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Determination of water sources for underground structures flooding in Mar Del Plata, Argentina, applying mixing indexes

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INTRODUCTION

Mar del Plata city, the main tourist resort in Argentina (Figure 1), registered a massive migration process during the second part of the last century, at a rate of 100,000 inhabitants each decade. During the rapid development of the city as a summer centre, most of the family houses placed near to the coast were replaced by buildings that include subsurface services, like parking lots, cellars or locker areas. Intensive groundwater exploitation led to an important piezometric level drawdown and seawater intrusion.

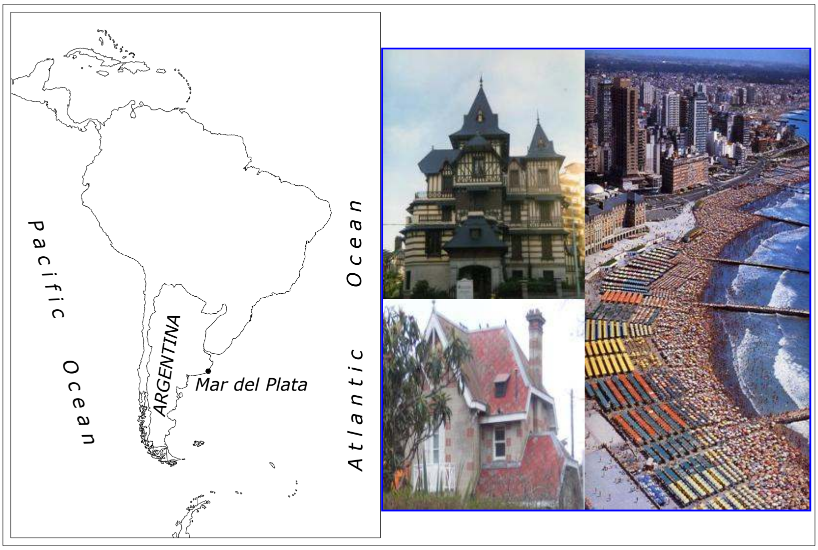

Figure 1. Location map.

As a consequence of salinization many urban pumping wells were abandoned during the late 70's. This process, together with increased recharge due to urbanization (Vázquez Suñé et al, 2005) (leakage from sewage and runoff networks), caused heads recovery up to 22 m over a 25 km^2 area. Many subsurface structures built during low head periods were flooded, which damaged reinforced concrete structures (Figure 2).

Figure 2. Basement flooding and damage of the reinforced concrete structures.

The purpose of this study is to assess water sources in flooding urban underground structures in Mar del Plata**.**

METHODOLOGY

The full approach consisted of the following steps: a) to identify the sources of recharge or end members, b) select the chemical species to be included in the geochemical balances, c) compute mixing ratios, and d) synthesis of results.

In order to quantify the sources of increased recharge, a geochemical and isotopic survey was carried out on both potential end members and samples from underground structures leakage. As end members, five sources were identified: urban groundwater, water supply, sewage water, rain water and sea water intrusion.

The resulting data were interpreted with the aid of code MIX (Carrera et al., 2004), which computes mixing ratios, while acknowledging uncertainties in end members. This methodology was applied to the Barcelona aquifers, where 12 chemical species from 25 wells were analysed, computing mixing ratios of waters from the Besós river, rainfall infiltration, Ter river water supply, Llobregat river water supply, Ter river sewage water, Llobregat river sewage water, city runoff and sea water intrusion (Vázquez Suñé, 2003).

CHEMICAL AND ISOTOPIC CHARACTERIZACTION OF WATERS

Chemical composition of end members are represented through Stiff diagrams (Figure 3).

