

Preliminary Studies on ^{222}Rn Concentration in Groundwater of Yaounde, Cameroon

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Abstract

This work presents a preliminary study on groundwater samples carried out from selected groundwaters of some localities of Yaounde, Cameroon. Radon concentration was ranged from $0.11 \text{ Bq}\cdot\text{l}^{-1}$ to $1 \text{ Bq}\cdot\text{l}^{-1}$, with an average of $0.48 \text{ Bq}\cdot\text{l}^{-1}$. The comparison between the physico-chemical parameters and the radon concentrations in groundwater showed a good correlation between these radon concentrations and the values of Electroconductivity (EC). The annual effective dose due to ingestion of radon in water ranged from $0.30 \mu\text{Sv}\cdot\text{y}^{-1}$ to $7.90 \mu\text{Sv}\cdot\text{y}^{-1}$ with an average of $1.93 \mu\text{Sv}\cdot\text{y}^{-1}$. The obtained results of this study were shown that the concentrations of radon in groundwaters and annual effective doses due to ingestion of this groundwater were below the references recommended by WHO.

Keywords

Radon Concentration, Groundwater, Annual Effective Dose, Ingestion

1. Introduction

Radon (^{222}Rn) is a naturally occurring radioactive gas, which is inert, colorless, and odorless. ^{222}Rn and its parent radionuclide ^{226}Ra are the member of the uranium decay series, which are commonly found in nature. As an inert gas, radon can move through porous media such as soil or rock [1] and it can be dissolved into the water in pores. Radon gas is partially soluble in water transported through water in the homes. The mole fraction solubility of radon in water is 2.3

$\times 10^{-4}$ at 15°C and it is produced mainly by leaching of hexavalent uranium present in traces. The solubility coefficient of radon in water is 0.254 at 20°C and its variation with temperature has been established [2] [3]. It is well known that inhalation of ^{222}Rn is a significant risk for lung cancer while ingestion of water-borne radon can lead to a risk of stomach and gastrointestinal cancer [4] [5]. However, it is reported that the risk caused by the inhalation of radon rich air is higher than the risk of ingestion of water with the same amount of radon [6] [7]. The radon concentrations in water vary from surface water to well water related to the ^{226}Ra into the surrounded environment [8] [9]. Drinking water is the most important food for human beings. Access to safe drinking water is essential to health, a basic human right and a component of effective policy for health protection [10]. Ingestion of radionuclides in drinking water causes human internal exposure, these radionuclides transported in groundwater can enter the food chain through irrigation waters and the water source through ground water wells [11]. Radon gas is continuously generated within the rock strata and migrates through the earth's crust to the atmosphere [12] [13]. Radiological health hazards associated with radon due to the consumption of ground water have become a global key issue in recent times [14]. The public is therefore unaware of potential hazards associated with drinking water contaminated with naturally occurring radioactive materials (NORMS). In Cameroon, the risk associated with radon is not yet considered a national public health problem. To this end, several studies on exposure to radon and their progeny are being carried out in certain localities of the country to establish a reference level. These localities are generally zone of uranium and thorium bearing areas. These studies generally focus on assessing radon levels in homes and the associated risks [15]-[20]. But there are no studies which have been carried out to investigate radon concentration in Cameroun groundwater resources.

This study is therefore aimed at determining radon concentration in groundwater and the effective dose from intake of water from some wells serving as sources of domestic water in some communities in the Yaounde city, Cameroun.

2. Materials and Method

2.1. Description of Study Area

Yaounde is the capital of Cameroon located within latitudes $3^{\circ}50'\text{N}$ and $3^{\circ}55'\text{N}$, and $11^{\circ}27'\text{E}$ and $11^{\circ}35'\text{E}$. The population is about 2.5 million inhabitants with a growth rate of 5.7%/y [21]. Annual average precipitation in the city is about 1600 mm. The mean annual temperature is 23°C [22] [23]. Moreover, it has the equatorial climate with four (04) seasons: long dry season (December-February), a rainy season with light rains (March-June), a mild dry season (July-August) and a rainy season with heavy down pours (September-November). The relief is characterized by an alternation of hills and plains. The highly domesticated landscape was initially semi-deciduous forest [24]. The geology is made up of crystalline basement rocks such as paragneiss, migmatitic gneiss and schists of

proterozoic age, metamorphosed in the panafrican orogeny at the northern margin of the Congo craton [25] [26] [27].

