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GROSS ALPHA AND GROSS BETA DETERMINATION IN SURFACE AND GROUDWATER WATER BY LIQUID SCINTILLATION COUNTING (LSC)

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ABSTRACT

The present study has used 40 samples of groundwater and surface water collected at four different sites along the period of one year in Brumadinho and Nova Lima, two municipalities in the State of Minas Gerais, Brazil, as part of a more extensive study aiming at determination of the natural radioactivity in the water used for domestic use. These two sites are inside an Environmental Protection Area is located in a region of very intensive iron ore exploration. In addition of mineral resources, the region has a geological characteristic that includes quartzitic conglomerates associated with uranium. Radioactivity levels were determined via liquid scintillation counting (LSC), a fast and high counting efficiency method that can be advantageously employed to determine gross alpha and gross beta activity in liquid samples. Previously to gross alpha and gross beta counting the samples were acidified with concentrated HNO_3 in the field. The technique involved a pre-concentration of the sample to obtain a low detection limit. Specific details of the employed methodology are commented. The results showed that concentrations of gross alpha natural activity and gross beta values ranged from less than the detection limit of the equipment (0.03 $Bq.L^{-1}$) to 0.275 ± 0.05 $Bq.L^{-1}$ for gross alpha. As regards gross beta, all samples were below the limit of detection.

1. INTRODUCTION

Precise and accurate measurements of radionuclides in low concentrations are often needed when monitoring radioactivity levels and performing research in the environment. All radionuclides comprising the progeny of uranium and thorium decay by alpha or beta emission. As these are short range radiations, humans are exposed to them when ingesting or inhaling these radionuclides. According to UNSCEAR, water is considered an important factor for increasing the exposure of humans to natural radiation [8]. Therefore, it is important to study and monitor the environment, especially the water compartment, in order to ensure compliance with quality standards.

The Nova Lima and Brumadinho municipalities are located in the Environmental Protection Area to the southeast of the Metropolitan Region of Belo Horizonte city and are inserted in the Iron Quadrangle (Fig. 1) [7]. The Iron Quadrangle has geological and stratigraphic features which favor the formation of uranium and thorium deposits. In the 70's and 80's several uranium prospection work was conducted in the Iron Quadrangle, specifically targeting the location of radioactive metaconglomerates [1,9,10].

