HYDROGEOCHEMICAL FACIES OF GROUNDWATER IN THE TWO MAIN AQUIFERS DURING DRY AND RAINY SEASONS IN HANOI, VIETNAM

Tokyo Metropolitan University ○Thuy Thanh NGUYEN
Tokyo Metropolitan University Akira KAWAMURA
Tokyo Metropolitan University Naoko NAKAGAWA
Tokyo Metropolitan University Hideo AMAGUCHI

1. INTRODUCTION

In Hanoi, the capital of Vietnam, nearly the entire population depends on groundwater for daily water consumption. Sustainable management of groundwater is thus necessary to secure its future availability and ecological value. Hydrogeochemical facies, an important diagnostic chemical aspect of groundwater solutions occurring in hydrologic systems, provides information on the distinct zones of cations and anions along different layers of aquifers (Christopher and Robert 2005). Groundwater interacts with surface hydrologic systems, such as rivers, lakes, and oceans, and is indirectly influenced by seasonal changes during recharge and discharge. Thus, the change in seasons can potentially affect the hydrogeochemical properties of groundwater, especially in areas that have two distinct dry and rainy seasons, like Vietnam. Investigation of seasonal changes in the hydrogeochemical properties may reflect the groundwater hydrodynamics and circulation, which may help improve the data collection programs for groundwater assessment and enable better use of groundwater supplies. In addition, in Hanoi, groundwater from the Holocene unconfined aquifer (HUA) and Pleistocene confined aquifer (PCA) is the major source of water supply. High groundwater abstraction from PCA causes vertical percolation of water from HUA, leading to changes in groundwater chemistry. Therefore, the investigation of the different hydrogeochemical characteristics between the two aquifers, HUA and PCA, is critical for effective water management and water use planning.

In Hanoi, groundwater quality data of the unconfined and confined aquifers were collected in 2011 during dry and rainy seasons. The Piper diagram was used to investigate the hydrogeochemical facies. This study will provide valuable insights in understanding the changes during the dry and rainy seasons, as well as the differences between two aquifers in the groundwater hydrogeochemical properties in Hanoi.

2. STUDY AREA

Hanoi is the capital of Vietnam with a total area of about 3.344 km^2 in the northern part of Vietnam (Fig.1). The population was about 6.5 million in 2009, occupying 7.5% of the Vietnam's population. The Hanoi belongs to the tropical monsoonal region with two distinctive seasons. The rainy season is from May to October and the dry season lasts from November till April. The annual rainfall is about 1,600 mm of which rainfall in the rainy season occupies about 75%. The river network is quite dense with the density of about 0.7 km/km^2. There are also more than 100 lakes with a total surface area of more than 21.8 km^2. (Bui et al. 2012).

3. DATA USED

Groundwater samples were collected from the two major aquifers (HUA and PCA) in Hanoi using 13 conjunctive observation wells for HUA and PCA (Fig. 1). The samples were collected in February (dry season) and August (rainy season) of 2011 and were analyzed according to ISO standard test methods (National technical regulation on underground water quality, 2008) for the following physico-chemical parameters: major cations (Ca^{2+}, Mg^{2+}, Na^+, K^+), major anions (HCO_3^-, Cl^- and SO_4^{2-}) and pH. The water analyses were conducted in the laboratories of the Ministry of Natural Resources and Environment.

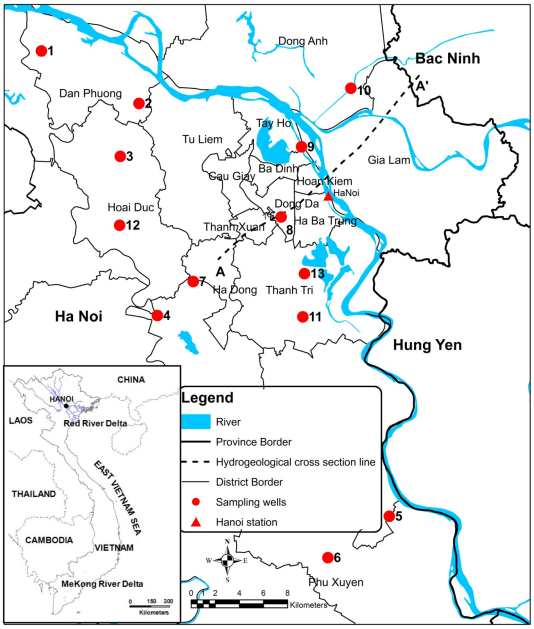

Fig.1 Study area and distribution of sampling points.

