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title: **Vanadium as an indicator of groundwater arsenic contamination in urban environments**

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ABSTRACT

Variable concentrations of arsenic, As, and vanadium, V, have been found in the Salamanca aquifer system, in Mexican Highlands. Water supply located inside the urban area show temporal and spatial variations of arsenic content. There are not rock outcrops containing such elements. A groundwater and a soil monitoring were carried out. Groundwater arsenic is related to particulate emitted for local industries using fuel number 6. Particulate deposited over vulnerable areas migrates to the upper part of the aquifer system. High As and V concentrations are been found in soils around the industrial area. As is also coming from As-bearing minerals of deeper units.

INTRODUCTION

Since early 90´s, arsenic, As, concentrations over Mexicans standards for drinking water has been detected in the Salamanca aquifer system (Rodriguez et al, 2005; Mendoza, 1980). Vanadium as also been detected in groundwater. Both elements present spatial and temporal variations. As and V were found in the particulate emitted by local industries, mainly a refinery and a thermoelectric plant (Mejia et al., 2007). The origin of both elements was not associated to any formation outcrop. Salamanca City is located in Guanajuato State, central Mexico (Fig. 1).

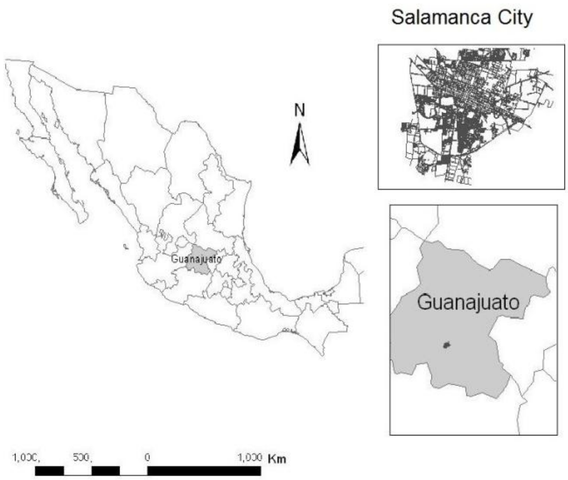

Figure 1. Location Map. Salamanca City.

The area is part of the Mexican Transvolcanic Belt. The oldest rocks are ignimbrites. Tertiary granular sediments overlay the volcanic rocks. Quaternary sediments of variable grain size and thickness form the shallow unit (Rosales, 2001). Groundwater is the only source of water for the more than 140, 000 Salamanca inhabitants. There are not alternate water supply source. The Lerma River crosses the urban area, but it is one of the most polluted rivers in Mexico.

Groundwater vanadium does not represent environmental risks, for that reason it is not included in the Mexican drinking water standards. There are not health affectation reports due to water ingestion even for long periods of time (NIOSH, 1977). By the way arsenic is a dangerous contaminant. It health effects are well known.

METHODOLOGY

A preliminary groundwater monitoring was carried out using the portable test kit Arsenator© for arsenic determinations in situ. Samples form areas with anomalous As values were analyzed in the Analytical Chemistry Lab of the Geophysics Institute using Graphite Furnace.

A soil monitoring was carried out, 10 cm depth. Soil monitoring points were located over vulnerable areas around the industrial area. An aquifer vulnerability assessment based on the SINTACS method (Civita and De Maio, 1997) was carried out. A monitoring network was defined around the industrial area, where a thermoelectric plant, a refinery and chemical industries are located. Samples were collected after Mexican standards. Samples were desiccated over plastic trays into a greenhouse type tunnel. Desiccated samples were crushed in a tungsten vial using a Sepx 8000 Mixer/Mill equipment, after that, samples were quartered and classified to get the finest particles. A second monitoring was carried out in a northern rural area between Salamanca and Irapuato Cities. Analyzes including vanadium, V, some trace metals that conform hydrocarbons; chromium (Cr), lead (Pb), Zinc (Zn) and nickel (Ni).

Descriptive statistic (mean, median, standard deviation, range, minimum, maximum and variation coefficient) was applied using STATISTICA 7.0 Stat Soft Inc and OriginPro 8, OriginLab Co. Correlation and determination coefficient was calculated to determine relationships between variables and its linear tendency.

RESULTS

The presence of fine sediments of high permeability determines the relatively high aquifer vulnerability of areas around the riverbed. The water table is near to surface contributing also to increase vulnerability (Fig. 2).

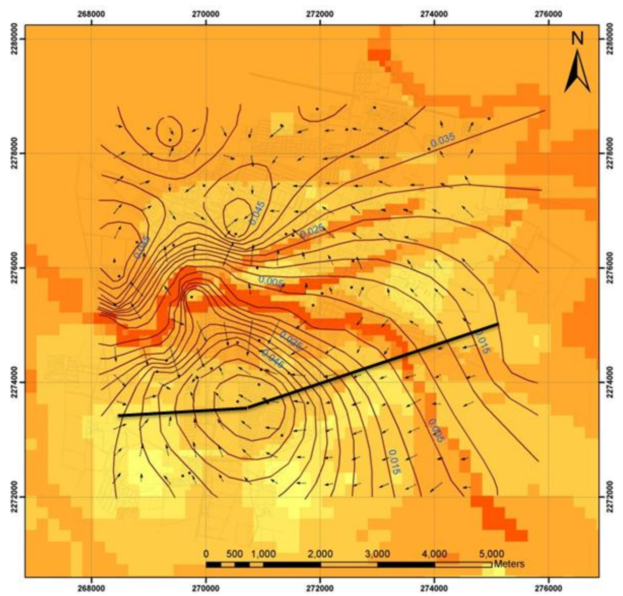

Figure 2. Aquifer vulnerability assessment with V concentrations, November 05 (yellow low values, red high values), including geological profile.