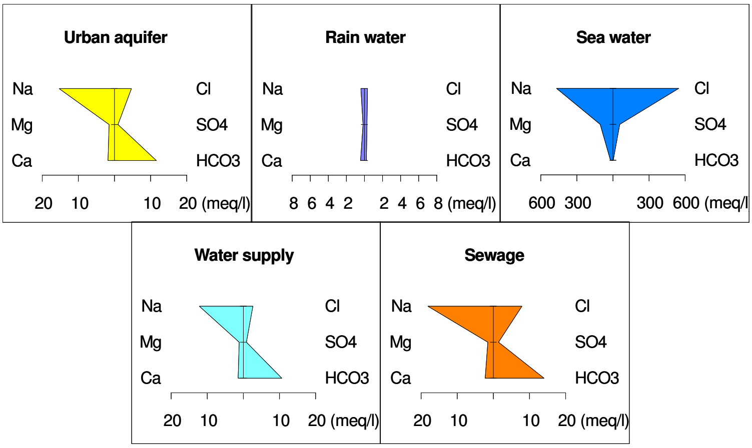

Figure 3. Stiff diagrams of end members.

Water from urban aquifer is sodium bicarbonate, mean electrical conductivity 1645 μS/cm and mean nitrate concentration 106 mg/l. Water supply from the aquifer located on the northern rural area is sodium bicarbonate, electrical conductivity 1200 μS/cm and nitrate concentrations less than 6 mg/l. Sewage water is also sodium bicarbonate, electrical conductivity 2150 μS/cm and concentration of total nitrogen 60 mg/l, 35 mg/l from human excretes and 25 mg/l from the leakage of the fishery industry. Rain water has a very low salinity and the type is sodium calcium without dominant anion; this water would enter to the underground structure by city runoff. Sea water is sodium chloride and its conductivity 56000 μS/cm.

Stiff diagrams and location of twelve samples from cellars of public, commercial and housing buildings in the urban area of Mar del Plata are shown in Figure 4. Water in the underground structures is affected not only by mixing process, but also by interaction with concrete, which affects HCO_3, SO_4, Ca and Mg (Bocanegra et al., 2009).

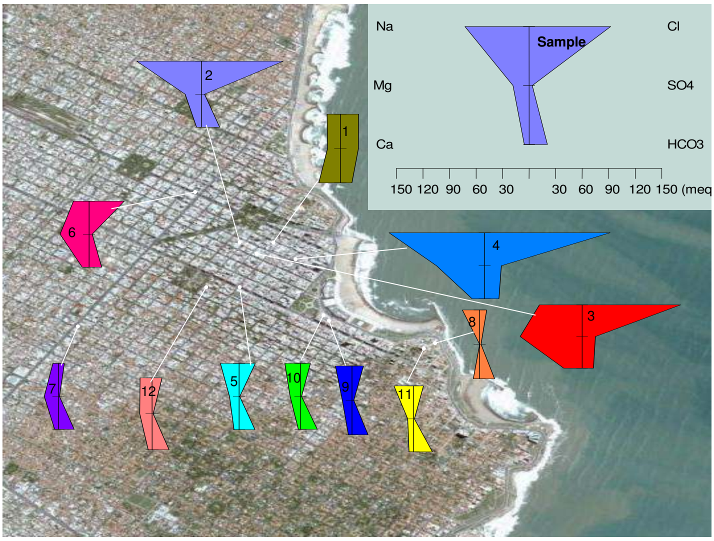

Figure 4. Stiff diagrams of underground structures leakage.

Isotopic composition is represented in a $\delta^{18}O$ vs δ^2H diagram (Figure 5). From this point of view it is noticeable that the water sampled in flooded underground structures in plotted on the meteoric water line, around the groundwater samples. Sewage water has also the same isotopic composition of groundwater, as it can be expected in a city where groundwater is the only source for water supply.

