Hydrogeochemical characterization of groundwater in Soc Trang Province, southern Vietnam

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ABSTRACT

Environmental isotope techniques were applied to study the hydrogeochemical characteristics of groundwater in Soc Trang Province, southern Vietnam in frame of the project Improvement of Groundwater Protection in Vietnam (IGPVN). Water samples were collected from both monitoring wells, private tube wells and production wells (at the Water Treatment Plant). Surface water samples were collected from a number of river, pond or channel. Major ions and stable isotope data of both groundwater and surface water samples in dry season showed no hydraulic connection between surface water and groundwater in Soc Trang Province. Some aquifers may be located in previously occurring salty areas. Salt water intrusion during the dry season occurs to some extent on Hau River, but did not affect the target aquifer. ^{3}H analytical results differentiated two categories of groundwater: recharged with submodern water (prior to 1953) that includes qh, qp, qp_{2-3} and n_2^2 aquifers and mixture of pre- and post- 1953 water that includes qh and qp aquifers. The mean transit velocity in the qp_{2-3} aquifer located in Soc Trang Province was in a range between 2.3 – 7.8 m/yr. The pump rate at the two WTPs (My Xuyen and Long Phu districts) were exceeding the maximum sustainable yield of the aquifer and contamination from surface water may eventually occur.

INTRODUCTION

Lower Pleistocene (qp_1) and middle-upper Pleistocene (qp_{2-3}) aquifers are dominantly used for various purposes among seven porous aquifers in Soc Trang Province which locates in a coastal area in the Mekong Delta of southern Vietnam. The fresh water-bearing aquifer qp_{2-3} was reported to be widely saline. The qp_1 aquifer is of high water bearing capacity and not fully understood. Since 1985, groundwater resource in Soc Trang Province was investigated. Recently, in 2010, aquifer storativity as well as groundwater hydrochemical characteristics were fully reported in frame of the planning for groundwater exploitation, utilization and protection in Soc Trang Province. However, the connection between groundwater and surface water, the origin of groundwater and groundwater flow processes were not clearly studied. Moreover, application of environmental isotope hydrology in hydrogeochemical study to manage and protect groundwater system in Soc Trang Province in particular and in the south of Vietnam in general was not fully concerned.

MATERIALS AND METHODS

The project Improvement of Groundwater Protection in Vietnam (IGPVN) constructed a groundwater monitoring network in Soc Trang Province, including five monitoring wells located in different districts, up to 150 m deep and provided access to the qp aquifer. In

2013, the IGPVN conducted two field surveys in dry season (4/2013) and rainy season (11/2013) to collect water samples from all the five monitoring wells and three other private tube wells and four surface water samples for chemical analysis as well as stable isotope (^{2}H and ^{18}O) determination. Another sampling for ^{14}C, stable isotopes and ^{3}H determination were conducted in June, 2013, during which, groundwater samples were collected from monitoring wells (5 monitoring wells of the National Monitoring Network and 1 monitoring well of IGPVN project), production wells (at the water treatment plans in 5 districts in Soc Trang Province) and surface water samples were collected from the pond or channel nearby. Chemical analysis and stable isotope determination were done at the Water Laboratory in the Federal Institute for Geosciences and Natural Resources (BGR). ^{3}H and ^{14}C determination were conducted by the Institute for Nuclear Science and Technology, Vietnam. Field data and laboratory analytical data were processed using relevant software (AquaChem, SigmaPlot, ArcGIS).

RESULTS AND DISCUSSION

Major ions

Field survey data in dry season 2013 showed low Na/Cl ratio (0.55) together with high Cl content (4910 mg/L) in river water sample collected far from the coastal line that may indicate salt water intrusion. However, this is not the case for other river water samples as well as groundwater samples. Most of the groundwater samples displayed high Na/Cl ratios and low Cl contents indicating desalination process in which freshwater is dominant, or both low Na/Cl ratios and low Cl contents indicating mixed processes. Analytical results for surface water sample collected in rainy season did not show any high Cl content, maximum value was only 35.7 mg/L. No salt water intrusion process was inferred from rainy season data.

Groundwater samples collected from the target aquifer (qp_{2-3}) are mainly of Na-HCO_3-SO_4, Na-Mg-Ca-HCO_3 and Na-Mg-HCO_3-SO_4 types in which, SO_4 was believed to originate from pyrite oxidation process or gypsum dissolution. Heavy metals and trace elements were not detected or were observed at low concentrations.

There was no difference in major ion contents of groundwater samples (both private tube wells and IGPVN monitoring wells) between dry season and rainy season. However, among four surface water sampling locations investigated, three locations (SW1, SW2 and SW3) showed significant variations in major ion contents from dry season to rainy season. Accordingly, those water samples shifted from Na-Cl type in dry season to mixed water type or bicarbonate Ca-Na-Mg type in rainy season.

Stable isotopes

The stable isotopic compositions $\delta^{2}H$ and $\delta^{18}O$ (in permil (‰) difference in $^{2}H/^{1}H$ and $^{18}O/^{16}O$ ratios between the samples and the Vienna Standard Mean Ocean Water (VSMOW)) were determined for water samples from Soc Trang Province.

