



## Urban soil gas geochemistry to identify permeable zones and possible upflow of deep-seated gases at the city of Ourense, Galicia, Spain

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Thermal waters from natural hot springs and boreholes are clear geothermal features of the city of Ourense (Galicia, Spain). The urban area of Ourense is located in the Miño River's valley which is characterized by two fault systems (NW–SE and NE–SW) that determine the groundwater circulation in the region. The low permeability of the granite and granodiorite only allows fluid circulation throughout faults and fractures transporting the fluid and transferring the heat to the lower elevations in the valley (Araujo 2008; Fernández Portal et al. 2007). During July to August 2019, an intensive soil gas geochemical survey was carried out at urban area of Ourense in order to identify the presence of vertical permeable structures and possible upflow of deep-seated gases. A total of 539 soil gas samples were taken with an average distance of  $\approx 100$  m between sampling sites and covering an area about  $13\text{Km}^2$ . In-situ soil  $\text{CO}_2$  efflux and soil gas  $^{222}\text{Rn}$  activity measurements were performed at each sampling site. In addition, soil gas samples at 40 cm depth were collected for chemical (He, Ne,  $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{CH}_4$  and  $\text{CO}_2$ ) and isotope ( $\text{d}^{13}\text{C}\text{-CO}_2$  vs. VPDB) analysis by micro-gas chromatography and IRMS, respectively. Soil  $\text{CO}_2$  efflux and  $^{222}\text{Rn}$  activity values ranged from 0.7 to  $92\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$  (mean value of  $16\text{ g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$ ) and from 2.7 to  $743\text{ Bq}\cdot\text{m}^{-3}$  (mean value of  $73\text{ Bq}\cdot\text{m}^{-3}$ ), respectively. Regarding soil gas He and  $\text{H}_2$  concentration, the values ranged from 5.2 to 25.0 ppmV (mean value of 6.2 ppmV) and from 0.5 to 24.9 ppmV (mean value of 1.9 ppmV), respectively. Soil  $\text{CO}_2$  concentrations showed a range between 355 and 53,766 ppmV (mean value of 7,824 ppmV) with a range of isotopic ratios from -14.1 to -28.5‰ vs. VPDB (mean value of -22.1 ‰). The binary plot of  $\text{d}^{13}\text{C}\text{-CO}_2$  vs  $1/\text{CO}_2$  concentration suggest the presence of small fractions of  $\text{CO}_2$  deep-seated in the soil gas atmosphere (mainly an atmospheric and biogenic gas mixture) of the city of Ourense. Soil  $\text{CO}_2$  efflux, soil gas Rn-222 activity and soil gas He,  $\text{H}_2$  and  $\text{CO}_2$  concentration contour maps were constructed using the sequential Gaussian simulation (sGs) interpolation method. Estimated diffuse  $\text{CO}_2$  emission from the study area is about 201 tons per day and about 8 tons per day could be considered deep-seated degassing.

Spatial distribution analysis of the soil gas geochemical data show relatively high values of soil CO<sub>2</sub> efflux and soil gas H<sub>2</sub> concentration at the Chavasqueira-Tinteiro urban sector, while As Burgas and Outariz-Muiño urban sectors showed relatively high values of soil <sup>222</sup>Rn activity. These results show the usefulness of the soil gas geochemistry to identify permeable zones and possible upflow of deep-seated gases at the city of Ourense.