

**Groundwater exploration at the Coacoyul-San Miguelito coastal aquifer,
Guerrero, Mexico.**

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EXTENDED ABSTRACT

Geophysical exploration, well boring and hydrogeochemical techniques were applied to analyze the fresh/saline water relationships and define prospective zones for groundwater supply at the Coacoyul-San Miguelito coastal aquifer. Present study resulted from the increasing water demand for Ixtapa-Zihuatanejo resort facilities in the Pacific shore of Guerrero State, Mexico. Local unconfined aquifer consisted of a sedimentary member (25-m maximum thickness and mean $K = 10\text{-}30$ m/day) and a fractured igneous/metamorphic member (50-m maximum thickness and mean $K = 0.5\text{-}1.5$ m/day). Water chemistry data showed the presence of four hydrochemical facies (Na-Cl, Cl-Ca, $\text{HCO}_3\text{-Ca}$ and $\text{HCO}_3\text{-Cl-SO}_4$). Na-Cl and $\text{HCO}_3\text{-Ca}$ end-member facies interact through both conservative and non-conservative (*i.e.*: ion exchange) mixing. Water quality analyses showed that there is no concern for groundwater contamination on study area regarding nitrates, fecal coliforms, iron and manganese. This study allowed the identification of new sites for drinking water wells.

INTRODUCTION

The Ixtapa-Zihuatanejo Region in Guerrero State constitutes one of most important Pacific shores for national and international tourism in Mexico. Both State and Federal governments are willing to develop more resort facilities by constructing new hotels and villages. It is expected an increase in visitors and local population with a subsequent growing drinking-water demand that can be satisfied by groundwater abstraction from neighboring coastal aquifers. The main goal of this study is to apply hydrogeochemical techniques to analyze the fresh/saline water relationships at Coacoyul-San Miguelito aquifer and define prospective zones for groundwater supply. Study area is located 5 km to the East of the Ixtapa-Zihuatanejo Region. Specific objectives are: (1) define the hydrodynamic conceptual model, (2) determine the hydrogeochemical nature of groundwater, (3) investigate fresh water thickness and identify zones influenced by saline water, and (4) recommend sites for well location and pumping rates to avoid sea water intrusion.

METHODS AND RESULTS

Both the hydrodynamic and hydrochemical conceptual models were defined through several field activities including geological and geophysical surveying, well census up-dating, determination of hydraulic heads and land elevations, well boring, pumping tests, and groundwater sampling for chemical analyses. Geological surveying allowed the identification of metamorphic rocks (Xolapa Complex) that

outcrop as a 50-100 km wide belt extended along the Pacific Coast in Guerrero and Oaxaca States. Metamorphic rocks were affected by Tertiary (?) acid-to-intermediate igneous intrusions and the complete sequence was subsequently step-faulted forming a graben filled out by a sequence of sands and gravels that constitutes the Coacoyul-San Miguelito coastal aquifer.

Regarding well census, 58 active wells were identified most of them being small-yield dug wells mainly used for domestic supply and cattleship. One million and a half cubic meters of fresh groundwater are being abstracted yearly, from them 56% is conveyed to satisfy potable water demand, 37% is used for agricultural purposes, and the remaining part is for domestic and industrial uses. Ground water flow and hydraulic gradient (0.003) were determined through both hydraulic head and land elevation surveys during November 1999 and February 2000. No drawdown zones were identified even in areas of heavy well concentration. Water table evolution was -0.7 m with a maximum of -1.5 m at the western part of Coacoyul village, Guerrero State from November 1999 through February 2000. This negative evolution represents a volume of $1.18 \times 10^6 \text{ m}^3$ taken from storage corresponding to a three-month period in the study area. The aquifer geometry was defined through 30 electrical soundings (Schlumberger arrangement, where $AB/2 = 300 \text{ m}$) located in unexplored areas according to the seashore orientation and to certain geologic features.

Twenty water samples (12 dug wells, 3 wells, 2 exploratory wells, 1 from Coacoyul River, 1 from San Miguelito River, and 1 from a lagoon) were collected for bacteriological, physical and chemical analyses (*i.e.*: total coliforms, fecal coliforms, temperature, pH, Eh, specific conductance, dissolved O_2 , major ions, NO_3^- , Mn and Fe). Ionic imbalances were <5%, allowing the construction of Piper and Stiff diagrams and the identification of two extreme members: freshwater ($\text{HCO}_3\text{-Ca}$, total dissolved solids < 400 mg/l) and saline water (TDS > 10,000 mg/l). Four hydrochemical facies were found: (1) Na-Cl (saline member), it occurs along the shoreline; (2) Cl-Ca, it results from water mixing and ionic exchange from an original Cl-Na facies; (3) $\text{HCO}_3\text{-Ca}$ (freshwater member), it includes recent infiltrating water in contact with sediments derived from igneous and metamorphic rocks; (4) $\text{HCO}_3\text{-Cl-SO}_4$, it represents groundwater interacting with intermediate-composition igneous rocks. Water quality data showed that even of the lack of proper waterworks in populate zones and the use of some fertilizers in agricultural lands within the study area, there is no concern for groundwater contamination.

