



COOPERAÇÃO CANADÁ-BRASIL



Canadian International Development Agency (CIDA) - Agência Brasileira de Cooperação (ABC)
ABAS - Comunidade Solidária - CPRM - GSC



Projeto Água Subterrânea no Nordeste do Brasil
PROASNE-BRASIL
Northeastern Brazil Groundwater Project

ISOTOPE HYDROLOGY AND GEOCHEMISTRY IN NORTHEAST BRAZIL May-June 2001

Mission Report



by: Ramon Aravena
University of Waterloo

July 2001

Cover page photograph:

*Reverse osmosis unit used to desalinate groundwater
in northeast Brazil being exhibited outside the ABAS
auditorium in Fortaleza during the Hydrogeology Week, May 28 to June 2, 2001*

Mission Tasks and Objectives:

(1) To deliver a short course in Fortaleza, Ceará on *Theoretical Aspects of Applications of Isotopic Geochemistry to Groundwater Studies* and take part in other short course sessions;

(2) To present a lecture on the *Role of Isotope Geochemistry in the Study of Water Quality*, also in Fortaleza, as part of a workshop on the Salinity of Groundwater in Semi-Arid Regions;

(3) To take part in a field trip to the interior of the state of Ceará to develop collaborative research projects with PROASNE partners working in the region. These projects to focus on improving our understanding of high salinity levels in the groundwaters of northeastern Brazil. To provide expert advice during the field trip, as required;

(4) To present part of a workshop in Natal, Rio Grande do Norte, on the subject of “*metodologias de avaliação de recarga em regiões semi-áridas e análise de problemas de salinização (origem e mecanismos), com a apresentação de casos*”;

(5) Participate in a field trip to the interior of the state of Rio Grande do Norte, to the various sites where studies are being conducted on the hydrogeology of the Açu aquifer. Provide professional advice to PROASNE partners as required.

Mission Agenda

Dr. Yvon Maurice of the Geological Survey of Canada (GSC) and coordinator of the Canada-Brazil Cooperation Project, in consultation with Brazilian partners and Canadian participants in the mission, Drs. Ramon Aravena (University of Waterloo) and Nilson Guiguer (Waterloo Hydrogeologic Inc.), developed the agenda for this mission. The work was carried out in the northeastern Brazil states of Ceará and Rio do Grande do Norte. In Ceará, the main activities including short courses, workshops and meetings

were carried out in the state capital, Fortaleza, at the Amigo das Águas auditorium of ABAS, which is annexed to the CPRM offices in that city. The fieldwork was carried out in the Irauçuba area, some 250 km west of Fortaleza. In Rio do Grande do Norte, the workshops and meetings were held at the Federal University of Rio Grande do Norte (UFRN) in the city of Natal, the state capital. The fieldwork was done in the recharge areas of the Açu aquifer, specifically in the areas of Apodi, Caraúba and Upanema.

Main Activities, Ceará

The first activity carried out during the mission was to present a course on the Applications of Environmental Isotopes in Water Resources Studies. This was a two days course (28-29 May) that was taught by Dr. Aravena and Dr. Marlucia Santiago of the Federal University of Ceará (UFC) in Fortaleza. About 40 people attended, including representatives from CPRM, UFC, SOHIDRA, FUNASA, SEMACE, SRH, DNPM, DNOCS, UECE, CAGERH, CAGECE, and FUNCEME. The program and the list of participants are attached to this report. During the third day (May 30th) Dr. Aravena participated in a meeting at the Department of Physic, UFC, involving professors Dr. Marlucia Santiago, Dr. Horst Frischkorn and Dr. Porfírio Sales Neto. This is the main group that is working on groundwater salinity problems in the northeast of Brazil. During the meeting, the group reviewed the work accomplished and in progress, and discussed potential research activities that might be included in a future proposal to be submitted to the Canada-Brazil Cooperation Project. The discussion was centered on the main hypotheses that can be postulated to explain the groundwater salinity in the Northeast and the approach that might be used for testing these hypotheses. The research facilities at UFC were evaluated and the participation of students in the future study was discussed. Part of the meeting was also devoted to planning the field trip to the Irauçuba area, the Project's pilot area in Ceará.