The geological substratum is made of fractured embrechites, constituting exploitable reservoirs for wells and boreholes. It is covered by sandy-clay alluvia in thalwegs and laterites on the flanks of hills. The bedrock is covered by alluvial hydromorphic clay and sand in the valleys and ferralsols on the hillsides [28] [29]. The seasonal dynamics of unconfined groundwater flow are given by Ntep *et al.* [30], who reported mean groundwater level fluctuations of 0.49 m for the valleys, 0.65 m for slopes and 1.3 m for plateau positions between the rainy and dry seasons.

2.2. Sampling and Sample

Sampling points of the studied groundwaters were selected in some cities of Yaounde. These sampling points were recorded by using a Global Positioning System (GPS) as shown in **Figure 1**. A total of twenty (20) groundwater samples were collected from drilled wells and boreholes located in some selected city districts of Yaounde. Physicochemical properties such as electrical conductivity (EC), pH, were determined by the WTW Multimeter. The containers were first rinsed with sample groundwater before measurement in order to minimize

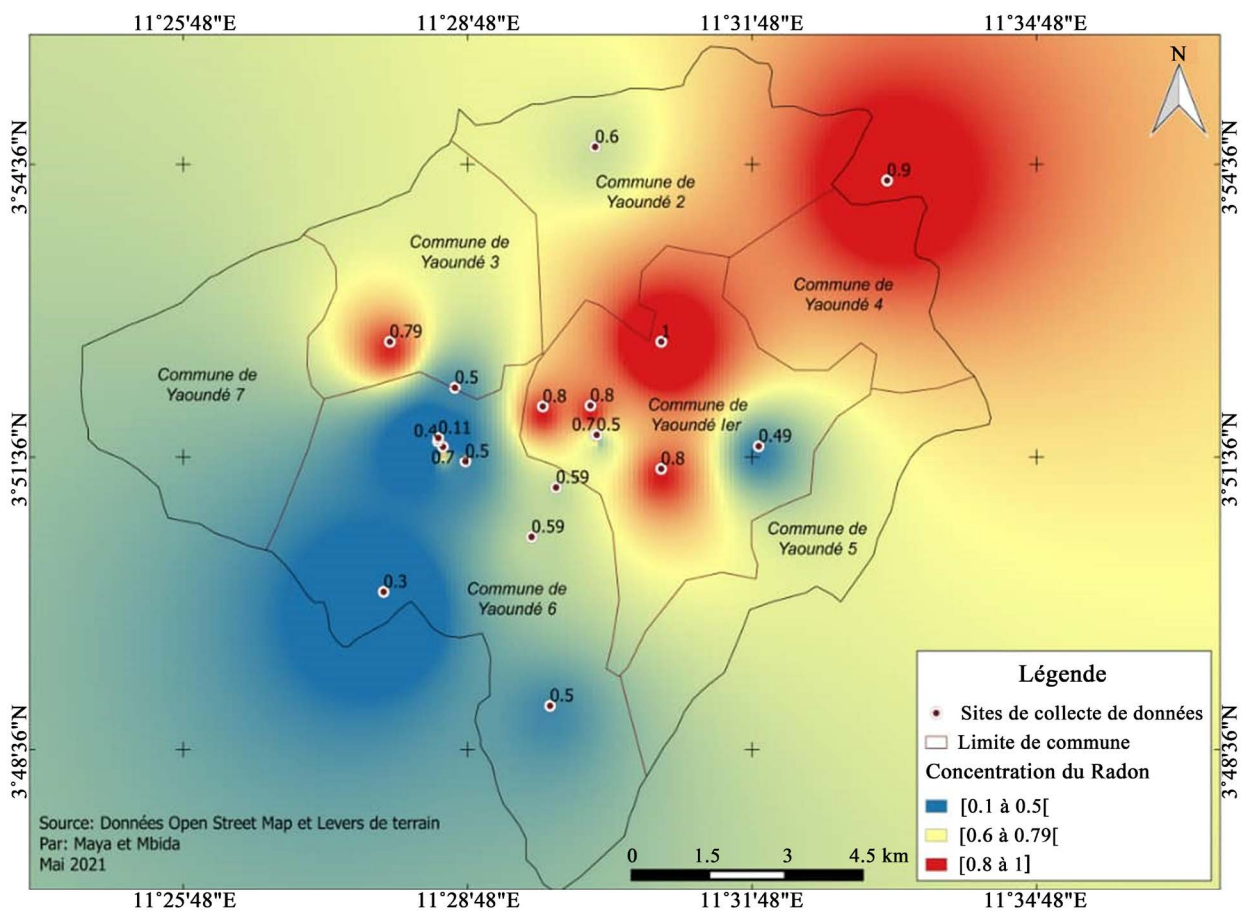


Figure 1. Radon concentration of in groundwaters samples of Yaounde.

contamination. The samples were collected in 1.5 litre polyethylene containers with about 1% air space left for thermal expansion and a few drops of hydrochloric acid were added to bring the pH to an appreciable level of 2 in order to prevent adherence of the radionuclides to the walls of the containers. Then collected groundwater samples were stored in the laboratory for preparation into 1 L Marinelli beakers and analysis. Before use, the Marinelli beakers were first soaked with diluted nitric acid, washed, rinsed with distilled water and left dry so as to prevent contamination. The sealed samples were stored for ~30 days before carrying out gamma analysis to allow secular equilibrium [31] [32] [33].

2.3. Activity Measurement

