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Radon Assessment in *Ceratophyllum demersum* Plant Samples

Rana R Al Ani, Sahar A Amin*, Ahmed Alwan
Environment Research Center, University of Technology, Baghdad, Iraq

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Abstract

The amount of radioactive isotopes in submerged *Ceratophyllum demersum* plants samples were estimated using passive track detector CR-39. The samples were collected from four selected sites along the Tigris River in Baghdad city, on a monthly basis for one complete year of 2019. Certain factors like radon concentration ($Bq.m^{-3}$), radium content ($Bq.kg^{-1}$) and uranium concentration (ppm) were evaluated. The average values of ^{222}Rn level, ^{226}Ra content and ^{238}U concentration in *Ceratophyllum demersum* samples for site (1) were (593.1 $Bq.m^{-3}$, 5.8 $Bq.kg^{-1}$, 0.113 ppm), site (2) were (413.4 $Bq.m^{-3}$, 3.8 $Bq.kg^{-1}$, 0.074 ppm), Site (3) were (465.5 $Bq.m^{-3}$, 4.3 $Bq.kg^{-1}$, 0.083 ppm) and site (4) were (431.3 $Bq.m^{-3}$, 3.9 $Bq.kg^{-1}$, 0.077 ppm), respectively. The results obtained in this work indicated that the radium content and uranium concentration present in the *Ceratophyllum demrsum* is acceptable which does not pose any risk to the aquatic ecosystem.

Keywords: *Ceratophyllum demersum*; CR-39; radium content; radon; Tigris River; uranium concentration.

تقييم تركيز الرادون في عينات نبات الشمبلان *Ceratophyllum demersum*

رنا رياض العاني, سحر احمد امين*, احمد علوان
مركز بحوث البيئة, الجامعة التكنولوجية ، بغداد، العراق

الخلاصة

في هذا البحث تم تقدير النشاط الاشعاعي لعينات نبات الشمبلان Ceratophyllum demersum باستخدام كاشف الاثار النووية CR-39. لقد تم جمع العينات من أربعة مواقع مختارة من نهر دجلة في مدينة بغداد (جسر المثنى, جسر الصرافية, جسر الشهداء و جسر الدورة) حيث جُمعت العينات شهرياً ولمدة عام كامل ابتداءً من كانون الثاني ولغاية كانون الاول/2019. بينت النتائج ان القيم المتوسطة لمستويات الرادون في نبات الشمبلان للمواقع الاربعة المختارة هي (593.1, 413.4, 465.5, 431.3) $Bq.m^{-3}$على التوالي. اما متوسط قيم محتوى الراديوم كانت كالتالي (5.8, 3.8, 4.3, 3.9) $Bq.kg^{-1}$ ومعدل قيم تركيز اليورانيوم فكانت (0.113, 0.074, 0.083, 0.074) ppm على التوالي. أشارت النتائج التي تم الحصول عليها في هذا العمل إلى أن قيم محتوى الراديوم وتركيز اليورانيوم الموجود في عينات نبات الشمبلان *Ceratophyllum demrsum* مقبولة ولا تشكل أي خطر على النظام البيئي المائي.

*Email: sahar.a.amin@uotechnology.edu.iq

1. Introduction

Various environmental effects together with human activities can essentially change the aquatic ecosystem [1]. The quality of air, water and soil must be preserved so as to establish sustainable and healthy living environment for human community [2-4]. Assessment of environment qualities has become a considerable research subject during the last two decades [5].

Heavy metals are one of the most important toxic causes in ecosystem qualities degradation and human hazards [6, 7]. In the same way, naturally occurring radioactive materials (NORM) from anthropogenic activities can be a second type of hazards for human lives. So, in order to evaluate such kind of health risk, suitable observations of environmental parameters are requisite worldwide [8].

Long-lived radioisotopes caught in stable waterways are likely accessible for the remainder of their actual half-lives for consolidation into aquatic ecosystem (flora and fauna) [9].

Radioactive materials were classified by the US Environmental Protection Agency (EPA) as one of the eight categories of environmental pollutants [10]. Among these, Rn-222 is considered as one of the most biologically important radiation hazards because of its extreme radio toxicity and the easy way of its separation both in soil and air; it can highly increase the danger of cancer when inhaled or ingested [11].