The two-day field trip, June 1 and 2, included visits to the municipalities of Itapagé and Irauçuba, and to the community of Juá . The personnel that took part in this field trip were Dr. Aravena, Dr. Marlucia Santiago and CPRM geologists Oderson

Antonio de Souza Filho and Liano Silva Verissimo. Among other issues, the group discussed the geological and geochemical work that has been done and is currently in progress at CPRM within the study area. The visit was important as it permitted to evaluate the field infrastructure (mainly wells) that could play a critical role in a future project to investigate the origin of groundwater salinity in the Ceará pilot area. Based on available groundwater geochemical data, the distribution of wells and geological information, a preliminary sampling plan was developed for the salinity study. This will be included in a project proposal to be presented at a later date.

Main Activities, Rio do Grande do Norte

The activities in Natal began with a 2-day workshop on June 4 and 5 (see program attached). Presentations were by Canadian consultants Dr. Aravena and Dr. Nilson Guiguer, and UFRN professor Dr. José Geraldo de Melo and Mr. Marcelo Augusto de Queiroz of CAERN. About 25 people representing government institutions and universities participated in this workshop. A group consisting of Dr. Aravena, Dr. Guiguer, Dr. Yvon Maurice, Dr. José Geraldo de Melo, Dr. Walter Medeiros(UFRN), Mr. Marcelo Augusto de Queiroz, and graduate students Ms. Paula Stein and Mr. Edeweis Junior left for the field in the afternoon of June 5th. The days of June 6 and 7 were spent examining wells and other groundwater related infrastructures in the Apodi, Caraúbas and Upanema areas within the Açu aquifer. The available geological and geochemical information for the different areas were examined and discussed as part of the planning process for a new study to be proposed in collaboration with Dr. Guiguer of WHI to investigate various aspects of the hydrology of the Açu aquifer. There is a sufficient number of wells located in the recharge areas of the aquifer, and along the groundwater flow system, to carry out the study. A large numbers of these wells are part of CAERN's network while others are privately owned. There is also a significant amounts of groundwater conductivity data available for the study area. The project to be proposed will focus mainly on modeling the Açu aquifer but should include a geochemical component to support this work. The new project will be lead by Dr. Nilson Guiguer of WHI.

On June 8th, two meetings were held in Natal. The first, in the morning, was at UFRN with Dr. Aravena, Dr. Guiguer, Dr. Yvon Maurice, Dr José Geraldo de Melo (UFRN), Dr. Walter Medeiros(UFRN and RN state coordinator for PROASNE) and Mr. Marcelo Augusto de Queiroz (CAERN). The discussions revolved around the outcome of the field trip and details of how the new modeling study of the Açu aquifer should be implemented. The second meeting was held at the Water Resources Secretariat for Rio Grande do Norte (SRH). The people involved in that meeting were Dr. Aravena, Dr. Guiguer, Dr José Geraldo de Melo (UFRN), Dr. Walter Medeiros(UFRN), Mr. Marcelo Augusto de Queiroz (CAERN), Dr. Vera Lucia (SRH), Dr. Lucio Dantas, Director of CAERN and Dr. Paulo Varella, Head of the Water Resources Secretariat. During this meeting, the main activities that were carried out as part of the Canada-Brazil Cooperation Project during the week of June 4 to 8 were discussed. Dr. Guiguer presented the outcome of the field activities and an outline of a proposal to model the Açu aquifer. The directors of CAERN and of the Water Resources Secretariat were very pleased with the progress report and the proposed study, and they offered all the support required to carry out the field work and other activities in Natal. CAERN will facilitate the participation of Mr. Marcelo Augusto de Queiroz in the project.

Conclusions and Recommendations

In general, there is adequate infrastructure and geological and geochemical knowledge base to perform the next phases of the studies at both the Ceará and Rio Grande do Norte pilot areas. Regarding human resources, the personnel of CPRM and CAERN has the necessary background to carry out geological and hydrogeological work, but they will require training in groundwater modeling and geochemistry. The university personnel at UFC have the necessary knowledge base and equipment to carry out isotope and geochemical studies that will be required for the salinity project. One aspect that will need improvement is the quality control of the chemical analyses. From discussions held with professors at UFC and UFRN, and with CPRM and CAERN personnel, it was clear that no quality control protocols currently exist to monitor the quality of the chemical data obtained in their respective laboratories.

