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Mutagenic potential assessment associated with human exposure to natural radioactivity

Alexandre Endres Marcon [a, 1], Julio Alejandro Navoni [b, 1], Marcos Felipe de Oliveira Galvão [c], Anuska Conde Fagundes Soares Garcia [b], Viviane Souza do Amaral [b, c, g], Reinaldo Antônio Petta [d], Thomas Ferreira da Costa Campos [d], Renata Panosso [e], Antônio Luiz Quinelato [f], Sílvia Regina Batistuzzo de Medeiros [a, b, c, g, *]

[a] Graduate Program in Health Sciences, Center for Health Sciences, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[b] Graduate Program in Development and Environment, Biosciences Center, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[c] Graduate Program in Biochemistry, Biosciences Center, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[d] Geology Department, Center for Exact and Earth Sciences, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[e] Department of Microbiology and Parasitology, Biosciences Center, Federal University of Rio Grande do Norte, Natal, RN, Brazil
[f] Centro Nacional de Energia Nuclear, Poços de Caldas, MG, Brazil
[g] Department of Cell Biology and Genetics, Biosciences Center, Federal University of Rio Grande do Norte, Natal, RN, Brazil

HIGHLIGHTS

- Supplied water in semiarid region was analyzed concerning heavy metals, cyanobacteria and radiation.
- Indoor radon and gamma emitters (U, K and Th) concentrations were measured.
- High radon levels are present inside urban residences.
- It was found high frequencies of micronuclei and nuclear alterations in human oral mucosa.
- High background radioactivity could explain the observed mutagenic effect observed.

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ABSTRACT

Lucrécia city, known to harbor a high cancer rate, is located in a semiarid region characterized by the presence of mineral reservoirs, facing a high exposure to metal and natural radioactivity. The present study aimed to assess the environmental scenario at a semiarid region located in Northeastern Brazil. Metal concentration, alpha and beta radiation, and cyanobacteria content in tap water along with indoor radon and gamma emitters (U, K and Th) concentrations were measured. In addition, mutagenic and nuclear instability effects were assessed using buccal micronucleus cytome assay. The study included five samplings corresponding to a period between 2007 and 2009. Drinking water from Lucrécia city presented levels of Mn, Ni and Cr along with cyanobacteria in concentrations one to four times higher than regulatory guidelines considered. Furthermore, high levels of all the tested radionuclides were found. A high percentage of the houses included in this study presented indoor radon concentrations over 100 Bq m^{-3}. The mean annual effective dose from Lucrécia houses was six times higher than observed in a control region. The levels of exposure in most of the Lucrécia houses were classified as middle to high. A significant mutagenic effect, represented as an increase of micronuclei (MN) frequency and nuclear abnormalities as nuclear buds (NB), binucleated cells (BN), and pyknotic cells (PYC) were found. The results obtained highlight the role of high background radioactivity on the observed mutagenic effect and could help to explain the exacerbated cancer rate reported in this locality.

* Corresponding author. Departamento de Biologia Celular e Genética, CB – UFRN, Av. Salgado Filho, s/n – Campus Universitário, Lagoa Nova, Natal, 59072-970, RN, Brazil.
E-mail address: sbatistu@cb.ufrn.br (S.R.B. de Medeiros).

[1] Both authors contributed equally.

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1. Introduction

Scarcity of water supply is a major problem to be faced by human population in the XXIst century. According to the World Health Organization (WHO) more than seven hundred millon people still lack with water supply (WHO, 2016). This scenario is especially dramatic in drylands which take up 41.3% of the land surface. Drylands includes arid and semi-arid areas many of which are threatened by desertification in approximately a hundred countries, home for about 1 billion people (UNESCO, 2009).

Furthermore, water quality needs to be considered of vital importance for human development because the contamination of aquatic ecosystems can transform water into a source of exposure and dissemination of pathogenic microorganisms or toxic substances, broadening the resulting affected area and consequently the exposed population (Datta et al., 2009; Verma and Dwivedi, 2013; WHO, 2016).

For example, many cyanobacteria species are natural components of phytoplankton and are known to produce cyanotoxins that have toxic effects on humans (Sieroslawska, 2013; Zanchett and Oliveira-Filho, 2013), which may endanger the health of the population that consumes water from such a source (Žegura et al., 2011). Cyanobacteria blooms may increase as a consequence of eutrophication following water pollution and excess nutrient.