The activity concentration of radon-222 in groundwater samples was analysed using gamma spectrometry. The gamma-spectrometry system consists of a high pure germanium detector (HPGE) connected to a desk top computer provided with a Canberra DSA-1000 multichannel analyzer (MCA). The data acquisition and the analysis were made possible by using Genie 2000 software version 2.1. A spectral interactive deconvolution proposed by the Genie 2000 software was performed to examine the multiplets lines. The detector is housed in a lead shield, built with 5 cm thick lead bricks to reduce the background radiation reaching the detector to a minimum. Digitized counts were collected in the Canberra DSA1000 multi-channel analyser. The detector is cooled with liquid nitrogen at -196°C (77 K). Calibration of the gamma spectrometry system was made prior to analysis of the water samples using solid water standard in 1.0 L Marinelli geometry. The samples were counted for 86,400 s. Background measurements were also made for the same period. The ^{222}Rn activity concentration in the water samples was determined by measuring the parent nuclide ^{226}Ra . The ^{222}Rn activity concentration was calculated according to the equation [14] [34]:

$$C_{R_n} = C_{R_a} \left[1 - \exp(-\lambda_{R_n} \times T_d) \right] \quad (1)$$

C_{R_n} and C_{R_a} are the activity concentrations of ^{222}Rn and ^{226}Ra in $\text{Bq}\cdot\text{l}^{-1}$, respectively, T_d is the delay time between sampling and counting, and λ_{R_n} is the decay constant of ^{222}Rn .

2.4. Annual Effective Doses from ^{222}Rn Ingested with

The annual effective dose due to intake of radon was calculated on the basis of the mean activity concentration using the relation:

$$E_{R_n} = C_{R_n} \times Fc_{R_n} \times I_w \quad (2)$$

E_{R_n} , C_{R_n} , and I_w where Fc_{R_n} is the committed effective dose per unit intake of radon in water for adults taken as 10^{-8} Sv/Bq from UNSCEAR 1993 report [35]. Au Cameroun il n'existe pas encore de données sur le niveau de radon dans les eaux de consommation. According to WHO 2004 report, I_w is the water consumption rate (l/a) taken to be 1.5 L per day from WHO report [36].

2.5. Statistical Analysis

To perform normality tests, the Shapiro-Wilk test was applied at statistically significant level of 0.05. Furthermore, statistical analysis was performed by using the software OriginPro8.0 (OriginLab Corporation, USA).

