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USE OF ENVIRONMENTAL ISOTOPES TO ASSESS THE SUSTAINABILITY OF INTENSIVELY EXPLOITED AQUIFER SYSTEMS (2012-2015). FIRST RESULTS OF THE COORDINATED RESEARCH PROJECT CRP F33019.

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1. INTRODUCTION

Intensive exploitation of groundwater over longer period has led, in many important aquifers, to marked lowering of water tables, increasing exploitation costs, and often, to a progressive deterioration of water quality. Concentrated pumping may also alter flow patterns permanently with the risk of migration of pollutants into aquifers from the surrounding aquifers or surface water bodies due to lack of physical protection to prevent them. Isotope hydrology tools have proven to be very useful in assessing groundwater hydrology, addressing aspects related to recharge processes, delineation of flow patterns, water quality issues and interactions with other water bodies; this unique information can be further used to evaluate long term aquifer sustainability. The objective of the Coordinated Research Project F33019 is to develop and review approaches and methodologies, mostly based on the combined use of conventional hydrogeological techniques and environmental isotopes, to assess the response of groundwater systems to intensive exploitation and groundwater availability. Access to new dating tools and approaches for groundwater dating covering different time scales offers the possibility to evaluate changes in groundwater dynamics and flow patterns, providing key data to predict the evolution of aquifers and their sustainability as major sources of water. The CRP aims to assess the performance of these new tools and approaches and the possible adoption of these methods by water management experts.

2. METHODOLOGY

Five geographical areas presenting a large variety of aquifer systems (large/small, confined/unconfined, multilayered, alluvial, coastal, porous/fissured/karstic) and different climatic settings (temperate, semi-arid, arid, tropical) have been investigated during this CRP. The collaborating member states are: Argentina (Mar del Plata aquifer), Mexico (San Luis Potosi aquifer), France (Valréas aquifer), Poland (Bogucice and Czeszochowa aquifers), Spain (Loma de Úbeda aquifer), Ghana (Upper Ghana aquifer), Morocco (Souss Massa aquifer), Tunisia (Sfax aquifer), China (North China plain aquifer), India (North-Eastern Punjab aquifers), Pakistan (Lahore aquifer), Vietnam (Hanoi aquifer) and New Zealand. Each member states have evaluated the (over)intensive exploitation of groundwater with a set of measured parameters including at least one of the following: general parameters (water level, T, EC, Eh, DO, pH), environmental isotopes (^2H , ^{18}O , ^{13}C -DIC, ^{34}S - SO_4 and ^{18}O - SO_4 , ^{15}N - NO_3 and ^{18}O - NO_3 , $^{87/86}\text{Sr}$, $^{11/10}\text{B}$), radioactive isotopes (^{14}C -DIC, ^3H , ^{222}Rn), noble gases, anthropogenic gases (SF_6 , CFCs, SF_5CF_3 , H-1301), major ions and trace elements, NH_4 , nitrate, nutrients, Methane, DOC.

3. RESULTS

Most of the participating member states evaluated the past and present data/trends of conventional hydrological, chemical, isotopic and groundwater age/data and observed the site specific changes as drop in water table, in stable isotopic contents' and groundwater age tracers' characteristics (Figure 1).

The drop in groundwater table was observed in many cases from very high to high (5 m/year-Spain, 3 m/yr-China, 2.5 m/yr- Morocco, 2m/yr- Mexico, 1.5 m/yr-Pakistan, 1 m/yr- India) and comparatively less in case s (0.15/m/yr) of Argentina), while few others have to still evaluate their data. In case of Poland, New Zealand and France, being the artesian aquifers, the artesian conditions were notices to be diminished. Most of the participating countries have observed the changes in chemical characteristics of groundwater in terms of changes in major ions- (France, Mexico, Argentina, India, Pakistan and Tunisia), anthropogenic

pollutant (nitrate in most cases) and geogenic origins (fluoride & arsenic in Mexico) or trace elements (India, Pakistan, Spain and Vietnam) as consequences of intensive exploitation of aquifer systems. At last, the changes in stable isotopic characteristics of groundwater were observed in many cases (China, India, Morocco, Tunisia, Pakistan, Spain, Argentina, etc.) while in few other cases no appreciable change in stable isotopic composition has been noticed, particularly in case of artesian aquifers (France, Poland and New Zealand). In few cases, this effect is yet to be evaluated.

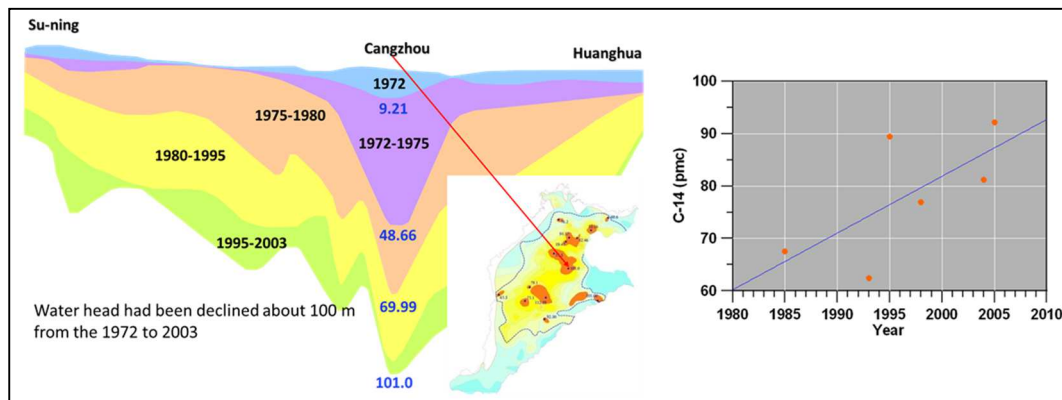


Figure 1: Dramatic changes of depression cones in Cangzhou, China. Increasing ^{14}C activity with groundwater exploitation indicates a short turnover time of the local groundwater system after the intensive groundwater abstraction

Stable isotopes (^{18}O , ^2H) and age tracers (^3H , ^{14}C) can indicate changes in the flow dynamics and can be considered as early warning tools. Tritium is and will remain a first-choice tracer for identifying modern recharge, especially with the bomb-tritium signal finally fading off. However, it is recommended, that ^3H should be accompanied whenever possible, by other transient tracers (SF_6 , $^3\text{H}/^3\text{He}$, CFCs, others). It is very important to accumulate time series of tritium data for intensively exploited aquifer systems for quantitative interpretation in terms of water/tracer ages, calibration of 3D flow and transport models. The group strongly recommends a full use of carbon isotope data (^{13}C , ^{14}C content of TDIC/DOC pool) in conjunction with chemistry and available geochemical codes (Phreeqc, Netpath). This is the only, widely available tracer pair to assess timescales of groundwater flow in the order of 10^3 - 10^4 years. Whenever feasible and justified, other available tracers should be employed (^4He , ^{36}Cl , ^{81}Kr , others).

Isotopes and chemical elements mapping in vertical and horizontal scales is a fundamental tool to display spatial information and to compare time evolution in relation with the intense exploitation of aquifer systems. Today's technology (GIS, laser spectrometry etc.) can provide large number of data at low cost. It is also useful to elaborate conceptual and numerical models and for calibration purposes, to define a baseline and its evolution in time and space, to represent the structure, units and functioning of an aquifer system and determine the origins of recharge. Tracer-calibrated 3D flow and transport model should be viewed as ultimate management tool for intensively exploited aquifer systems. Environmental tracer data proved to be excellent calibration tool for 3D flow and transport models.