Proceedings of ICGG7 (2003): 3–5

ICGG7 2003

Radiological geohazard survey in the south east of Manizales city (Colombia)

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Abstract. A survey of radon levels in soils, public waters and indoor was carried out in the south east of Manizales city (Colombia) with the purpose to stablish radiological geohazard in this city. A network of 43 radon stations was installed in an area of 8 square kilometers, distributing each station from another at a distance of 500 meters. Simultaneously, $\delta^{13}C(CO_2)$ were measured with the aim to understand the genesis of trapped gases in each station. Indoor radon and dissolved radon in public waters were analyzed in the studied area. In all cases for radon measurements was used the EPERM ionizing chamber system and for analyses of C^{13} in carbon dioxide from soils was used a quadrupole mass spectrometer Balzers Prisma, using PDB CO_2 gas as standard reference.

A map of radiological geohazard produced for radon was contructed for the SE part of Manizales city.

1 Introduction

Radon is a colorless, tasteless, odorless, radioactive gas that occurs everywhere in the environment as a by-product of the natural decay of radioactive elements, like uranium, thorium and radium, and it is broadly distributed in the Earth: in rocks, soils, waters and in the atmosphere.

Rocks that appear in the present study area, can be divided into two groups: (1) rocks with a low degree of metamorphism, debris flows and failed rocks (Quebradagrande complex), with uranium concentration more than 2 ppm; and, (2) rocks with uranium concentration below 2 ppm, like basaltic igneous rocks (Lusitania lava flow, Sancancio dome), piroclastic fall.

Radon is in constant emission from the Earth's interior toward the atmosphere by two main mechanisms: (1) by diffusion, where radon moves with respect to fluid filling the pores of the medium (concentration gradient); and, (2) by advection, where fluid itself moves through porous medium and carries radon along with it (pressure gradient). Both two mechanisms are influenced by some soil and rock properties, like: (1) relative humidity, which can affects inversely radon emission; (2) permeability, which facilitates radon emission toward the surface; (3) active radium concentration in soils and rocks, which gives information about radon production in soils; and, (4) structural geology of the studied area.

Radon daughters are fine particles which result from radioactive decay of radon gas, and are hazardous because of alpha radiation, which they emit. When radon daughters are breathed and deposited in the lungs, alpha radiation can harm sensitive lung tissue, and may cause lung cancer after years of exposure.

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2 Methodology

Because of ionic nature of alpha particles produced by natural disintigration of radon, to measure radon in soils, waters and in the air of home's interior it was used a passive integrating ionization method consisting of a very stable electret mounted inside a small chamber made of electrically conducting plastic. The electrect, a charged Teflon disk, serves as both a source of the electrostatic field and as a sensor. Radon gas passively diffuses into the chamber through filtered inlets, and the alpha particles emitted by the decay process ionize air moleculees. Ions produced inside the chamber are collected onto the electret, causing a reduction of its surface charge. The reduction in charge is a function of the total ionization during a specific monitoring period and the specific chamber volume (Kotrappa, 1988).

In some radon soil stations were collected CO_2 gas samples with the purpose to understand the genesis of trapped soil gases and then the structural features of the studied area. Soil CO_2 was analyzed in a gas chromatograph Varian Vista 6000, and $\delta^{13}C(CO_2)$ analyses were carried out in a quadrupole mass spectrometer Balzers Prisma, using PDB CO_2 gas as standard reference.

