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## Hydrogeochemistry of groundwater supplied to the City of Monterrey, Mexico

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### Abstract

The Monterrey Metropolitan Area (MMA) is the third greatest urban area of Mexico. Owing to the rapid industrialization and urbanization of this city, more water resources are necessary in this semi-arid region. Thus, the objectives of this work were to characterize the chemical properties of groundwater supplied to MMA and to assess inter-annual variations in the water chemistry. Three groups of water were identified: recharge waters from mountain belts dominated by marine sedimentary rocks (Ca-HCO<sub>3</sub> type), transition zone waters from alluvial sediments (Ca-HCO<sub>3</sub>-SO<sub>4</sub> type) and waters flowing through conglomerates and alluvial sediments of the northeastern MMA (Ca-SO<sub>4</sub> type). The ionic composition and the salinity gradient of each water group were in agreement with the topographic flow paths of the study area. The non-parametric Mann-Whitney U-test indicated that there have been no significant changes on the groundwater quality supplied to the MMA between the years 2006 and 2012.

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### 1. Introduction

The city of Monterrey, located in a semi-arid region of northeastern Mexico, is the third greatest metropolitan area of this country (~4.2 million inhabitants) and it is located at the borders of two tectonic provinces: Sierra Madre Oriental (SMO) and the Gulf Coastal Plain. The water supplied to Monterrey Metropolitan Area (MMA) is coming from groundwater and surface water resources: groundwater originates from wells located within or a short

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distance from the urban area, whereas surface water sources come from three reservoirs (La Boca, Cerro Prieto and El Cuchillo dams), which supply the MMA through 400 km of aqueducts. However, because the rapid development of industrialization and urbanization of this city and the fact that there is limited surface water availability around the surrounding areas, more water resources for industrial and domestic uses have become necessary. Owing to the increasing water demand in the area, there is a real necessity to increase groundwater extraction and improve its quality. Nevertheless, excessive extraction of groundwater and other factors such as climate change, could increase the pressure on this hydrologic system<sup>1</sup>. Therefore, the objectives of this study were to investigate the hydrogeochemical characteristics of groundwater supplied to the MMA and the inter-annual variation of the groundwater quality in a period of 6 years, and to assess the geochemical processes controlling the groundwater chemistry in this semi-arid region. Several chemical analyses were carried out in groundwater taken from different wells along the city of Monterrey and surrounding populations in the years 2006 and 2012.

## 2. Study area and regional geology

The study area was located in the state of Nuevo León, Mexico. The climate is semi-arid and the annual mean temperature is 22 °C, with minimum (-10 °C) and maximum (45 °C) values in winter and summer, respectively. The annual mean precipitation is 585 mm, although the highest rainfall values are found along the flanks of mountains. The studied zone is bordered on the southwest and south by SMO, a 2-3 km-thick Mesozoic-Cenozoic sedimentary belt containing a mixture of carbonates, shales, siliciclastic rocks and evaporites such as halite and gypsum; however limestones and gypsum from the lower cretaceous dominate (Fig. 1)<sup>2</sup>. In the foothills of SMO is the Campo Buenos Aires area (between 700 and 1000 masl), which is composed by clastic marine sedimentary rocks and considered a semi-confined aquifer. Moreover, toward the southwest of Monterrey, there are several wells and galleries located in the foothills of SMO that supply water to the population of Santiago. The MMA is located in the frontal part of SMO. Limestone and shale outcroppings from the upper Cretaceous are found in sedimentary rocks of the valley borders. Also, these rocks form gentle hills in the valley. The valley of Monterrey is filled by 18-24 m-thick fluvial and alluvial sediments from the Quaternary, which have been deposited during accumulation-erosion cyclic changes<sup>3</sup>. The most recent sediments have been deposited along the channels and riverbeds of the La Silla and Santa Catarina rivers. Thus, this aquifer is constituted by gravelly sand, sand, silts and alluvial sediments. Finally, the Campo Topo Chico (NW) and several zones located to the northeast of Monterrey, are composed by Tertiary conglomerates (Reynosa conglomerate) of calcareous fragments (3-24 m-thick) packed in a sandy matrix and alluvial deposits of gravel, sand, silt and clay. Overall, the groundwater flows from SMO (SW-S) and foothills located close to the Santiago (SE) toward the MMA, Campo Topo Chico and other zones located toward the northeast of Monterrey<sup>4</sup>.

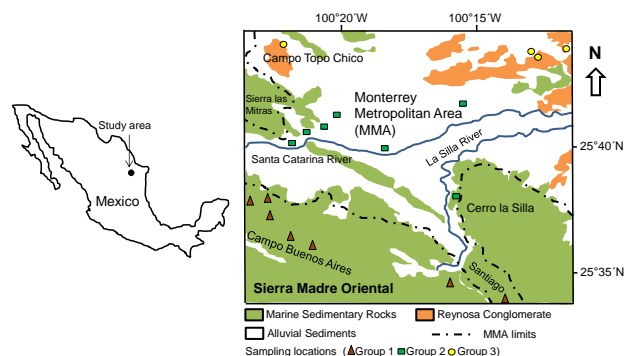


Fig. 1. Geological map of the studied area and localization of the groundwater sampling locations.

## 3. Materials and Methods

The field sampling campaigns were conducted in the years 2006 and 2012. In 2006, the 24 sampled wells were located between Campo Buenos Aires, MMA and surrounding areas such as Santiago population and Campo Topo

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