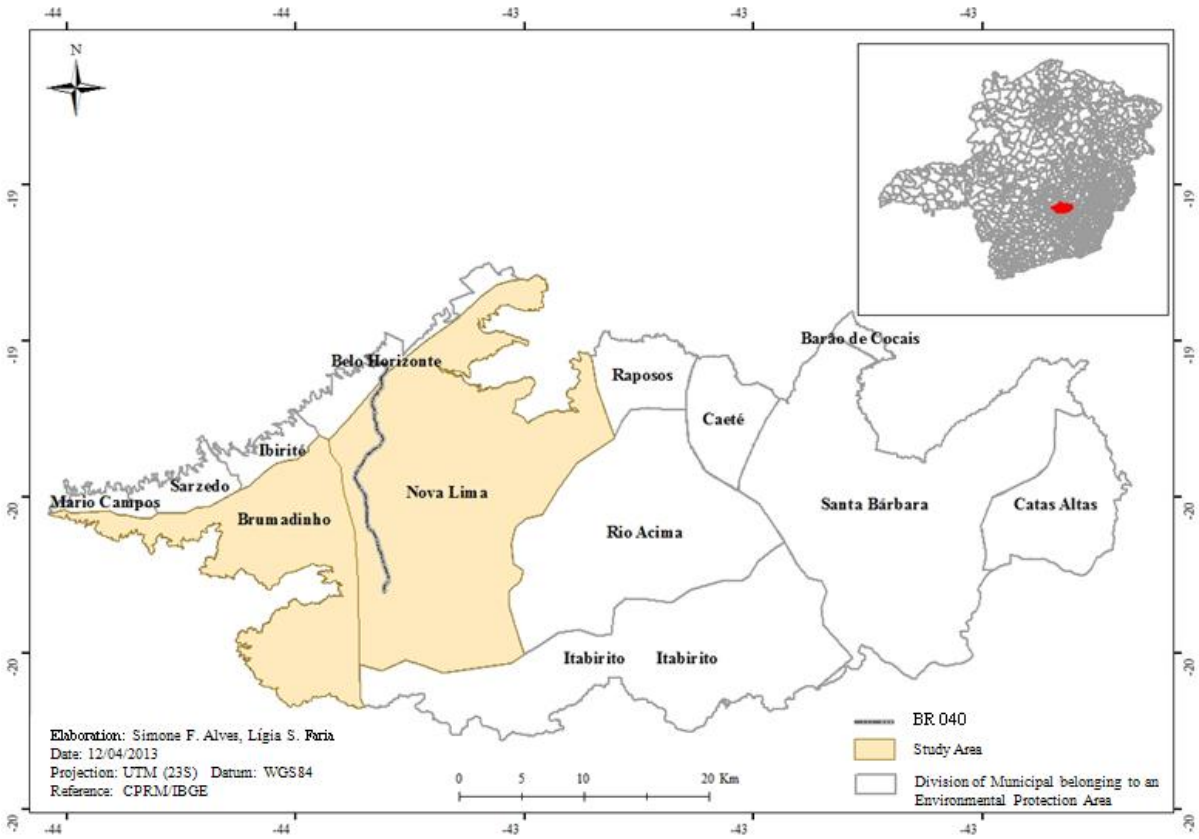

Figure 1: Location of the municipalities of Nova Lima and Brumadinho.

The evaluation of the radioactivity of groundwater and surface waters of these two municipalities is critical inasmuch as surface, spring and groundwater are widely captured in the region for public supply.

In Brazil, the Ministry of Health has defined the radioactivity screening values for potable water and set the limits of 0,5 $Bq.L^{-1}$ for gross alpha and 1,0 $Bq.L^{-1}$ for gross beta [6]. If the values exceed these limits, ^{226}Ra (alpha emitter), ^{228}Ra (beta emitter) and ^{210}Pb (beta emitter) activities must be determined and should not exceed 1,0 $Bq.L^{-1}$ (^{226}Ra) and 0,1 $Bq.L^{-1}$ (^{228}Ra, ^{210}Pb).

In this work, the water radioactivity profile of the studied area were determined via liquid scintillation counting (LSC), a fast and high counting efficiency method that can be advantageously employed to determine gross alpha and gross beta activity in liquid samples.

2. EXPERIMENTAL

2.1. Sampling points

The gross alpha radioactivity and gross beta levels were determined in four sampling stations, three of which (surface water) are sited in Brumadinho and a fourth station (groundwater) is

sited in Nova Lima. All stations sample the same aquifer (Quartzito Aquifer System). The sampling stations are shown in Figure 2.