Concerning the proposals for new projects in Ceará and Rio do Grande do Norte (Açu aquifer), the following can be stated at this time:

- (1) A preliminary sampling program was outlined for the salinity project.
- (2) An overall strategy for the project was discussed and it was agreed that Dr. MarluCIA Santiago will prepare a draft of a proposal which she will send to Dr. Aravena for revisions and suggestions. When all the project participants have agreed with the proposal, it will be submitted to PROASNE via Dr. Yvon Maurice for comments and eventual approval. This project will include the participation of graduate students from the UFC who will work under the supervision of Dr. MarluCIA Santiago.
- (3) It was agreed that the C-14 analyses of groundwater will be done at UFC while the stable isotope will be analyzed at the University of Waterloo. Due to the absence of quality control protocols for chemical analysis at UFC, Dr. Aravena proposed that the trace element analyses also be done in Canada.
- (4) The sampling strategy will include sampling during the wet and the dry seasons. It was agreed that the first sampling should be done in November 2001 during the dry season. Dr. Aravena will be involved in the first sampling event.
- (5) It was recommended that a plan to monitor changes in the water table should be established. There are two wells in the community of Juá that are not being used to supply water to the population. These wells can be monitored monthly, and this work could be done in collaboration with the local school. It was also recommended to obtain salinity profiles in wells that are not being pumped. All the wells are tubular wells (borehole types), and therefore have no casing or discrete screens. The salinity profiles may provide evidences about the depth of the main fractures that are contributing the saline groundwater.

This study will benefit also from the collaboration of Dr. Thomas Bullen of the US Geological Survey. During a recent conference in the USA, Dr. Aravena discussed the salinity project with Dr. Bullen and he agreed to provide free of charge, analysis of boron and strontium isotopes that may be important tracers to determine the origin of the salinity in northeastern Brazil groundwaters.

The approach that will be used to study the origin of the salinity is based on the main hypotheses that can be postulated to explain this salinity. First, the salinity could be related to water-rock interaction associated to a long residence time. This could mean that salinity is related to the age of the groundwater. Second, it could be related to evaporation in the recharge areas. Some depressions in the study area are filled with alluvial sediments. Therefore, it is possible that salts accumulate in these deposits due to evaporation and then are transferred to the aquifers during the wet season. The other possibility is that the salt is associated with saline fluids trapped in the rock-forming minerals. The main tools to be used in the salinity study will be geochemical (chemical constituents) and isotope tracers (^{18}O , ^2H , ^{14}C , B, Sr). The geochemistry will serve to evaluate the main geochemical reactions and processes (e.g. evaporation) that could explain the chemistry of the groundwater. Besides the main cations and anions, trace elements such boron and strontium will be also be analyzed. Stable isotopes (^{18}O and ^2H) will be use to evaluate the role of evaporation in groundwater salinity and ^{14}C will provide information about the residence time of the groundwater. Boron and strontium isotopes will provide information to evaluate the origin of the salinity and water-rock interaction.

The sampling strategy will include collecting water from springs in the higher parts of the basins that drain the main rock types, with groundwater derived from the crystalline rocks and the alluvial deposits. A preliminary network of wells has already been selected for the study and the springs will be chosen after CPRM has completed their survey of springs in the study area. A pilot study that has been carried out in the Juá area to evaluate the interaction between reservoir water and groundwater will be incorporated as part of the salinity study.

Concerning the Açu aquifer, it was agreed with CAERN and UFRN personnel to incorporate geochemical and isotope tracers to support the development of a groundwater model for the aquifer. Dr. Aravena will also collaborate in a general geochemical study that is being carried out by Dr. José Geraldo de Melo (UFRN) with the support of CAERN in the outcropping areas of the Açu aquifer. The geochemical (chemical constituents) and isotope (^{18}O , ^2H , ^{14}C) tools will help to constrain the origin and residence time of the groundwater in the aquifer. They will also provide information about the groundwater flow system. The domains that will be considered for the groundwater model (Dr. Guiguer's project) include the areas of Apodi, Upanema, Caraúbas, and Mossoró. Preliminary isotope data from the area of Mossoró indicate the groundwater was recharged under much wetter conditions than at present. Therefore the groundwater in parts of the Açu aquifer could be very old. The sampling approach will include collecting groundwater from recharge areas and along the groundwater flow system in the Açu aquifer, including from deep wells in the City of Mossoró.