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Analysis of the Radon-222 Concentration and Physical-chemical Quality, in Drinking Water of Taxco, Guerrero

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ABSTRACT

In this work the determination of radon gas (^{222}Rn) and the characterization of chemical elements in drinking water of the city Taxco was carried out. Ingesting or inhaling a small number of radionuclides, as well as water of poor chemical quality, can become a potential public health problem. We are collecting 8 samples of water from a spring, physicochemical parameters were measured in field on different days of the dry season. Measurements of ^{222}Rn were performed in the laboratory with an AlphaGUARD equipment. The chemical quality was analyzed in laboratory too by means of mayor and minor ions, by volumetry and colorimetry. The sodium was determined by Flama Atomic Absorption Spectroscopy (FAAS). Trace elements were analyzed by were determined by Atomic Emission Spectroscopy with Plasma Coupled by Induction (ICP-AES). The concentrations of ^{222}Rn present an average of 22.06 ± 2.52 BqL^{-1}. The results obtained from the main ions and field parameters show a type of diluted sodium-calcium-bicarbonate water. The trace elements present are very small and not exceed the limit of quantification. Radon gas is produced by the igneous rock that is the top of the stratigraphic column, of the hydric recharge. Rainwater when descending through the fractures is impregnated with ^{222}Rn gas and accumulated in the underlying rock that has sufficient porosity to accumulate water and gas in the Chacualco's spring.

1. Introduction

The radionuclides in drinking water come from the series of uranium, thorium and actinium, they can be dangerous to health due to their presence in drinking water. One of the decay products is the ^{222}Rn that can damage the organisms cells [1]. It is known, that human consumption with radionuclides water contained induce an important hazard on the population's health, because ^{222}Rn and its progeny passage water and/or air and adhere to the surface's lungs. In addition, the water drinking can take place at additional exposition of the stomach to the entire body. In recent years, international scientific community has reported the natural radioactivity in drinking water, mainly of the ^{222}Rn which exceed the internal regulation in many countries and those recommended by EURATON, 2010 [2], EURATON, 2013 [3], WHO, 2008 [4]; and EPA, 1999 [5]. Some examples are Spain [6], Servia [7], Greece [8], Austria [9], Germany [10] and Italy [11]. In Mexico, mainly in the south of the country does not exist reports about ^{222}Rn radiation measurements. However, the inhabitants depend mainly on shallow waters which have not previous treatment and/or have not been analyzed for possible contaminants. The main source of supply for the Taxco city, Guerrero, is the surface water captured in the Chontacuatlán River, the distance between the intake and the water treatment plant is approximately 12.5 km with a vertical difference of ~ 920 m. Other alternative sources of supply for the city are both Chacuhalco and Tenería springs and two dikes called San Marcos and El Sombrerito that store rainwater. The collection of water treatment from these sources is conditioned by its supply to the population; nevertheless, a part of the population directly extracts the water from springs, dams and rivers for supply and for their consumption. The treatment plant is located at 0.5 km from the Chacualco's spring; however, a part of the population takes directly from the spring without any treatment. This study contributes to monitoring water quality for human consumption from Chacualco's spring. Were analyzed parameters in field from the spring, and radon concentration were measured in the laboratory. The chemical quality of water was evaluated by measuring concentrations of major

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ions Na^+, K^+, Ca^{2+}, Mg^{2+} ,HCO_3^-, Cl^-, SO_4^{2-}, SiO_4; minor ions F^-, NO_3^- and trace elements Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Pb, Sr.

2. Materials and Methods

2.1 Radon Analyses and Field Parameters

To verify the presence of ^{222}Rn in the Chacualco's spring, were taken eight water samples. Water samples were analyzed on November 6th, 13th and 27th and December 4th, 11th, 18th and 19th of 2017 and on January 6th of 2018 (Chac1-Chac8). A liter of water was used to measure the concentration of ^{222}Rn, trying to minimize the bubbling to avoid the loss of radon. In situ parameters such as temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and pH were determined with a multiparametric equipment EUTECH model PCSTestr 35, the calibration was made with buffer solutions of pH 4, 7 and 10 (Table 1). The concentration of ^{222}Rn was determined in the laboratory of the Institute of Physics from the Autonomous National University of Mexico within 3 to 6 hours after the collection of the sample.