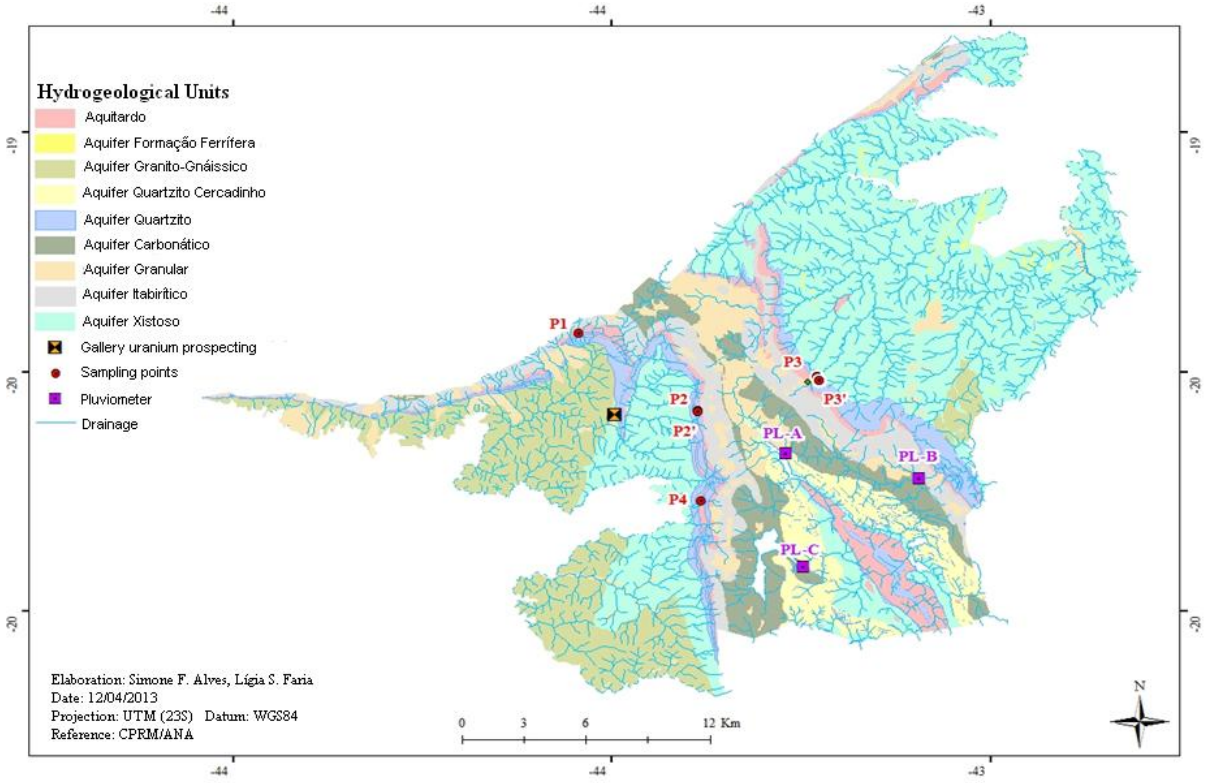

Figure 2: Location of sampling points.

2.2. Calibration

The technical characteristics of the ultra-low background Quantulus 1220 (Perkin Elmer) liquid scintillation spectrometer allows the simultaneous measurement of alfa and beta emitters with efficiencies close to 100%. These two types of radiation can be discriminated by identification their dissimilar pulses performed with the Pulse Shape Analyzer - PSA circuit, a special feature of this apparatus [3,4].

Standard solutions of ^{241}Am (alfa emitter; 5,485 MeV) and ^{90}Sr/^{90}Y (beta emiters, E_{max} = 0,546 MeV / 2,284 MeV) with activities of 10 Bq/100 mL. The Ultima Gold^{TM} AB scintillation cocktail was used to optimize the PSA.

2.3. Sample preparation

The method for determining gross alpha and gross beta counting using the Liquid Scintillation Counting technique was based on the ISO 11704 standard [11]. According to Mingote, when checking compliance with the drinking water standard, a pre-concentration step is required to achieve the low detection limits required in the determination of gross alpha and gross beta radioactivity [5].

The samples were collected in 1 liter polyethylene bottles and acidified with nitric acid (HNO_3) 70% to pH < 2 to avoid losses due to adsorption of radionuclides on solid surfaces. When necessary, the samples were filtered prior to acidification to prevent the release of radioactive material already adsorbed on the particulate material present in the raw sample. A 100 mL aliquot of sample was heated on a hot plate at 60 ^{0}C until complete evaporation of the sample. After cooling, the residue was solubilized with 0.05 M HNO_3 in four steps of 2 mL each and transferred to a previously weighed polyethylene vial with a capacity of 20 mL, taking care to fully dissolve the residue obtained while drying. The vial with the final portion of the sample was weighed once more. A volume of 12 ml of scintillation cocktail Ultima Gold^{TM} AB, which is suitable for the discrimination of alpha and beta inasmuch as it contains diisopropilnaftaleno (DIN). Following its addition to the cocktail, it was necessary to vigorously shake the vial to warrant homogeneity. The waiting time for samples was 42 hours in the dark, to achieve a reduction of the photo- and chemo-luminescence. After this the samples were counted.