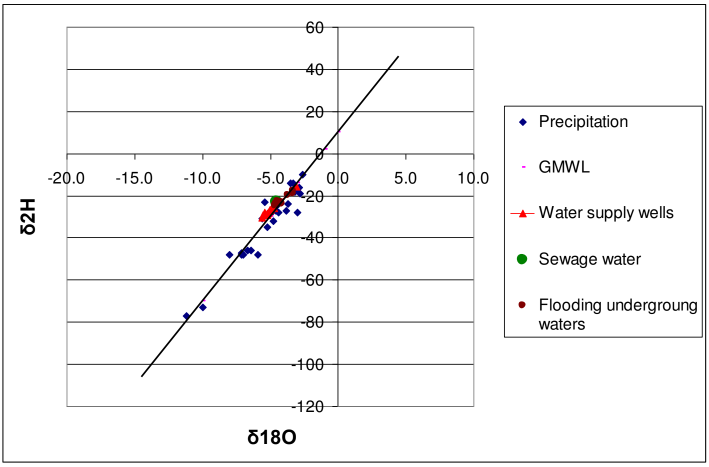

Figure 5. Diagram showing the isotopic composition of end members and water in flooded underground structures.

Mixing ratios were obtained using Cl, total N, δ 2H, and δ 18O as conservative tracers. N vs. Cl (Figure 6) and δ2H vs. δ18O (Figure 7) diagrams show that all samples are in the frame of the end members composition.

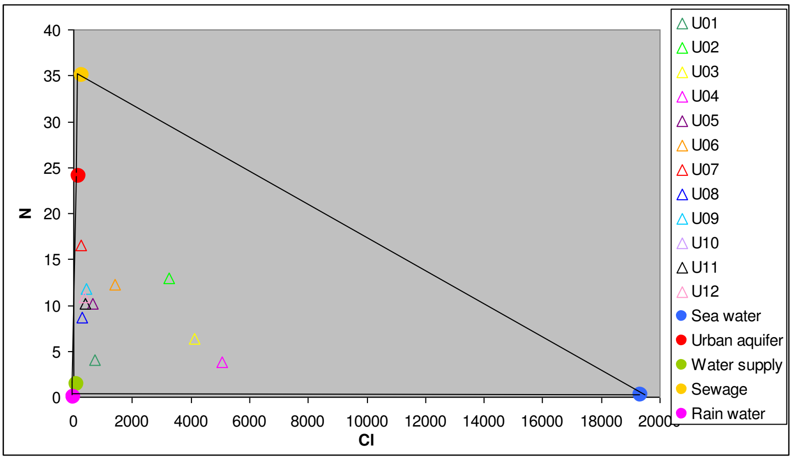

Figure 6. N vs. Cl⁻ diagram of end members and underground structures leakage.

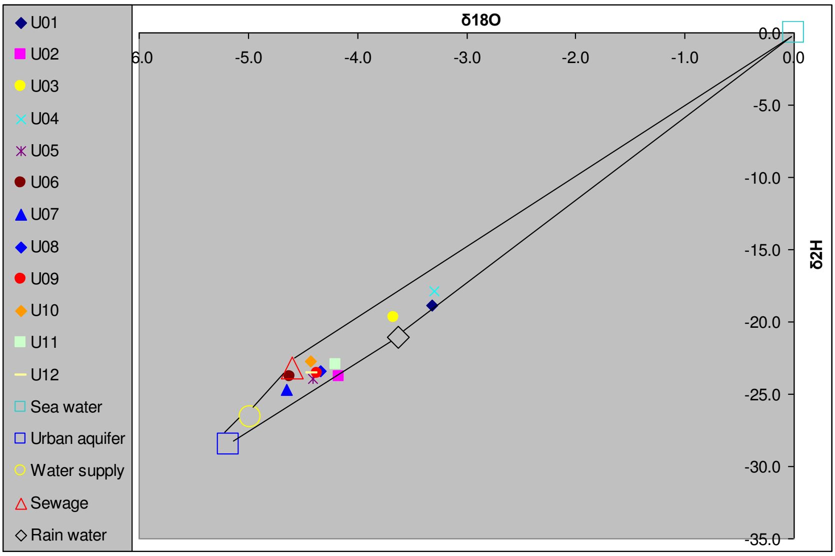

Figure. 7. δ^{2}H vs. δ^{18}O diagram of end members and underground structures leakage.

