewise, the sediments analyzed with the CR-39 detector proved to be below the levels recommended by health and environmental organizations and can be reused in civil

construction without causing damage. The low concentration of ^{222}Rn in drinking water is due to the filtration process of the treatment plant and the geological nature of the rocks through which the water percolates. On the other hand, the concentrations of radionuclide in sediments are high when compared to samples of drinking water. This is due to the granulometry and morphology of the material that directly influences the sorption/desorption of ^{222}Rn . According to the results of this research, the population of the city of Al-Diwaniya/Iraq is safe regarding drinking water because the concentration of ^{222}Rn is below the acceptable limits in the environmental protection and public health agencies.

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Figure 1. Diagram of RAD7 instrument for active Radon measurement.

Figure 2. Apparatus for measurements of Radon in sediments.

Figure 3. Optical microscope and track on CR-39 detector.

Figure 4. Ratio of average concentrations of Radon in drinking water and sediments.

Figure 5. Comparison of Radon ingestion to children and adults (Sv 10^{-10}).

Table 1. The concentration of indoor Radon in drinking water and sediment from the water treatment plant (Al-Diwaniya, Iraq).

Site	Code	Concentration of Radon in water	Contribution of Radon to indoor	code	Concentration of Radon in sediment C_{S222Rn}
		C_{W222Rn} (Bq/L)	C_{A222Rn} (mBq/L)		(Bq/m ³)
Al-liskan	W01	0.27 ± 0.09	0.11 ± 0.03	S01	40.70 ± 2.16
Al-Sdyr	W02	0.40 ± 0.10	0.16 ± 0.04	S02	39.25 ± 1.90
Sumir Al-Qadim	W03	0.13 ± 0.06	0.05 ± 0.02	S03	37.80 ± 1.77
Al-Husain	W04	0.20 ± 0.06	0.08 ± 0.02	S04	47.25 ± 2.63
Il-Hemad	W05	0.47 ± 0.20	0.19 ± 0.08	S05	60.52 ± 4.33
1 Million Sumir	W06	0.27 ± 0.08	0.11 ± 0.03	S06	43.15 ± 2.28
Al-Jazayir 1	W07	0.05 ± 0.02	0.02 ± 0.01	S07	48.97 ± 2.76
Al-Jazayir 2	W08	0.20 ± 0.07	0.08 ± 0.02	S08	29.16 ± 0.93
Al-Shamiya	W09	0.40 ± 0.20	0.16 ± 0.08	S09	44.70 ± 2.35
Al-Diwaniyah	W10	0.07 ± 0.03	0.03 ± 0.01	S10	32.80 ± 1.28
Average		0.24 ± 0.11	0.10 ± 0.03		42.43 ± 2.24

Table 2. Effective doses of ingestion of drinking water samples from the water treatment plant (Al-Diwaniya, Iraq)

Site	Code	Committed effective doses from ingestion E_d (Sv 10 ⁻¹⁰)	
		For children	For adults
Al-liskan	W01	0.004 ± 0.005	0.002 ± 0.002
Al-Sdyr	W02	0.006 ± 0.001	0.003 ± 0.001
Sumir Al-Qadim	W03	0.002 ± 0.003	0.002 ± 0.001
Al-Husain	W04	0.003 ± 0.003	0.002 ± 0.001
Il-Hemad	W05	0.007 ± 0.001	0.004 ± 0.001
1 Million Sumir	W06	0.004 ± 0.004	0.002 ± 0.002
Al-Jazayir 1	W07	0.001 ± 0.002	0.001 ± 0.003
Al-Jazayir 2	W08	0.003 ± 0.004	0.002 ± 0.002
Al-Shamiya	W09	0.006 ± 0.001	0.003 ± 0.001
Al-Diwaniyah	W10	0.002 ± 0.001	0.002 ± 0.001
Average		0.004 ± 0.002	0.002 ± 0.001

Table 3. Comparison of Radon concentrations in drinking water in the world.

Country	²²² Rn concentration (Bq/L)	Reference
Pakistan	0.602 ± 0.005	Nasir and Shah, 2012
Iraq	0.174 ± 0.001	Subber <i>et al.</i> , 2011
UK	0.19 ± 0.001 – 71.1 ± 0.023	Henshaw <i>et al.</i> , 1993
Iran	11.44 ± 0.023	Binesh <i>et al.</i> , 2012
Turkey	0.025 ± 0.001 – 0.128 ± 0.001	Kiat <i>et al.</i> 2008
Portugal	1.9 ± 0.002 – 112.77 ± 0.89	Lopes <i>et al.</i> , 2005
Iran	1.23 ± 0.002 – 11.94 ± 0.046	Kurnaz and Cetiner, 2016
Malaysia(a)	2.64 ± 0.003	Ahmad <i>et al.</i> , 2018
Austria	1.46 ± 0.005 – 644 ± 2.86	Wallner and Steininger, 2007
Cyprus and Greece	0.3 ± 0.002 – 24 ± 0.29	Nikolopoulos and Louizi, 2008
India	12.5 ± 1.5 – 862 ± 38	Fares, 2017
Malaysia(b)	5.37 ± 0.008	Ahmad <i>et al.</i> , 2018
Iraq, Al-Diwaniyah	0.05 ± 0.02 – 0.47 ± 0.20	Present study

Table 4. Comparison of Radon concentrations in sediment in the world.

Country	²²² Rn concentration (Bq/m ³)	References
Yemen	103.88 ± 8.80	AS-Subaihi <i>et al.</i> , 2020
Iraq (Basra)	304.3 ± 79.4	Subber <i>et al.</i> , 2011
Iraq (Arabian Gulf)	400.7 ± 198	Jaber <i>et al.</i> , 2015
Saudi Arabia (Jazan)	88.17 ± 0. 5.6	Nasir and Shah, 2012
Saudi Arabia (Arabian Gulf)	33 ± 2.10	Alshahri <i>et al.</i> , 2019
Egypt	29.40 ± 4.08	Fares, 2017
Thailand	4.5 ± 0.6	Chanyotha <i>et al.</i> , 2016
Jordan	918 ± 214	Atallah <i>et al.</i> , 2001
China	37.64 ± 3.89	Wang <i>et al.</i> , 2011
Iraq (Al-Diwaniyah)	42.43 ± 2.24	Present study