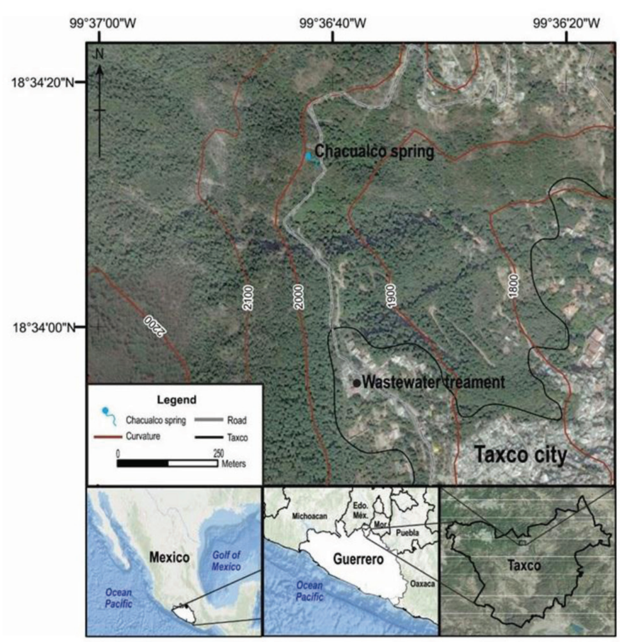

Figure 1: Location map of the Chacualco's spring and plant the water treatment for the Taxco City, Guerrero.

The concentration of ^{222}Rn was determined with a measuring system composed of AlphaGUARD monitor measuring radon concentration by means of an ionization chamber, an AquaKIT set and AlphaPUMP. The set of AquaKIT with an AlphaPUMP was used to dissolved radon from water to the gas phase. The volume examined was 100 mL into AquaKit, where it was aerated intensively, which makes the dissolved radon pass into the closed air circuit AlphaGUARD - AlphaPUMP - AquaKIT. Radon released from the water was pumped into the ionization chamber, the measurement was taken each 20 min. The measurement consists in transferring radon dissolved in water into the air, and then introduced into the ionization chamber. ^{222}Rn samples concentration was examined by computer software and algoritms AlphaEXPERT The calibration of the AlphaGUARD system was carried out through the certification of Genitron Instruments GmbH. The limit of detection for this method was 0.1 BqL^{-1}.

Table 1: Field parameters in the Chacualco's spring. Temperature **(°C)**, pH, Electrical Conductivity (EC, μS), Total Dissolved Solids, field (TDS field, mgL^{-1}), and ^{222}Rn laboratory concentration (BqL^{-1}).

Sample	**DATE**	**Tem (°C)**	**pH**	**EC (μS)**	**TDS field mgL^{-1}**	**^{222}Rn BqL^{-1}**
CHAC 1	D061117	21.1	6.7	90	45	24.6
CHAC 2	D131117	20.4	6.5	90	45	21.6
CHAC 3	D271117	20.6	6.7	90	45	18.7
CHAC 4	D041217	20.7	6.5	80	40	19.8
CHAC 5	D111217	20.6	6.8	90	45	20.7
CHAC 6	D181217	20.8	6.5	70	35	26.4
CHAC 7	D191217	20.2	6.5	90	45	21.9
CHAC 8	D061218	20.8	6.6	88	44	22.8
Minimum		20.2	6.5	70	35	18.7
Maximum		21.1	6.8	90	45	26.4
Mean		20.7	6.6	86	43	22.1
Standard deviation		0.27	0.1	7	4	2.5