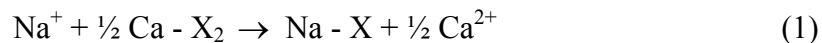
Geophysical, hydrogeological and geochemical information served to propose three sites for well boring to investigate water-quality changes related to the saline/freshwater interface and associated diffusion zone. Boring depths varied from 25 through 30 m reaching the fractured top of the metamorphic and igneous rocks. Therefore, the maximum thickness of the sedimentary sequence was 25 m. Additionally, exploratory activities allowed the identification of brackish groundwater at the Playa Larga-Las Pozas zone at the western part of the study area. Neuman (1972) pumping test analysis for unconfined aquifers and a two-zone layered aquifer numerical model (Rathod and Rushton, 1990, modified by Cardona and Hernandez, 1994) were used to determine hydraulic parameters of 5 pumping tests from previous studies and 5 new tests including two exploratory wells. Resulting hydraulic conductivity (K) values ranged from 1.5 to 280 m/day (Newman, 1972) and from 0.5 to 200 m/day (Rathod and Rushton, 1990). The short-lasting nature of the pumping tests did not allowed the determination of reliable values for specific yield by any analytical method.

DISCUSSION

The present study allowed the identification of an unconfined, heterogeneous and isotropic aquifer composed by two members:

(1) a sedimentary member, composed by sands and gravels of variable grain size, with a 25-m maximum thickness, and a mean $K = 10\text{-}30$ m/day, and (2) a fractured member associated to the upper part of an igneous and metamorphic sequence with a maximum thickness of 50 m and a mean $K = 0.5\text{-}1.5$ m/day. In some parts of study area, the thickness of the sedimentary member is almost negligible and the fractured member only composes the aquifer. The impervious igneous and metamorphic sequence represents the lower and lateral aquifer boundaries.

Hydrogeochemical data in the Piper diagram showed that water samples plotted within a line represent a conservative mixing of two end members (*i.e.*: $\text{HCO}_3\text{-Ca}$ facies and Na-Cl facies). However, evidences of non-conservative water mixing were found. According to Appelo and Postma (1996), ionic-exchange reactions occur when fresh groundwater displaces saline groundwater in coastal zones. The fresh water extreme member in the study area is dominated by Ca^{2+} and HCO_3^- ions; therefore, cation exchangers in the aquifer have mostly Ca^{2+} adsorbed on the surfaces of aquifer matrix. In seawater, Na^+ and Cl^- are the dominant ions, and sediment in contact with seawater mainly contains Na^+ adsorbed. If seawater intrudes into a coastal fresh-water aquifer the following exchange reaction takes place:



where X = soil exchanger.

Sodium is taken up by the exchanger, and is Ca^{2+} released. The resulting water quality changes from Cl-Na to Cl-Ca , a water facies type found in the study area.

Water quality analyses showed that there is no concern for groundwater contamination in study area. However, it is recommended to collect water samples during dry season, since stronger concentrations in terms of nitrates, iron and magnesium could be expected. Data analysis on spatial distribution of hydrochemical facies and water quality along with information on aquifer thickness and hydraulic conductivity, allowed the identification of sites for new drinking water wells in the study area. Site selection was also supported by a simulation of drawdown using the two-zone layered aquifer numerical model by Rathod and Rushton (1990). A maximum abstraction rate of 5 l/s and a minimum distance of 1300 m between two neighboring wells are recommended.

CONCLUSIONS

An unconfined, heterogeneous and isotropic aquifer was identified at the Coacoyul-San Miguelito area. A sand member (25-m maximum thickness and mean $K = 10\text{-}30$ m/day) and a fractured igneous/metamorphic member (50-m maximum thickness and mean $K = 0.5\text{-}1.5$ m/day) compose it. Water chemistry data showed the presence of four hydrochemical facies (Na-Cl , Cl-Ca , $\text{HCO}_3\text{-Ca}$ and $\text{HCO}_3\text{-Cl-SO}_4$). Na-Cl and $\text{HCO}_3\text{-Ca}$ end-member facies interact through both conservative and non-conservative (*i.e.*: ion exchange) mixing. Water quality analyses showed that there is no concern for groundwater contamination in study area. This study allowed the identification of sites for new drinking water wells.

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