The main objective of this research was to determine Rn-222 concentration by monitoring *Ceratophyllum demersum* plant samples picked from selected sites along the Tigris River in Baghdad city, taken over a period of one-year of 2019. The ability of *Ceratophyllum demersum* plant to uptake radioactive radon gas, as well as determining the performance of this plant in improving water quality was also studied.

2. Material and Methods

2.1 Tigris River

The Tigris River is perhaps the longest river in Western Asia of a length of roughly 1800 km and a drainage area of 472,606 km^2. It rises from the Taurus Mountains of eastern Turkey. The Tigris River streams 400 km in turkey at that point become a piece of Syrian-Turkey line which is broaden just 44 km in Syria prior to entering Iraq [12]. It goes through numerous Iraqi urban areas before it joins the Euphrates in the city of Qurna shaping Shatt-alArab and afterward inflows into the Arabian Gulf [13]. Five fundamental feeders start in Iran, they are in diving request Fiesh Khabur, Gretaer Zab, Lesser Zab, Adhaim and Diyala (Sirwan), notwithstanding many sub-feeders [13-15].

2.2 Sampling sites

The positions of the sampling sites and their coordinates along the Tigris river were (as shown in Figure (1)). Site 1 (upstream site) is situated near Al-Muthanna Bridge, north of Baghdad city. Site 2 (midstream site) is situated northeast of Baghdad city at Al-Sarrafia Bridge. It is a profoundly populated territory with private houses, clinics, government establishments, plantations and restaurants and cafes. Site 3 (midstream site) is located near Al-Shuhada Bridge at the middle of Baghdad City, where enormous number of residential buildings, restaurants and other human activities are found. Fish shops are spread around the area. Site 4 (downstream site) is situated toward the south of the Tigris River near Al-Dora Bridge 150 m away from the Rasheed thermal power plant south of Baghdad. It represents the extension and continuation of the flow which comes from the effluent of the vegetable oil plant and gas and thermal power station south of Baghdad. The river banks are characterized by abundant natural aquatic plant growth such as cane, papyrus, and bushes, *Eichhornia crassipes*, and *Ceratophyllum demersum*, which can clearly be seen on the edges of the site. The total distances from site 1 to site 2, from site 2 to site 3 and from site 3 to site 4 are 4.10 km, 3.65 km and about 8.67 km, respectively.

Figure 1: Sampling sites along Tigris River in Baghdad city, Iraq [16].

2.3 *Ceratophyllum demersum* plant

Ceratophyllum demersum (Coontail or hornwort) is a totally submersed plant and generally found in rivers, ponds, lakes, channels, and calm streams with moderate to high nutrient levels [16]. It has no roots; it retains all the nutrients it needs from the surrounding water. If it grows close the lake base, it will shape altered leaves, which it uses to anchor to the sediment. Nevertheless, it can float free in the water column and occasionally shapes thick mats just beneath the surface.

Ceratophyllum demersum is normally strong and energetic plant essential species in numerous wetland conditions around the world. This plant fills in various ecological and can uptake, move and accumulate a wide extent of contaminations in its tissues. It can absorb the fundamental nutrients from the water and can be a viable bio sorbent for the removal of heavy metals like (zinc, lead, and copper) under dilute metal conditions [17]. Many researches show that *Ceratophyllum demersum* is effective in removing heavy metals and has the ability in accumulating all metals [18,19] and thus in this research, *Ceratophyllum demersum* was used to investigate the concentration of uranium through radon concentration measurement in the plant samples.

2.4 Sampling methods

The submerged plant of the species *Ceratophyllum demersum* was collected on a monthly basis for a period of one year during 2019 from the two banks of the Tigris River in Baghdad city. *Ceratophyllum demersum* was kept in plastic bags for in the laboratory. The plant was rinsed with distilled water, cut into small pieces and left to dry in air. After drying, they were grounded by ceramic mortar and sieved by 2mm mesh. Ten grams of each sample were put in closed plastic cans with a 1 cm^2 CR-39 plastic detector fixed on the inner side of the can's cover.