2.2 Ions and Trace Elements

The sampling was carried out based by the Official Mexican Standard NOM-230-SSA1-2002; at each selected sampling point, water samples were stored in 1 L polyethylene bottles for anion analysis, and 500 mL polyethylene bottles for cation analysis and total metal concentration; nitric acid was used (HNO_3) for its preservation. The analysis of carbonates (CO_3^{2-}), bicarbonates (HCO_3^-) and chlorides (Cl^-) were determined by volumetry, while sulfates (SO_4^{2-}), (F^-) fluorine and nitrates (NO_3^-) were determined by colorimetry. Alkalinity was determined using 0.02 M hydrochloric acid (HCl) as titrant and phenoftalein, bromocrezole green and methyl red as colorimetric indicators. The cations Ca^{2+}, K^+, Mg^{2+} and trace elements (Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Pb, Sr, Si and Zn) were determined by Atomic

Emission Spectroscopy with Plasma Coupled by Induction (ICP-AES) using a Perkin Elmer Optima 3200 DV device. Flama Atomic Absorption Spectroscopy (FAAS) was used to determined Na^+ using a Perkin Elmer Aanalyst 100 device. For both determinations, the acidified samples were previously filtered in cellulose acetate with a pore size of 0.45 µm. Certified high-purity standards (CWW-TM-A and CWW-TM-D) were used to verify accuracy. The limits of quantification (QL) of the analytical method used are Al, Ba, Co, Cr, Cu, Fe, Mn, Pb, Sr, V, and Zn 0.025 mgL^{-1}; Cd 0.005 mgL^{-1}; As and Ba 0.01 mgL^{-1} (Table 2).

Table 2: Ions and traces elements of Chacualco's water, all concentrations in mgL^{-1}.

Sample	TDS Lab	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO^{3-}	NO^{3-}	F^-
CHAC 1	148.22	5.98	2.39	10.14	0.15	0.43	61.0	1.6	0.13
CHAC 2	140.06	6.34	2.11	8.70	0.13	0.43	63.4	2.0	0.14
CHAC 3	172.86	8.54	3.34	12.95	0.21	0.43	61.0	1.1	0.18
CHAC 4	186.48	8.88	3.32	13.46	0.22	4.17	63.4	3.0	0.12
CHAC 5	177.97	7.32	2.96	11.89	0.18	8.33	61.0	5.8	0.15
CHAC 6	102.49	5.21	1.07	5.63	0.08	8.33	78.1	4.0	0.09
CHAC 7	85.96	5.35	0.98	4.77	0.06	1.67	68.3	4.7	0.11
CHAC 8	139.13	5.14	1.03	5.60	0.07	8.33	78.1	4.0	0.09
Minimum	85.96	5.14	0.98	4.77	0.06	0.43	61.0	1.1	0.09
Maximum	186.48	8.88	3.34	13.46	0.22	8.33	78.1	5.8	0.18
Mean	144.15	6.60	2.15	9.14	0.14	4.02	66.8	3.1	0.13
Standard Deviation	35.74	1.49	1.02	3.50	0.06	3.78	7.4	1.6	0.03

3 Results and Discussion

Table 1 exhibit the temperature ranges from 20.2−21.1°C with an average of 20.7 ± 0.3 °C; with circum-neutral solutions. pH ranging from 6.5−6.8 with an average of 6.6 ± 0.1, the samples had low conductivity between 70−90 µS with an average of 86 ± 7 µS. TDS sampled in situ was 35−45 mgL^{-1}, with an average of 43.4 mgL^{-1}. The Table 1 presents the concentration of ^{222}Rn obtained at 8 samples from the Chacualco's spring. Radon values were ranged from 18.7−26.6 BqL^{-1} average 22.1 ± 2.5 BqL^{-1} (Table1).