3. Results and Discussion

In this study, 20 water samples were analyzed using direct gamma spectrometry by measuring the parent radionuclide ^{226}Ra from ^{238}U -decay series in order to determine the ^{222}Rn activity concentrations. **Figure 2** shows the distribution of radon concentrations in groundwater. Radon concentration range from $0.11\text{ Bq}\cdot\text{l}^{-1}$ to $1\text{ Bq}\cdot\text{l}^{-1}$, with arithmetic mean of $0.48\text{ Bq}\cdot\text{l}^{-1}$. The high radon levels obtained in this work were $0.89\text{ Bq}\cdot\text{l}^{-1}$ (GW6). The obtained ^{222}Rn concentrations were very lower than the reference level of $100\text{ Bq}\cdot\text{l}^{-1}$ [37]. The regulator of the United States of America Environmental Protection Agency (USEPA) declared that the maximum contaminant level for radon is $11.1\text{ Bq}\cdot\text{l}^{-1}$ [38]. All of these mean concentrations are below the values recommended by UNSCEAR 2000 [39]. It can be concluded that the groundwater samples taken from Yaounde town do not contain elevated radon levels.

The correlation between the activity ^{222}Rn concentration with the temperature, conductivity and pH has been given in **Figure 3**, **Figure 5** and **Figure 6**. The temperature, conductivity and pH were assumed to have some bearing on the activity concentration of ^{222}Rn and hence radiological quality of the water. A very low correlation was observed between radon activity concentrations and temperature and PH parameters (**Figures 4-6**). This reveals an independence between radon activity concentration and both two physical parameters and indoor and outdoor ambient equivalent dose rates. Meanwhile, **Figure 6** has revealed a relatively good correlation between radon activity concentration and

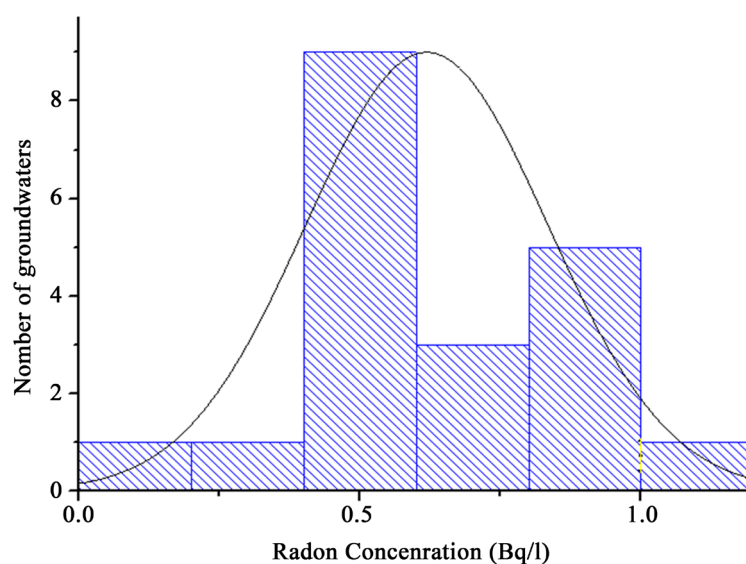


Figure 2. Frequency distribution concentrations of radon in groundwaters.

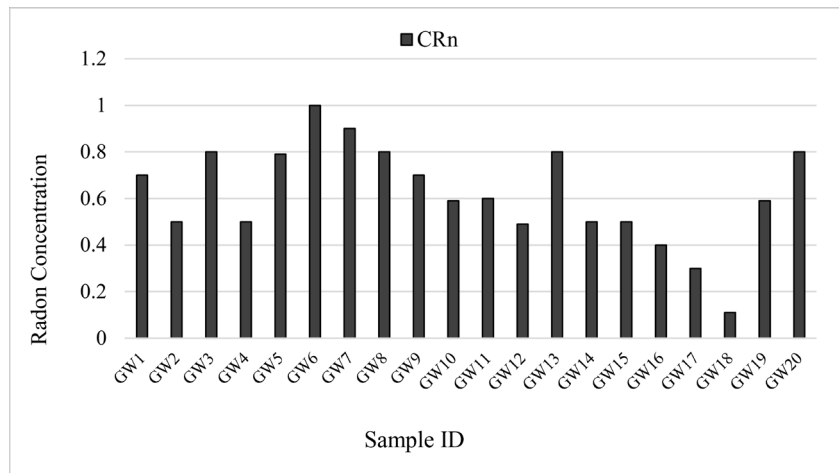


Figure 3. Distribution of radon concentration in different groundwaters.

