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DETERMINATION OF GROSS ALPHA AND BETA RADIOACTIVITY BY LIQUID SCINTILLATION COUNTING IN DRINKING WATER CONSUMED IN THE CITIES OF PARANÁ-BRAZIL

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ABSTRACT

The liquid scintillation counting (LSC) is a technique in which the sample is mixed to a chemical organic liquid, forming a scintillation solution, capable to convert the kinetic energy of nuclear emissions into light energy photons. The aim of this study was to quantify the concentration of gross alpha and beta radioactivity in drinking water using the LSC. The water samples were collected in the Paraná cities: Telêmaco Borba, Castro, Tibagi, Reserva, Curiúva, Ponta Grossa, Imbaú and Curitiba. They have free access sources of drinking water to the public. The initial step of the methodology was standardizing the pre-concentration of the water samples by heating on a hot plate from 1 L to a final volume of 50 mL, at maximum temperature of 80°C. An aliquot of 5 mL of the final solution was mixed with 15 mL of the scintillation solution (Hisafe 3) in a vial and measured on a LSC. The equipment used for the measurement of gross alpha and beta activities was a 1220 Quantulus™ Ultra Low Level Liquid Scintillation Spectrometer. The activity concentration of gross alpha varied from <0.10 to 0.20 Bq L^{-1} and gross beta varied from <0.18 to 0.23 Bq L^{-1}. The results of gross alpha and beta concentration obtained in the samples are below the maximum limits adopted by Ministry of Health in Brazil.

1. INTRODUCTION

Atomic nuclei in their natural state can emit radiation, but experiments conducted in 1934 proved that the production of radioactivity by artificial matters. Every process of radiation emission by a radioactive nuclide (natural or artificial) is called nuclear disintegration or nuclear decay [1].

Liquid scintillation counting (LSC) is one of the techniques used to quantify and detect nuclear α, β and γ decay. The particle α consists of 2 protons and 2 neutrons (nucleus of the helium atom) the β particle is the high energy electrons or positrons and the radiation γ is a high energy electromagnetic wave [1].

The basic process of detection of nuclear decay by LSC is done by mixing the sample with an organic material (scintillation solution) that causes the kinetic energy of the product of a nuclear decay to be transformed into photons [2]. The energy related to each photon allows

detecting the nature of the product of the nuclear decay, and the quantity of photons allows identifying the amount of decay.

Briefly, the photons hits a photocell, the electrons generated are extracted and multiplied by a photomultiplier that produces an electric pulse. When this electric pulse is transmitted to an amplifier, it provides additional electric pulses of the same nature to an electronic counter. This counter analyzes and separates them according to the amplitude. The electrons are then counted by a multichannel system. Radiations are identified from the amount of energy transmitted to the electronic counter.

Radioactivity in water may naturally occur with radionuclides ^{238}U, ^{232}Th and ^{40}K. Their decay products are the main sources of radioactivity [3]. The damage to health caused by radioactivity depends on the level of contamination and may be increased by human activities such as mining and fertilizer use, or by natural geological conditions of the site [4, 5, 6, 7].

The aim of this work was to identify and quantify the total alpha and beta radioactivity concentrations in drinking water samples from the cities of Telêmaco Borba, Tibagi, Curiúva, Imbaú and Ponta Grossa. We used the liquid scintillation technique made the comparisons based on the maximum levels of alpha and beta established by the Ministry of Health for human consumption water [8].

2. MATERIALS AND E METHODS

2.1. Sample area and Sample collection

Several public sites (bus station) in Paraná state were chosen for collecting drinking water for consumption. These were the bus station of the cities of Telêmaco Borba, Imbaú, Tibagi, Castro, Reserva, Curiúva and Ponta Grossa, as shown in the Figure 1.

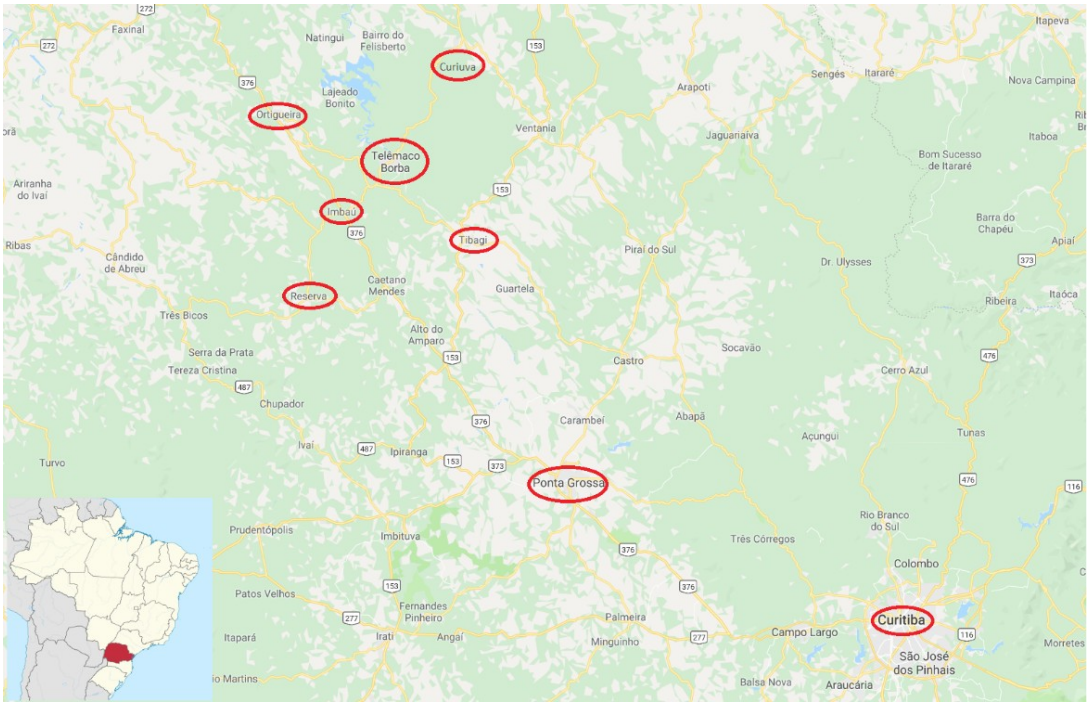

Figure 1: Cities in the state of Paraná chosen for drinking water collection: Telêmaco Borba, Imbaú, Tibagi, Castro, Reserva, Curiúva, Ponta Grossa.