The cans were left for 60 days so that the emitted α-particles from radon will be registered by CR-39 track detectors. Later, after the exposure time, CR-39 detectors were taken from the cans and chemically etched at a temperature of 70˚C with 6.25 normality NaOH solution, for 8 hours etching time. After etching, CR-39 detectors were rinsed with distilled water and left to dry in air. An optical microscope at a magnification of 400X was utilized to count the tracks of alpha particles registered on the CR-39 plastic detectors.

2.5 Calculations

Radon concentrations (C_{Rn}) (in units of Bq/m^3) in samples were calculated by the following equation [20]:

$$C_{Rn} = \frac{measured\ \alpha - \text{track density}}{\text{calibration factor} \times \text{exposure time}} = \frac{\rho(Tr/cm^2)}{\text{k}(Tr.cm^{-2}\,d^{-1}/Bq\,m^{-3}) \times T(d)} \quad (1)$$

Where $\rho = \frac{number\ of\ total\ tracks}{field\ of\ view\ area}$ and k was calculated by the formula given by [21, 22]:

$$k = \frac{R}{4}\left[2cos\theta_c - \frac{R}{R_\alpha}\right]$$

where R is the radius of the container (cm), θ_c (35°) is the critical angle of CR-39, and R_α (4.15 cm) is the range of α particles emitted from ^{222}Rn.
Radium content C_{Ra} ($Bq.kg^{-1}$) was estimated using the following equation [23, 24]:

$$C_{Ra} = \frac{C_{Rn}hA}{m} \quad (2)$$

where, h is the distance between the CR-39 detector and the sample (cm), A is area of the sample (cm^2), m is mass of the sample (kg).
In order to evaluate concentration of uranium (U_C) in (ppm), the following formula was utilized [25]:

$$U_C(ppm) = \frac{weight\ of\ uranium\ (w_U)}{weight\ of\ the\ sample\ (w_s)} \quad (3)$$

where, w_U is the weight of uranium in the sample which was calculated using the following equation [25]:

$$w_U = \frac{N_U w_{mol}}{N_{Av}} \quad (4)$$

Where, N_U the number of uranium atoms in a sample, w_{mol} is the uranium molecular weight, N_{Av} is Avogadro's number and w_s = 10 gm.

3. Results and Discussion

Alpha activity (expressed as radium content in $Bq.kg^{-1}$ and uranium concentration in ppm) was measured for *Ceratophyllum demersum* plant samples collected for one complete year of 2019 on monthly basis from 4 selected sites along Tigris River in Baghdad city. The obtained results are given in Table (1). Additionally, the minimum (min.), maximum (max.) and average (ave.), activity concentrations in were also included.

From Table 1, the radon concentrations in all studied plant samples, were higher than the global average activity value recommended by the International Commission of Radiation Protection (ICRP), which is in the range of 200 – 300 Bq.m^{-3} [26].
Figure (2) presents the monthly variations of radium content and their averages in the plant samples for the four selected sites. The average values of radium content of the plant samples for site-1, site-2, site-3 and site-4 were 5.8, 3.8, 4.3 and 4.0 Bq.kg^{-1}, respectively. The higher levels of radium content exceeding the average values were almost during February and March, while the rest of the months exhibits small seasonal variations in the activity of radon. The changes in the alpha activity values may be due to the variance in the structure of the sediment and human activities in different locations of Tigris River that affects its ecosystem [26, 27]. The parameters of seasonal changes like; climate variation, rainfalls and others have little effect on the activity of alpha emitted from radon. The maximum allowed concentration of radium content suggested by United Nations Scientific Committee on the Effect of Atomic Radiation is (32 Bq.kg^{-1}) [28]. Hence, all radium content average values for the investigated samples were below the allowable value.

The concentrations of uranium in the *Ceratophyllum demersum* samples were also calculated in parts per million (ppm). As shown in Figure (3), the calculated average values of uranium content, for the four sites, were 0.113, 0.074 and 0.083, 0.077 ppm. The obtained results of the concentration of uranium in the *Ceratophyllum dermsum* samples were lower than the permissible value of 11.7 ppm recommended by the by United Nations Scientific Committee on the Effects of atomic Radiations (UNSCEAR) [29]. Thus, the plant does not pose a threat to the aquatic ecosystem.