The chemical analysis shows in Table 2, TDS from the laboratory analyzes for Chacualco's spring ranges from 86.0−186.5 mgL^{-1} with an average of 144.1 ± 35.7 mg L^{-1}. Predominant cation is Na^+, with a concentration ranging from 5.14–8.88 mgL^{-1}; with a mean and standard deviation of 6.60 ± 1.49 mgL^{-1}; being a univalent ion; after Ca^{2+} with a concentration ranging from 4.77−13.46 mgL^{-1}; with a mean and standard deviation of 9.14 ± 3.50 mgL^{-1}. The K^+ ion concentration ranged from 0.98 − 3.34 mgL^{-1}; with an average of 2.15 ± 1.02 mgL^{-1} and finally the Mg^{2+} ion concentrations were below 0.2 mgL^{-1}. The dominant anion was bicarbonates being a univalent ion, with concentrations of 61.0−78.1 mgL^{-1} with an average of 66.8 ± 7.4 mgL^{-1}. Chloride had a concentration of 0.43−8.33mgL^{-1}, with an average of 4.02 ± 3.78mgL^{-1} (Figure 2). The nitrate ion has a concentration of 1.1−5.8 mgL^{-1}, with an average of 3.1 ± 1.6 mgL^{-1}, the fluoride has a concentration of 0.09−0.18 mgL^{-1}, with an average of 0.13 ± 0.03 mgL^{-1}. The results obtained from the major ions show a sodium-calcium-bicarbonate water type (Figure 2). The trace element Al, As, Ba, Cd, Co, Cr, Cu, Fe, Mn, Pb, Sr, Si and Zn present are very small and not exceeds are < QL.

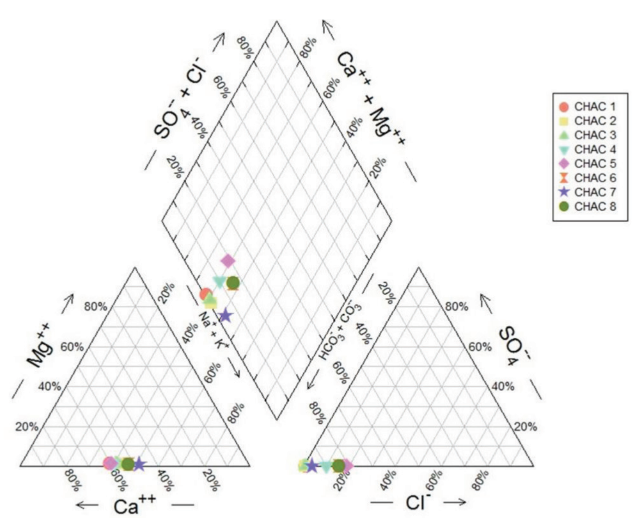

Figure 2: Piper diagram of 8 samples of Chacualco's spring. Show type sodium-calcium-bicarbonate water.

Physical parameters of the Chacualco's spring supplies show diluted water with low concentrations of ions for samples closer to the nearest recharge zone (RZ). The RZ consists of riolitic rocks from the Middle Tertiary [31-38 My] of the Tilzapotla Formation which covers the oldest units of rock of the stratigraphic sequence [13]. For the 8 samples of the Chacualco's spring the average concentration of ^{222}Rn were 22.06 ± 2.52 BqL^{-1}; this value is approximately twice the acceptable limit recommended by the EPA which is 11.1 BqL^{-1}; but it's very low for the concentration of 100 BqL^{-1} suggested by the WHO. The concentration of radon in water for supply to the population can be removed by a process of bubbling and aeration in open containers during the half-life of ^{222}Rn (3.82 days) for gas removal. These results suggest meteoric water with rapid transit from recharge to the output of the Chacualco's spring. The spring's recharge flows a short distance from the highest part of the Sierra of Taxco where the maximum height is of 2460 masl to the spring's point of discharge at a height of 1970 masl. Therefore, the concentration in the water is due to the interaction of the rainwater with the igneous rock and transported downstream according to the topographic gradient.

Conclusions

The results of analysis given the basis for to characterize the drinking water in Taxco with respect to ^{222}Rn concentration and its chemistry quality characteristics on Chacualco's spring, radon gas is released in water due to water-rock interaction, the rock at the top of the stratigraphic column and the interaction with meteoric water. It's necessary to include analysis of ^{222}Rn when water is obtained from springs, dams or aquifers related to silicon rocks that can give rise to radon gas, to know the origin and interactions of water with the rock as well as the quality of drinking water.

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