In the Brazilian northeast scenario, two additional factors need to be taken into account related to water safety. This region has important reservoirs of minerals, in particular uranium (and its by-products), along with the presence of other radionuclides such as potassium and thorium. The exposure of the population to high levels of these compounds can lead them to present an increased incidence of different types of cancer. For example, among the primary radionuclides ranked as responsible for human exposure to radioactivity, the 222 radon isotope (^{222}Rn), an uranium by-product that emits alpha particles, has proven to be the most important source of natural exposure. This radionuclide percolates through the soil and rocks, dissolving itself into water and accumulating inside residences. Its inhalation is the second leading cause of lung cancer worldwide (UNSCEAR, 2006; WHO, 2009). Moreover, metals as a product of radioactive decay or naturally present as part of a variety of different mineral reservoirs in the region can become an additional human health concern. The natural occurrence of these elements or their appearance as consequence to the exposure of mineral reservoirs due to mining activity has lead to metal contamination becoming one of the most widespread environmental concerns worldwide (Järup, 2003).

Metals, as environmental toxins, in addition to affecting health by altering function and/or integrity of different macromolecules are also classified as human carcinogens (Tchounwou et al., 2012). One of the common biological targets shared by the toxins described above is DNA. These compounds can elicit their deleterious effects by harming the integrity of the genetic material by altering DNA repair mechanisms, epigenetic regulation, DNA damage signaling or telomere length (Langie et al., 2015).

A variety of mutagenicity biomarkers have been proposed to monitor populations exposed to different pollutants (Fenech, 2007; Rohr et al., 2013; De Oliveira Alves et al., 2014; De Oliveira Galvão et al., 2014). Among them, micronucleus test in human buccal mucosa cells has been widely used, and has proven to be an appropriate tool to assess the mutagenic effect of an exposed population (Bonassi et al., 2011; Bolognesi et al., 2013; Ceretti et al., 2014; Coronas et al., 2016).

Lucrécia city is located in a semiarid region of Brazil. The water supply comes from an artificial source called Lucrécia dam that provides drinking water to a total population of 3633 inhabitants and is used as a source to supply other cities settled nearby such as Martins (8218 inhab.), Frutuoso Gomes (4233 inhab.) and Antônio Martins (6907 inhab.) (IBGE, 2015). A high rate of lung, stomach and leukemia cancer has been described in Lucrécia city (INCA, 2007). Previous reports described the potential risk that the population faces in the region due to the presence of some of the toxic substances previously described in the drinking water (Serra et al., 2006; Marcon et al., 2010; Garcia et al., 2011).

Therefore, the present study aimed to assess the environmental conditions that may be related to the high cancer rate of the population settled in Lucrécia city through: i) the determination and quantification of cyanobacteria, metals, and total alpha and beta radiation content in the water supply, ii) the estimation of indoor ^{222}Rn, U, K and Th concentrations and iii) an assessment of the frequency of micronuclei (MN) and nuclear abnormalities (NA) in human exfoliated buccal mucosa cells.

2. Material and methods

2.1. Water supply sampling

Residential tap water, supplied for Lucréciás dam, was collected between March 2007 and November 2009 in Lucrécia city. The methods for collection, preservation, packaging, transportation, and analysis were performed in accordance to the recommendations of the American Public Health Association (APHA, 2005).

Tap water, provided by groundwater, was also collected at the Federal University of Rio Grande do Norte (UFRN), located at Natal city, to be used as control for some experiments.

2.2. Water quality assessment

2.2.1. Cyanobacteria analysis

Four collections of 500 mL tap water samples were carried out and fixed with Lugol's solution. The density of cyanobacteria (cells mL^{-1}) was estimated using an inverted microscope (Olympus IX 70), by the Utermöhl sedimentation technique according to APHA (2005). This observation was done twice for each collection. As the water from UFRN is provided by groundwater, cyanobacteria characterization was done only for tap water from Lucrécia.

2.2.2. Analysis of metals

Metal content assessment involved five collections of 1000 mL tap water samples for both localities. Levels of cadmium (Cd), chromium (Cr), copper (Cu), manganese (Mn), nickel (Ni), lead (Pb) and zinc (Zn) were determined once by collection. Briefly, 4 mL of concentrated nitric acid was added into 250 mL of sample and then evaporated to close to 10 mL on a hot plate. Afterward, 2.5 mL of chlorhydric acid were added and the mixture was heated for 30 min, then dried and reconstituted in a volumetric flask to 50 mL using deionized water. The equipment used was a flame atomic absorption spectrophotometer (FAAS) (Varian model 50B).

All analyzed parameters (physicochemical and metal content) were compared with guidelines for water quality of the WHO (WHO, 2008) and from the Brazilian environmental legislation (CONAMA, 2005).

2.2.3. Total alpha and beta radiation

For the analysis of total alpha and beta radiation 2000 mL of tap water were sampled in five collections for Lucrécia and two for Natal cities. Quantification of total alpha and beta radiation was performed by the Poços de Caldas National Nuclear Energy Commission Laboratory (LAPOC/CNEN) using the scintillation counting technique, with an Eberline SAC-4 (alpha counter) and FHT-770T (beta counter), respectively. Three measurements for each sample were done.