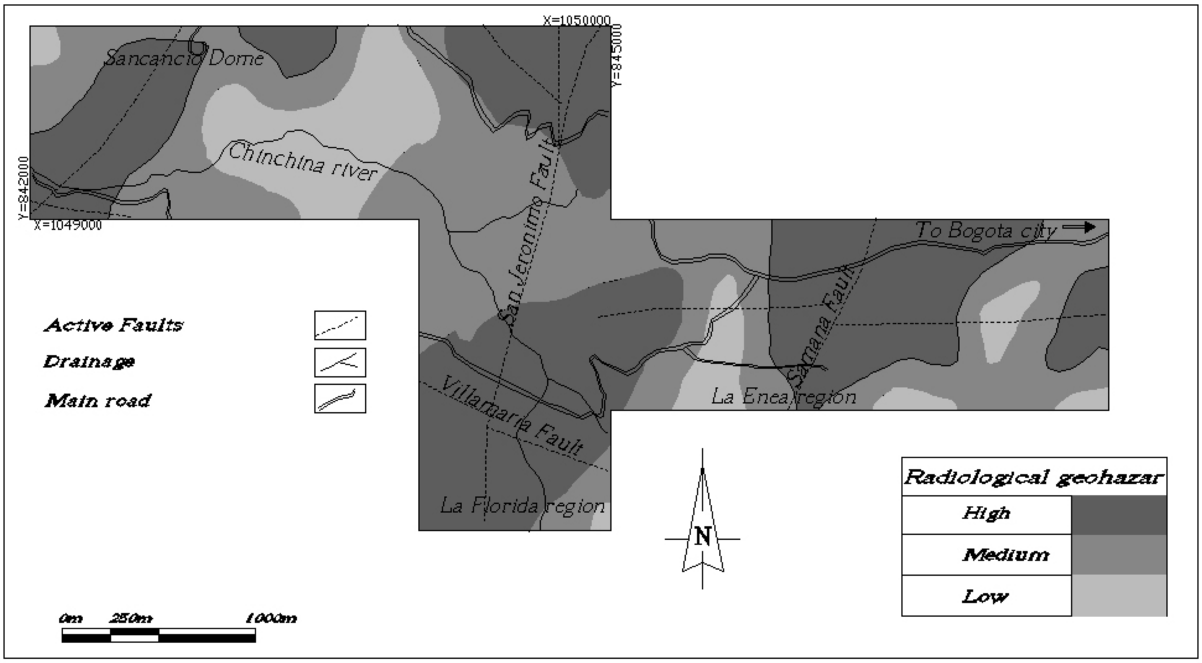

Fig. 1. Map of radiological geohazard produced by radon in the SE of Manizales city, Colombia.

Kriging method (Davis, 1986) and Radon Index Matrix (Gundersen et al., 1992) were the main statistical methodologies used in the present work. Indoor radon concentrations above 4 pCi/L were considered as high radiological hazard; from 2 to 4 pCi/L as medium; and below 2 pCi/L as low. Radon concentration in the supply water was stablished as low radiological harzard with concentrations below 300 pCi/L, as was suggested by US Environmental Protection Agency – US EPA.

3 Results

Indoor radon in the SE of Manizales city are between 0,3 and 13,1 pCi/L. Some critical values have to be taken into account like in a house in La Enea region with 4,5 pCi/L; in the administrative office of IDERNA industries with 4,9 pCi/L; and in the children garden Florida Blanca with 13,1 pCi/L. High indoor radon are caused by high soil radon levels and by a poor ventilation. Without the critical indoor radon level measured in the children garden, the averange is of 1,9 pCi/L; stablishing the studied area as a zone with low level of radiological hazard.

Measured radon in public waters in the SE of Manizales were as follow:
163 pCi/L in the distribution tank of AGUAS DE MANIZALES, Niza plant (summer time);
118 pCi/L in the distribution tank of AGUAS DE MANIZALES, Niza plant (rainy time);
108 pCi/L in the supply water in a home.

Taken into account the suggested by US EPA base level of 300 pCi/L for radon in public waters, the measured radon levels in public waters in the SE at Manizales city are low.

Radon in soils vary from 151 to 1830 pCi/L in the SE of Manizales city. A very high concentration of radon of 25 000 pCi/L was measured in an intersection of Villamaria and San Jeronimo geological active faults in Florida region.

Two different groups of soil radon levels may be considered:
(1) Radon soil emissions superior to 800 pCi/L; and,
(2) Radon soil emissions below 800 pCi/L.

Radon soil emissions superior to 800 pCi/L were measured on traces of Villamaria, San Jeronimo and El Perro active geological faults; and on intersections of cited active faults. In sites with high radon soil emissions, were observed structural features like slope changes, triangular facets and fault bench.

To constrain the origin of soil gases trapped in the natural soil profile (B horizon), were measured CO_2 isotopic ratios. The range of $\delta^{13}C$ of CO_2 from subduction zones is between -12 and $-2,5‰$. Biogenic carbon is in a range of $\delta^{13}C$ of CO_2 between -34 and $-10‰$ (Fischer et al., 1997). Thus, isotopic ratios of CO_2 measured in the present work gives two different categories: (1) those related to structural features with relative high contents of C^{13} which are in agreement with recent neotectonic works carried out in the studied area (Gonzalez and Garzon, 2001); and, (2) those unrelated to active geological faults.

4 Conclusions

All collected data directly reflect the structural features and chemistry of the underlying bedrock in the studied area. Radon is a better indicator because it is sampled directly from the surface and is therefore less subjected to deeper processes and human activities. Using radon data and applying some statistical methods like kriging and Radon Index Matrix, was made the map of radiological geohazard showing in the Fig. 1. High radon levels and then high natural radiological hazards can be correlated with activity of geological faults in La Florida region and in Malteria (industrial zone). Low radon levels and then low radiological geohazards are in the south east side of Sancancio dome in Manizales city.

Water distributed by AGUAS DE MANIZALES in the south east of Manizales city have low radiological hazards.

Indoor radon averange is 1,9 pCi/L in the SE of Manizales city, which is considered as a low level of natural radiological hazard.

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