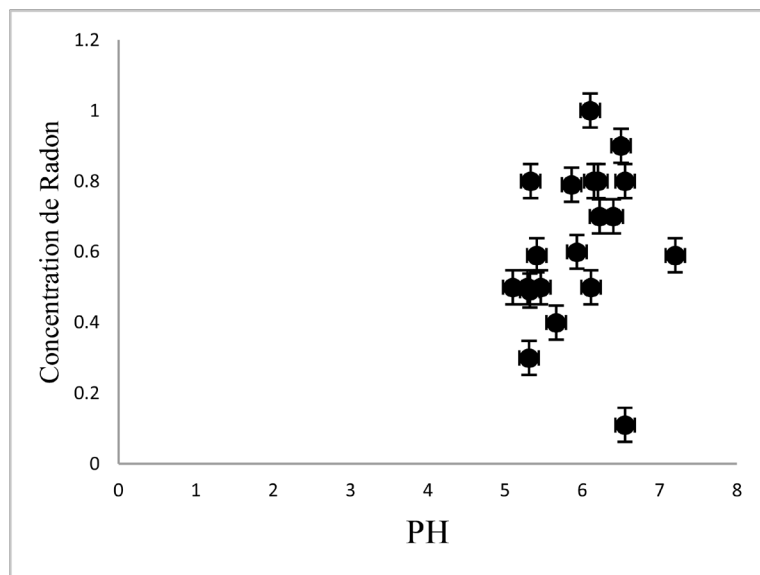


Figure 4. Comparison of the radon activity Concentrations with pH.

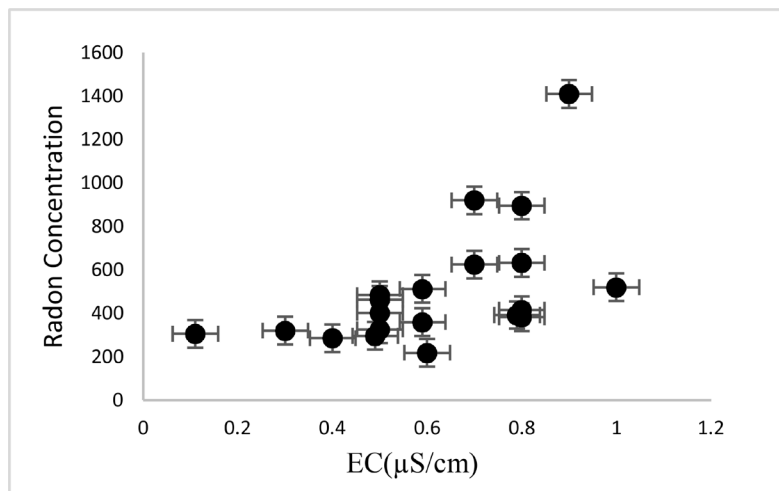


Figure 5. Comparison of the radon activity concentrations with conductivity.

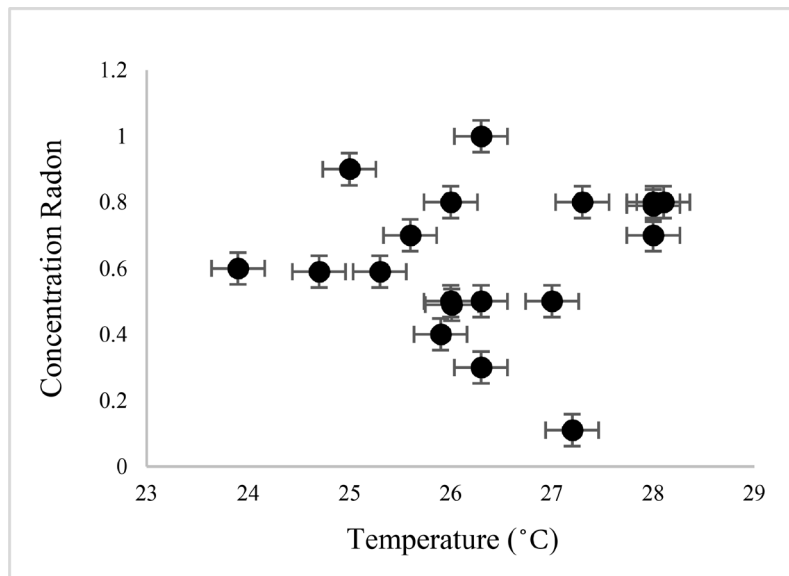


Figure 6. Comparison of the radon activity concentrations with temperature.