The $\delta^{2}H$ and $\delta^{18}O$ values of the groundwater ranged from -47.7 to -34.7 ‰ and from -6.82 to -3.77 ‰, respectively; and those of the surface water ranged from -54.5 to -14.5 ‰ and from -7.11 to -0.44 ‰, respectively.

Stable isotope data are not available for local meteoric water in Soc Trang Province, therefore, IAEA/WMO Global Network for Isotopes in Precipitation (GNIP) data set for Bangkok was adapted.

Basing on the location of the water sample points on the scatter plot, some possible interpretations are as follows:

SW1 was shifted far towards the direction of less negative $\delta^{18}O$ values, displaying a strong enrichment in ^{18}O that may indicate a strong evaporation effect and an intrusion of seawater. SW2 was enriched in ^{18}O because of the mixing between river water and seawater at the estuary. SW3 and SW4 were depleted in stable isotope contents comparing to SW2 that may indicate a dilution effect. However, samples were collected at the end of the dry season and it was complicated to explain this dilution effect, if existing.

ST1, ST11 and GW1 located close to the GMWL might be recharged from surface water bodies during the rainy season. ST7 and GW3 showed little enrichment effects and therefore, their recharge from surface water, if existing, might occur in the beginning of the dry season when evaporation process starts to occur. However, the differences between SW1 and ST7 and between SW4 and GW3 on stable isotope contents despite their nearby locations may indicate no hydraulic connection between those river waters and the corresponding groundwaters. Similar results can be inferred from the differences between SW2 and ST4 as well as between SW3 and ST3.

The enrichment of ^{18}O in the ST4 and GW2 samples at higher degree than in the SW2 sample suggest that ST4 and GW2 are located in previously occurring salty area. Salt water intrusion enhanced by tributaries during dry season may cause insignificant effect in stable isotope content of the target aquifer.

Tritium

The T concentrations ranged from below the detection limit of 0.46 TU to 1.05 TU and from 1.14 TU to 1.53 TU for groundwater and surface water, respectively. The 7 samples with T contents below the detection limit were most likely recharged with water prior to 1953, or older than 70 years. The 4 samples with T contents from 0.6 – 1.05 TU are a mixture of pre- and post-1953 water. The T contents of surface water samples were quite low indicating exchange process of surface water with groundwater which has lower T contents.

^{14}C dating

Carbon-14 ages ranged from 10,700 years to 22,500 years for groundwater from qp aquifer, and from 15,300 years to over 40,000 years for groundwater from n aquifer. The age of groundwater sample from the National monitoring well Q59804T (n^2_2) was so young possibly because the well was not perfectly sealed off so that younger water from upper aquifers could leak down into the well.

Among the seven groundwater samples from $qp_{2\text{-}3}$ aquifer, the two samples collected from the WTPs (My Xuyen and Long Phu) showed younger ages than the others, indicating that younger (ground)water from the upper layers may be drawn down as a result of over exploitation at those WTPs and that contamination from surface water may eventually occur. This may imply that the pump rate at those sites were exceeding the maximum sustainable

yield of the aquifer. However, this should be confirmed by annually monitoring data for ^{14}C to clarify if there is a progressively declining ^{14}C dates in those wells. Other 3 production wells did not show abnormally younger ages at least indicating that the aquifers are completely confined, and there was no hydrogeological window and therefore, no way for the overlying younger water to leak down. Still no information about pump rate can be inferred from these dating results.

Among three national monitoring wells of n aquifer, the well Q59804T (n^2_2) showed much younger age (15,300 years) than the other 2 wells, probably because the well was not perfectly sealed off and younger water from overlying aquifers could leak down into the well, or the casing could be cracked. It might also be possible that this well is part of different aquifer.

Static water level monitoring data from a number of the National monitoring wells in Soc Trang Province provided by DWRPIS was selected to input to ArcGIS and draw a contour map. Basing on the ^{14}C dating data of the qp_{2-3} aquifer and the apparent groundwater flow direction, three wells (LP, VC and MX) were used to determine the aquifer transit velocity. The mean transit velocity in the qp_{2-3} aquifer located in Soc Trang Province was in a range between 2.3 – 7.8 m/yr. Those values were obtained by considering the distances between LP – VC and MX – VC wells and the differences between the ^{14}C ages of the water samples there.

CONCLUSIONS

Major ions and stable isotope data of both groundwater and surface water samples in dry season showed no hydraulic connection between the rivers and the corresponding aquifer in Soc Trang Province. Any recharge from surface water to aquifers in Soc Trang should occur outside the vicinity of Soc Trang Province. Some groundwater sampling points are located in previously occurring salty area. Salt water intrusion during the dry season occurs to some extent on Hau River, but did not affect the target aquifer.

^3H analytical results differentiated two categories of groundwater: recharged with submodern water (prior to 1953) that includes qh, qp, qp_{2-3} and n_2^2 aquifers and mixture of pre- and post-1953 water that includes qh and qp aquifers.

The pump rate at the two WTPs (My Xuyen and Long Phu districts) were exceeding the maximum sustainable yield of the aquifer and contamination from surface water may eventually occur. It is necessary to control the pump rate at these WTPs to prevent any possible contamination.