COMPUTING MIXING RATIOS OF END MEMBERS

The results of the computed mixing ratios indicate that concentrations are rather close to the measurements (Figure 8).

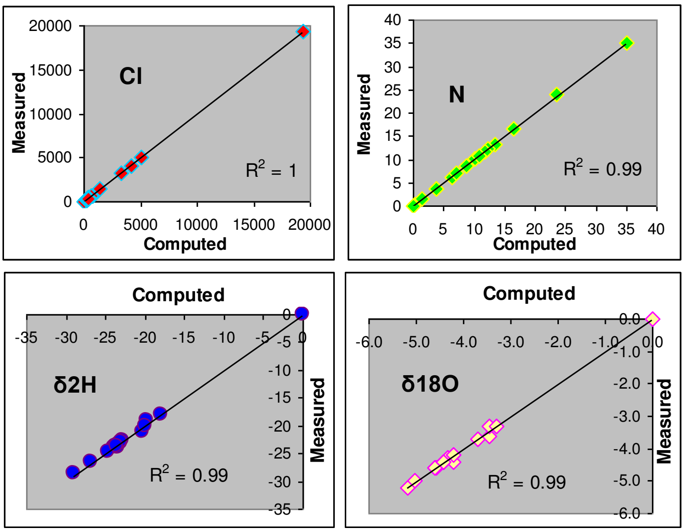

Figure 8. Computed vs. measured composition diagrams of Cl^-, total N, δ^2H and $\delta^{18}O$

Spatial distribution of mixing ratio in each sample is shown in Figure 9. Seawater intrusion is recognized for buildings with two or three under ground floors (samples 1, 2, 3, 4, y 6). Shallow samples just present traces of sea water. Running water and sewage losses and also rain water are the most important sources of flooding.

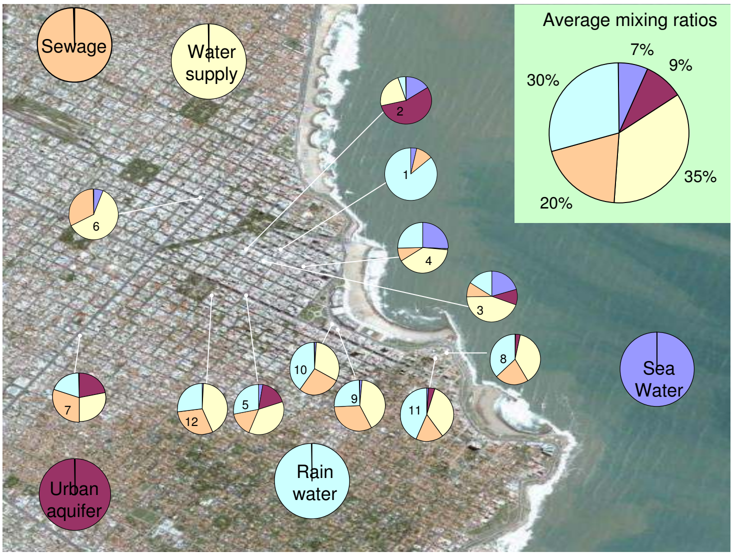

Figure 9. Spatial distribution of mixing ratio with end members.

The Control Agency of Drinking Water and Sewage for the Americas report for Mar del Plata a density of 0.4 running water breaks/km and 0.2 sewage breaks/km (GRTB, 2008). Since running water is 1550 km length and sewage 2900 km length, 1200 breaks are reported each year due to both losses of water and sewage systems.

CONCLUSIONS

Results allowed computing the proportion of each water source in flooding urban underground structures in Mar del Plata. The average mixing ratios for leakage into underground structures are: runoff water 35%; sewage leakage 19%; rain water 30%; seawater 7%; and aquifer water level rising 9%.

This calculation is possible thanks to the use all together of many selected parameters for the considered end members. The applied method is simple tool for preliminary identification of runoff water and sewage pipe lines leaking.

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