EC. A long time study would be necessary to investigate the dependence of radon activity concentrations on these physical parameters and other importance.

Table 1 presents ranges, means and standards deviation of radon concentration in water of several studies carried out around the world. Husenyin *et al.* 2007 measured radon concentration in well waters near the Aksehir fault zone in Ayonkarahisar, turkey [40]. Eissa 2006 Measured of radon concentration in water and air in Ehnasia City, Egypt [41]. Farai 1991 Year-long variability of radon-222 in a groundwater system in Nigeria [42]. Gwen *et al.* 1988 measured radon-222 concentration in groundwater and cancer mortality in North Carolina, USA [43]. E.O. Darko *et al.* 2021 studied radon concentrations in ground water from selected areas of the Accra metropolis in Ghana [14]. As seen in **Table 1**, the comparison of mean activity concentration of ^{222}Rn obtained in this study and those obtained in other parts of the world have shown that radon concentrations in groundwaters in this study were lower than those in most of the countries mentioned above with the exception of the one obtained in Egypt.

The annual effective dose due to ingestion of radon in water ranged from $0.30 \mu\text{Sv}\cdot\text{y}^{-1}$ to $7.90 \mu\text{Sv}\cdot\text{y}^{-1}$ with an average of $1.93 \mu\text{Sv}\cdot\text{y}^{-1}$. The minimum, maximum, average, standard deviation and WHO reference values are shown in **Table 2**. This average value is below the World Health Organization (WHO, 2004) [45] and the EU Council (EU, 2001a, 2001b) recommended action level for annual ingestion dose received from water consumption of $100 \mu\text{Sv}\cdot\text{y}^{-1}$ (WHO, 2004, EU, 2001a, 2001b). The obtained results showed that the total annual effective dose due to ingestion of the water was well below the reference level of $100 \mu\text{Sv}\cdot\text{y}^{-1}$ recommended by WHO and hence do not cause any health hazards from ^{222}Rn dose received by water in the study regions [46] [47]. Further direct measurements of radon concentrations in groundwaters using equipment such as RAD7, SARAD or AlphaGuard should be carried out to complete our study.

Table 1. Comparison of the ranges and means of indoor radon concentrations with other similar studies in the world.

Country	Radon concentration (Bq/L)			Reference
	Range	Mean	SD	
Turkey	0.7 - 31.7	-		[40]
Egypt	$(12.90 - 31.33) \times 10^{-3}$	20.59×10^{-3}	2.42×10^{-3}	[41]
Nigeria	-	14.8	1.4	[42]
USA	8.4 - 403.0	50.8	-	[43]
Ghana	2.15 - 28.70	8.1	2.6	[14]
India	2.37 - 171.35	22.62		[44]
Cameroon	0.11 - 1	0.48	0,2	This work

Table 2. Annual effective dose due to ingestion of radon in groundwater.

country	Annual effective dose due to ingestion of radon ($\mu\text{Sv}\cdot\text{y}^{-1}$)
Min	0.30
Max	7.90
Mean	1.93
SD	1
Median	1.53
N	20
Reference value (WHO)	100

4. Conclusion

In the present work, radon concentrations were measured in 20 groundwaters of Yaounde, Cameroon. The ^{222}Rn concentrations in groundwaters were found to vary between 0.11 - 1 $\text{Bq}\cdot\text{l}^{-1}$ with average concentration of 0.48 $\text{Bq}\cdot\text{l}^{-1}$. The comparison between the physico-chemical parameters and the radon concentrations in groundwater showed a good correlation between radon activity concentration and EC. Moreover, a long time study would be necessary to investigate the dependence of radon activity concentrations on these physical parameters and other importance. The annual effective dose values from radon ingestion in groundwater ranged from 0.30 $\mu\text{Sv}\cdot\text{y}^{-1}$ to 7.90 $\mu\text{Sv}\cdot\text{y}^{-1}$ with an average of 1.93 $\mu\text{Sv}\cdot\text{y}^{-1}$. All these results showed that they were lower than the reference values. According to the results of this study, the overall groundwaters investigated in the study area are safe from the radiological health point of view.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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