The rural area was considered as a pristine zone. Soil V in such area is related to geology, to volcanic rocks like basalts and rhylites, where as in the Salamanca urban area soil V concentrations has not relation with local geology. Urban soil V concentrations were higher that rural values. Maximum values up 600 ppm were found. Higher concentrations are associated to particulate distribution. Arsenic in the urban area showed greater values that in rural zones. There are not clear As tendencies in rural zones. In Groundwater V and As has similar tendencies.

Vanadium in urban soils is a consequence of the constant deposition of particulate, when V falls over aquifer vulnerable areas, it can migrate to the aquifer when water is available (precipitation, leakages form pipelines and sewage).

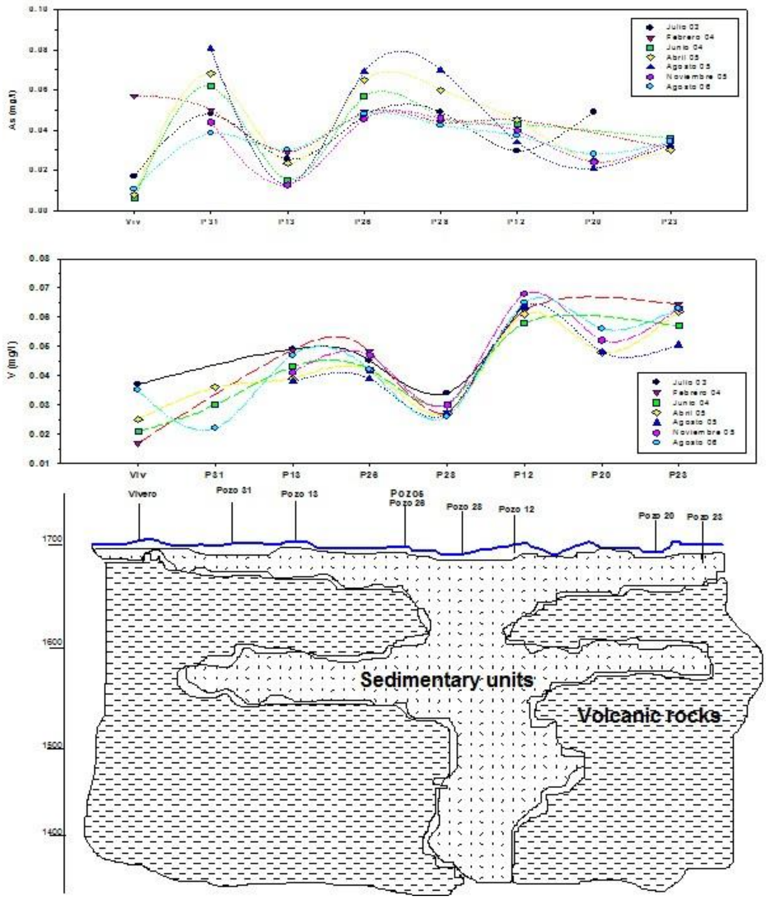

Figure 3. As and V variations and geological profile crssing the southern part of the Lerma River.

Particulate contains As, V, Ni, Zn and other elements and compounds. Its content variations in groundwater depend on solubility, load, composition of soils and vadose zone. Groundwater V and As variations are not similar in time and space (Fig 3). V ans As show a linear relationship in wells located over vulnerable zones (relatively fast infiltration, water availability). Its concentrations are differents but tendency is similar (Fig. 4).

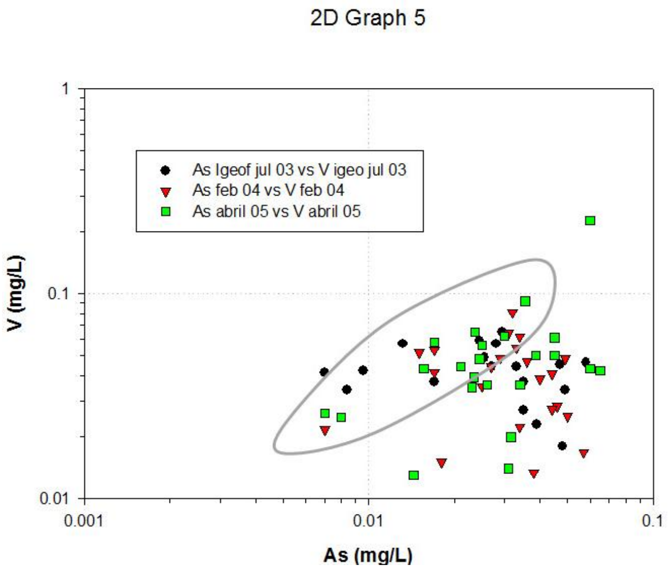

Figure 4. V vs As linear relationship in wells located over vulnerable areas.

DISCUSSION

Vanadium was used as a chemical tracer for arsenic. Vanadium is not an environmental concern whereas arsenic represents a risk for water consumers. In soils V can be used to proof the environmental impact of industrial particulate.

V and As found in urban soils are associated to particulate deposition over vulnerable areas according the results obtained with the SINTACS aquifer vulnerability assessment method. Rain infiltrations and locally water coming from pipeline leakages facilitate its incorporation to the local aquifer system. A subsidence induced fault also propitiates fast water infiltrations. Particulate emitted by industries using fuel num 6 contain great contents of V, As, Ni and Zn. The thermoelectric plant used 5,000 m^3 per day of this fuel. Its V contents vary from 290 to 500 ppm (Salinas et al., 2001). The accumulated contaminant in the last 50 years can explain the presences of both elements in soil and groundwater.

In the urban area must be also geologic contributions. The sedimentary rocks are originated in the surrounding volcanic ranges. The Guanajuato range ore areas are not so far from Salamanca.

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