Table 1: Radon concentrations, radium contents and uranium concentrations in*Ceratophyllum demersum* plant samples collected from Tigris River, 2019.

Month	Site 1			Site 2			Site 3			Site 4		
	C_{Rn} Bq/m^3	C_{Ra} Bq/kg	U ppm	C_{Rn} Bq/m^3	C_{Ra} Bq/kg	U ppm	C_{Rn} Bq/m^3	C_{Ra} Bq/kg	U ppm	C_{Rn} Bq/m^3	C_{Ra} Bq/kg	U ppm
Jan.	1295	4.5	0.087	350.7	3.2	0.062	1197.7	5.6	0.109	663.1	3.7	0.072
Feb.	1447.7	11.9	0.232	517.3	4.7	0.092	357.6	11.0	0.214	315.9	6.1	0.119
Mar	357.6	13.3	0.259	555.5	5.1	0.099	413.1	3.3	0.064	381.9	2.9	0.056
April	493.0	3.3	0.064	378.4	3.0	0.059	326.3	3.8	0.074	336.7	3.5	0.068
May	496.4	4.5	0.088	548.5	3.5	0.067	430.5	3.0	0.058	517.3	3.1	0.060
June	604.1	4.5	0.089	368.0	5.0	0.098	736.0	3.9	0.077	517.3	4.7	0.092
July	475.6	5.5	0.108	322.8	3.4	0.066	388.8	3.6	0.069	333.2	3.8	0.075
Aug.	406.2	4.4	0.085	420.0	3.0	0.057	322.8	3.5	0.067	520.8	3.1	0.059
Sept.	52.0	3.7	0.072	579.7	3.8	0.075	447.8	3.0	0.057	520.8	4.8	0.093
Oct.	378.4	4.8	0.093	312.4	5.3	0.104	263.8	4.1	0.080	41.6	4.6	0.090
Nov.	624.9	3.5	0.067	277.7	2.9	0.056	451.3	2.4	0.047	361.0	3.8	0.074
Dec.	593.1	5.7	0.112	399.2	2.5	0.049	1197.7	4.1	0.081	663.1	3.3	0.064
Ave.	593.1	5.8	0.113	413.4	3.8	0.074	465.5	4.3	0.083	431.3	4.0	0.077
Min	52.0	3.3	0.064	277.7	2.5	0.049	263.8	2.4	0.047	315.9	2.9	0.056
Max	1447.7	13.3	0.259	579.7	5.3	0.105	1197.7	11.0	0.214	663.1	6.1	0.119