3. RESULTS AND DISCUSSION

The 1220 Quantulus affords a choice of calibration standards at the turn up step for the definition of window channels, interference, efficiency, quenching, PSA, background, counting time and limit of detection. The establishment of an optimal value for the PSA parameter was developed by the simultaneous recording of alpha and beta emissions with the aim of correctly separating alfa beta from while keeping interference at the minimum possible level [5]. The values obtained in the calibration are shown in Table 1.

Table 1: Calibration values calculated for gross alpha and gross beta

Parameter	Gross alpha	Gross beta
Window channels	400-900	400-1000
Interferency (%)	1,3	3,8
Counting eficiency (%)	91,1	84,2
Limits of detection (Bq.L^{-1})	0,031	0,091
Background (cpm)	0,83 ± 0,23	4,95 ± 0,51
PSA	85	
Counting time	270 minutes	
Quenching	784 ± 6	

In sampling points P1 and P4, were collected at the bedside drainage, near the site of upwelling, so that contact with the air and geological materials were as small as possible wherefore doesn´t occur evaporation, oxidation or incorporation of other materials groundwater. The gross alpha and gross beta radioactivity determined these two points was below the limits of detection.

Sampling station P2, also a headwater, has a distinctive feature relatively to the other stations. During dry periods the water emerges in places of lower altitudes, Hence an alternative sampling site, P2’ was defined in the same stream. The maximum concentration of gross

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alpha found at P2 reached 0,275 ± 0,05Bq.L^{-1}, whereas gross beta concentrations were below the detection limit.

Table 2: Activities gross alpha and gross beta sample.

Point	Month	Gross α (Bq.L^{-1})	Gross β (Bq.L^{-1})	Point	Month	Gross α (Bq.L^{-1})	Gross β (Bq.L^{-1})
P1	January/12	< LD	< LD	P3	February/12	< LD	< LD
P1	February/12	< LD	< LD	P3	March/12	0,266 ± 0,061	< LD
P1	March/12	< LD	< LD	P3	April/12	< LD	< LD
P1	April/12	< LD	< LD	P3	May/12	< LD	< LD
P1	May/12	< LD	< LD	P3	Juno/12	< LD	< LD
P1	Juno/12	< LD	< LD	P3	July/12	< LD	< LD
P1	July/12	< LD	< LD	P3	August/12	0,193 ± 0,048	< LD
P1	August/12	< LD	< LD	P3'	October/12	< LD	< LD
P1	September/12	< LD	< LD	P3'	December/12	< LD	< LD
P1	October/12	< LD	< LD	P4	January/12	< LD	< LD
P1	November/12	< LD	< LD	P4	February/12	< LD	< LD
P1	December/12	< LD	< LD	P4	March/12	< LD	< LD
P2	March/12	0,275 ± 0,052	< LD	P4	April/12	< LD	< LD
P2	April/12	< LD	< LD	P4	May/12	< LD	< LD
P2'	July/12	0,213 ± 0,045	< LD	P4	Juno/12	< LD	< LD
P2'	August/12	< LD	< LD	P4	July/12	< LD	< LD
P2'	September/12	< LD	< LD	P4	August/12	< LD	< LD
P2'	October/12	< LD	< LD	P4	September/12	< LD	< LD
P2	November/12	< LD	< LD	P4	October/12	< LD	< LD
P2'	December/12	< LD	< LD	P4	November/12	< LD	< LD

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The P3 station is the only one in which groundwater was sampled. Its samples were collected from different wells, all of them sharing the same aquifer and flow of the hydrological system. At station P3 the maximum value of 0,266 ± 0,06 $Bq.L^{-1}$ was recorded. The gross beta activities of all samples collected at this sampling point was below the detection limit.

3. CONCLUSIONS

The LSC method used in the determination of gross alfa and beta is efficient for measurement of low activity environmental samples. As regards the parameters defined by Ministry of Health for the radioactivity levels of the water used for human consumption, it was observed that all samples collected over the period of one year exhibited gross alfa and gross beta concentrations are within the required drinking water levels.

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