2.2. Alpha and beta decay

We have measured alpha and beta decay. This was possible due to the specificities between this decay in relation to decay pulses of particles. This is because the decay pulse as a function of time α is greater than β. From this, it is possible to distinguish α from β (Figure 2).

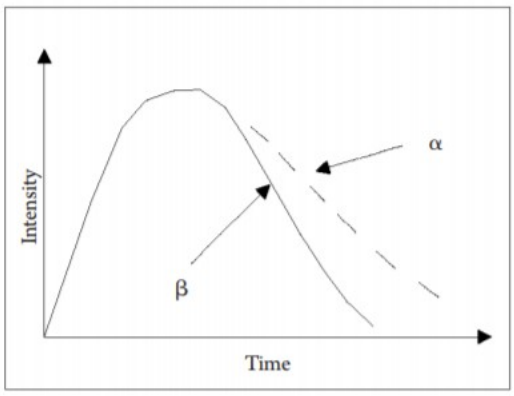

Figure 2. Graph showing the alpha and beta pulse difference (Intensity of decay pulse as a function of time).

2.3. Sample preparation

One liter of each sample of drinking water was measured in a volumetric flask and transferred to a 1 L beaker. The samples were placed on a heating plate (80°C) to reduce the volume to 45 ml. The content of each beaker was transferred to a graduated test tube, and we completed the volume to 50 mL using ultrapure water. Then, 5 ml of the concentrated sample was transferred to a 20 mL measuring vessel using a calibrated micropipette (low diffusion polyethylene vessel). Later, we added 15 mL of Optiphase Hisafe 3 scintillator solution into the vessel. Homogenization of the scintillation solution with the sample was carried out for approximately 1 minute on a shaker.

2.4. Sample analysis

The drinking water samples were prepared and counted to determine the gross alpha and beta radioactivity using 1220 Quantulus Ultra Low Level Liquid Scintillation Spectrometer.

The results of the counter were used to calculate the concentration of radioactivity through equation (1).

$$C = \frac{Sc - Bg}{ef \,.\, V \,.\, Sf \,.60} \tag{1}$$

Where:

C = Concentration ($Bq.L^{-1}$);
Sc = Sample count (cpm);
Bg = Background radiation count (cpm);
ef = Detector efficiency ($cps \cdot dps^{-1}$);
V = Sample volume (L);
Sf = Sample concentration factor;
60 = Unit conversion factor.

3. RESULTS

The results of the liquid scintillation counting analyzes are described in Table 1 and showed that the cities of Tibagi, Curitiba, Ponta Grossa, Imbaú, Telêmaco Borba, Reserva and Curiúva presented values of total alpha below 0.1 $Bq.L^{-1}$ and values of beta total values below 0.2 $Bq.L^{-1}$. The Castro samples presented total alpha and beta values of 0.21 ± 0.04 $Bq.L^{-1}$ and 0.23 ± 0.05 $Bq.L^{-1}$, respectively.

Regarding the maximum permitted values of radioactivity concentration, the Ministry of Health [8] establishes 0.5 $Bq.L^{-1}$ for total alpha radiation and 1 $Bq.L^{-1}$ for total beta radiation.

Therefore, our results of liquid scintillation spectrometry indicated values below the maximum allowed.

Table 1. Results of the total concentrations of alpha and beta radioactivity in the collection of water from the bus station in the cities of Telêmaco Borba, Imbaú, Tibagi, Castro, Reserva, Curiúva, Ponta Grossa.

CONCENTRATION OF RADIOACTIVE ACTIVITY (TOTAL ALFA AND BETA)		
SAMPLE	TOTAL ALFA ($Bq.L^{-1}$)	TOTAL BETA ($Bq.L^{-1}$)
TIBAGI A	< 0.1	< 0.2
TIBAGI B	< 0.1	< 0.2
CASTRO A	0.22 ± 0.04	0.22 ± 0.05
CASTRO B	0.19 ± 0.03	0.24 ± 0.05
CURITIBA A	< 0.1	< 0.2
CURITIBA B	< 0.1	< 0.2
PONTA GROSSA A	< 0.1	< 0.2
PONTA GROSSA B	< 0.1	< 0.2
IMBAÚ A	< 0.1	< 0.2
IMBAÚ B	< 0.1	< 0.2
TELÊMACO BORBA A	< 0.1	< 0.2
TELÊMACO BORBA B	< 0.1	< 0.2
RESERVA A	< 0.1	< 0.2
RESERVA B	< 0.1	< 0.2
CURIÚVA A	< 0.1	< 0.2
CURIÚVA B	< 0.1	< 0.2

3. CONCLUSIONS

The results of liquid scintillation counting indicated that from the radiological point of view, whose reference was the concentration of total alpha and beta radiation, the water is within the standards of potability of water for human consumption determined by Consolidation Ordinance No. 5 of the Ministry of Health of October 3, 2017.

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