4. RESULTS AND DISCUSSION

Fig.2 shows the Piper diagram plot for HUA. The number symbols in this figure correspond to the locations of the observation wells in Fig. 1. The circles and non-circular symbols indicate the dry and rainy seasons, respectively. As indicated in the left ternary diagram of Fig. 2, the water samples identified as the [Ca^{2+}], [Na^+], and [Mg^{2+}] types are 19, 4 and 3, respectively. The right ternary diagram shows all water samples to be of the [HCO_3^-] type. Thus, HUA is mostly of the [Ca^{2+}-HCO_3^-] type (calcium ion-bicarbonate ion type). The Piper diagram for PCA was also created as shown in Fig. 3. From the left ternary diagram, the numbers of the [Ca^{2+}], [Na^+], and [Mg^{2+}] types are 19, 4 and 3, respectively. The right ternary diagram indicates that 24 out of the 26 samples are dominated by the [HCO_3^-] type, while the remaining two samples (both in well P6) are of the [Cl^-] type. Thus, like HUA, the groundwater in PCA is primarily of the [Ca^{2+}-HCO_3^-] type.

Changes in the hydrogeochemical facies during the dry and rainy seasons are observed in both HUA and PCA. For instance, in well H13 of HUA, the water type during the dry

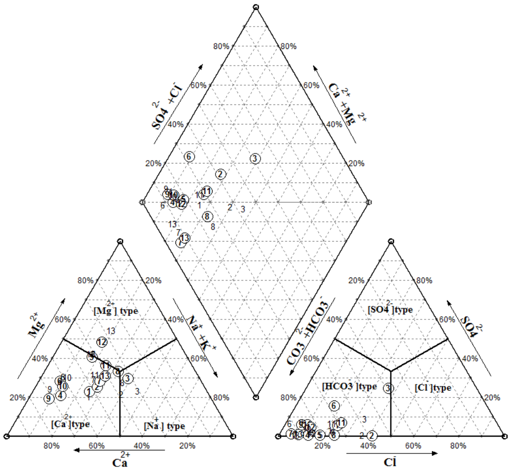

Fig.2 Piper diagram for HUA groundwater in Hanoi

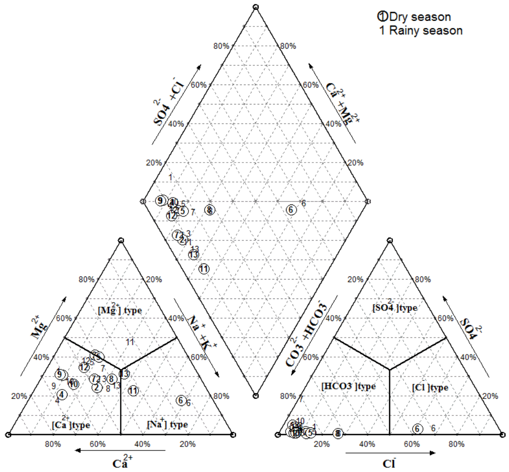

Fig.3 Piper diagram for PCA groundwater in Hanoi

season was [Ca^{2+}-HCO_3^-], but became [Mg^{2+}-HCO_3^-] during the rainy season. To have a better view of these changes, the hydrogeochemical facies of all observation wells in Figs. 2 and 3 are summarized in Table 1. In HUA, the hydrogeochemical facies of 5 out of the 13 observation wells exhibited seasonal changes, particularly of the cation type. H5 and H13 changed from the [Ca^{2+}] to [Mg^{2+}] type and H12 changed from the [Mg^{2+}] to [Ca^{2+}] type. H2 and H8 changed from the [Ca^{2+}] to [Na^+] type. This may be due to recharge from surface water such as rainfall, lake, or river. Regarding PCA, 4 out of the 13 observation wells showed changes in the cation type during the dry and rainy seasons. P3 and P5 changed from the [Mg^{2+}] to [Ca^{2+}] type, P11 changed from the [Na^+] to [Mg^{2+}] type, and P13 changed from the [Na^+] to [Ca^{2+}] type. This implies that water infiltration from HUA may affect the concentrations of chemical constituents of the PCA groundwater during the rainy season through hydrogeological windows, as mentioned above.

The differences in the hydrogeochemical facies between the two aquifers are also observed in Table 1. For instance, the water in H3 of HUA was of [Na^+-HCO_3^-] type during the dry

Table 1. Water types of groundwater samples in HUA and PCA.

Wells	HUA		PCA	
	Dry season	Rainy season	Dry season	Rainy season
1	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}- HCO_3^-]
2	[Ca^{2+}-HCO_3^-]	[Na^+-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
3	[Na^+-HCO_3^-]	[Na^+-HCO_3^-]	[Mg^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