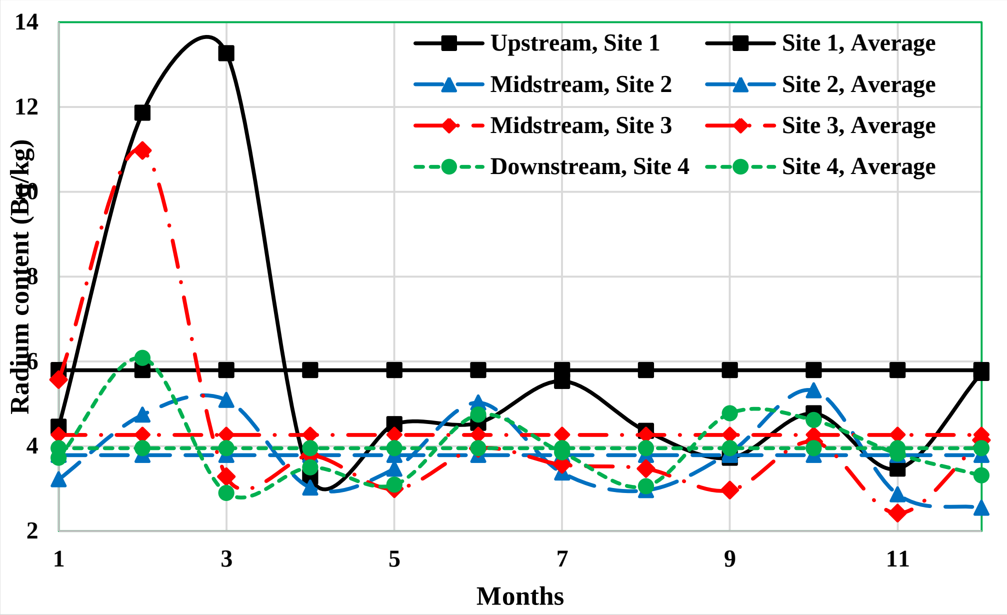

Figure 2: Monthly variations of radium content (Bq.kg^{-1}) of (*Ceratophyllum demersum*) plant samples collected from 4 selected sites along Tigris River in Baghdad city, 2019.

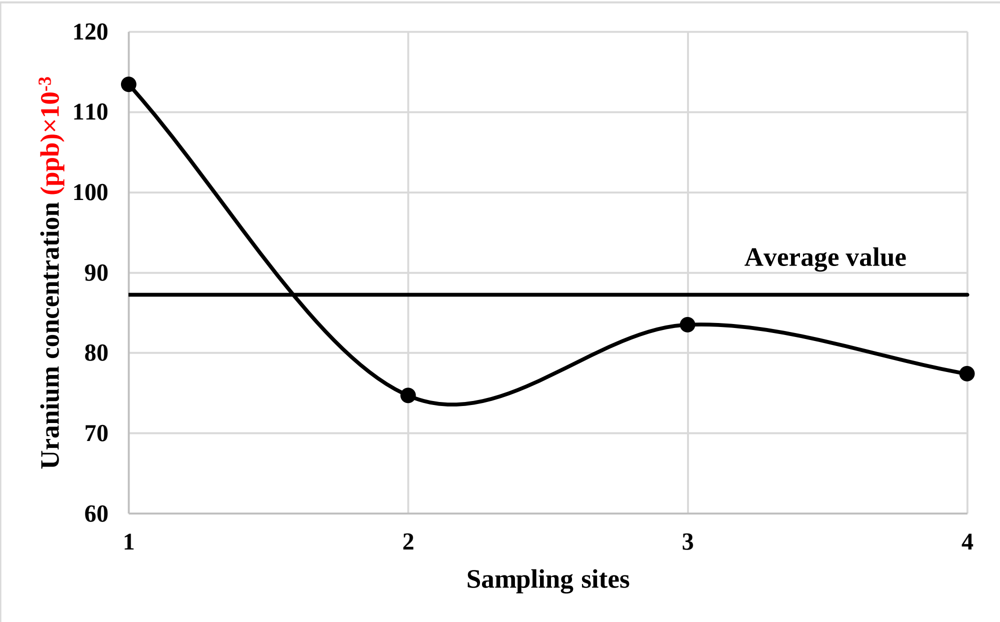

Figure 3: Average Uranium concentrations (ppb) of (*Ceratophyllum demersum*) plant samples for the 4 sampling sites along Tigris River Baghdad city, 2019.

4. Conclusions

The alpha activities of the *Ceratophyllum demersum* samples gathered from four destinations along the Tigris River in Baghdad city region were estimated with CR-39 plastic detector. The radon level was found to decrease as going towards downstream of the river. The variance may refer to the type of the sediment in the different sites and different human activities. The measured alpha activities did not show remarkable variations during most months of the year. The values of radon concentrations seem to be acceptable and were within the permissible values recommended by (ICRP) and (UNSCEAR). The results obtained in this work indicated that the radium content and uranium concentration present in the *Ceratophyllum demrsum* are acceptable and so does not pose any risk to the ecosystem and satisfy the safety criteria. *Ceratophyllum demersum* plant can probably be widely utilized in radon removal systems as a novel environmental strategy of radon contamination control in the future. This concept acquires more researches of the *Ceratophyllum demrsum* species and other epiphytic plant species regarding the amount and mechanism of uptake of the natural radioactive gas, radon.

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Disclosure and conflict of interest

Conflict of Interest: The authors declare that they have no conflicts of interest.

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