4	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
5	[Ca^{2+}-HCO_3^-]	[Mg^{2+}-HCO_3^-]	[Mg^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
6	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Na^+-Cl^-]	[Na^+-Cl^-]
7	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
8	[Ca^{2+}-HCO_3^-]	[Na^+-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
9	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
10	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
11	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Na^+-HCO_3^-]	[Mg^{2+}-HCO_3^-]
12	[Mg^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]	[Ca^{2+}-HCO_3^-]
13	[Ca^{2+}-HCO_3^-]	[Mg^{2+}-HCO_3^-]	[Na^+-HCO_3^-]	[Ca^{2+}-HCO_3^-]

season, but concurrently of the [Mg^{2+}-HCO_3^-] type in P3 of PCA. Interestingly, during the rainy season, the water in H2 of HUA was of the [Na^+-HCO_3^-] type, but of the [Ca^{2+}-HCO_3^-] type in P2 of PCA. In total, 6 out of the 13 observation wells during the dry season and 7 out of the 13 during the rainy season exhibited differences in the water type between the two aquifers. These differences are possibly influenced by the materials in the two aquifers, as well as interaction with surface water and between the two aquifers, which affect the groundwater chemical characteristics and flow paths.

5. CONCLUSION

The Piper diagrams for HUA and PCA show that the groundwater in both aquifers is primarily of the [Ca^{2+}-HCO_3^-] type. A change in the hydrogeochemical facies was detected from the dry to the rainy season in at least 30% of the sampling wells in both aquifers. The change particularly occurs in the cation type (i.e., [Ca^{2+}] to [Mg^{2+}] or [Na^+], [Mg^{2+}] to [Ca^{2+}], [Na^+] to [Ca^{2+}] or [Mg^{2+}]), whereas the anion type remains unchanged. Differences in the hydrogeochemical facies between HUA and PCA were also observed in the majority of the observation wells (6 out of the 13 observation wells during the dry season and 7 out of 13 during the rainy season). The findings of this study provide valuable information regarding the groundwater hydrogeochemical properties and hydrodynamics in Hanoi, Vietnam.

6. REFERENCES

Bui, D.D., Kawamura, A., Tong, T.N., Amaguchi, H., Nakagawa, N.,: Aquifer system characterization for potential groundwater resources in Hanoi, Vietnam, Hydrological Processes, Vol 26, No. 6, 932-946, 2012.

Chirstopher, J.D.&Robert, R.R: Definition of hydrochemical facies in the New Zealand National groundwater monitoring programme, Journal of Hydrology, 44(2), 105-130, 2005.

National technical regulation on underground water quality, 2008.

Piper, A.M: A graphic procedure in the geochemical interpretation of water analyses. Transactions American Geophysical Union, 25, 914-928, 1944.

Keyword: Hydrogeochemistry, Piper diagram, dry and rainy seasons. Holocene unconfined and Pleistocene confined aquifers, Hanoi.