Chemical characteristics of well water in Xaythani district

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Abstract

In order to obtain basic data for discussion on the possible effects of developments of rural villages on groundwater quality, three types of well waters collected from 28 rural villages in Xaythani district, Lao PDR, were analyzed. The deep well water was characterized by neutral pH with high concentration of chemical constituents. We also found that the wall material of well, concrete or soil, affects the water quality in shallow well. The specific well water was acidic with high concentration of nitrate, which was observed in several villages. The resolution of the sources of nitrate in well water should be necessary.

Introduction

Lao People's Democratic Republic is one of advantaged countries in natural environment such as forest ecosystem among south-east Asian countries. However, the development of rural area during the last decade has been remarkable especially around urban area like Vientiane city. Accompanied with the recent development, natural forests have been changing to rice paddy field gradually.

The change of land-use from forest to rice field affects hydrological process. Since water infiltration and evaporation depend on vegetation state, that is, how is the condition of land surface cover, it is supposed that quantity and quality of groundwater should be influenced by land-use change. In addition, the development in rural area, which means the change in life style of villagers, may cause an increase in discharge of wastewater containing various nutrient elements. This also affects not only the quality of surface water such as river water but also that of groundwater.

In Laos, there is no water supply system in most of rural villages. Villagers use well water for various usages, such as washing, bathing, cooking and sometimes drinking. Therefore, the change in quality of well water should be serious issue for life of villagers.

In order to discuss the effect of development of rural villages on water quality, it is necessary to outline the chemical characteristics of well water. In this paper, we focused on well waters in Xaythani district, which spreads from the vicinity of Vientiane city to mountain base including Num Gum River in the center of district. We collected well waters in rainy season and analyzed chemically, and then summarized their characteristics.

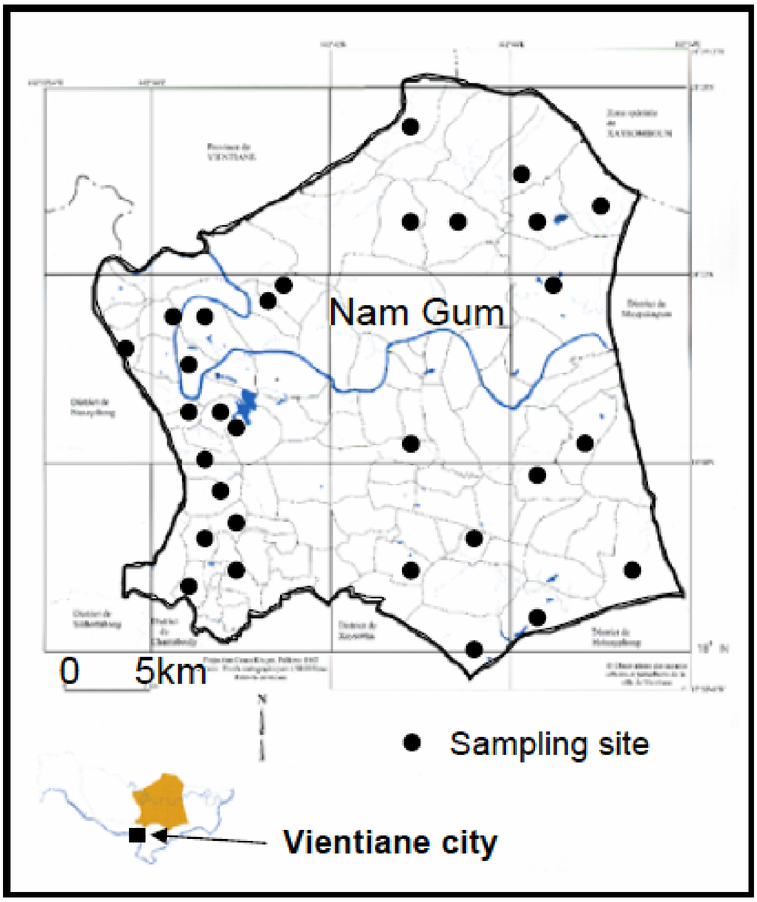

Fig.1 Sampling sites in Xaythani district
from Atlas Infographique de Vientiane

Samples and chemical analysis

Well water samples were collected from 28 villages in Xaythani district on September of 2004 and 2005. The sites were shown in Fig.1. Electric conductivity（EC）and pH of well water were measured in situ as soon as possible using EC/pH meter(TOA WM-22EP). All samples were brought back to our laboratory in Japan and stored in a refrigerator until chemical analysis. Cations and anions in samples were quantified by ion chromatograph (Shimadzu PIA-1000) after filtration with a 0.45 μm membrane filter.

The Kruskal-Wallis test and multiple comparisons with the Scheffe criterion were performed for evaluation of data.

Results and discussion

Wells were classified into three types. Deep well is drilled-type with a tube having 20 ~ 60 m depth, designating as DW. Shallow well is a hole dug to around 10 m depth at most. One type of shallow well has a concrete wall for protecting from breakdown of soil wall, designating as SCW. Another type of shallow well has a soil wall, designating as SSW .

Table 1. Comparison of pH among three types of well waters collected from deep well and two types of shallow in rainy season of 2004 and 2005

			2004						2005					
Type	Depth of well	Material of wall	n	Max.	Min.	Mean	Std		n	Max.	Min.	Mean	Std	
DW	Deep	(tube)	23	7.96	4.57	6.61	0.82		24	7.13	5.02	6.43	0.53	
SCW	Shallow	Concrete	16	6.96	4.76	6.04	0.65		24	6.69	4.41	5.76	0.61	*
SSW	Shallow	Soil	39	7.66	3.88	5.00	0.78	** ##	48	5.90	3.75	4.82	0.56	** ##

Siginificant difference compared with deep well water: **P<0.01, * P<0.05
Siginificant difference between two types of shallow well : ## P<0.01

Table 2. Comparison of electric conductivity (EC) among three types of well waters collected from deep well and two types of shallow well in rainy season of 2004 and 2005

(mS/m)

			2004					2005				
Type	Depth of well	Material of wall	n	Max.	Min.	Mean	Std	n	Max.	Min.	Mean	Std
DW	Deep	(tube)	23	1007	9.09	220a	220	24	522	7.65	136a	130
SCW	Shallow	Concrete	16	255	6.22	80.7ab	76.0	24	47.9	6.40	25.6b	13.2
SSW	Shallow	Soil	39	206	3.42	47.2b	49.1	48	65.2	2.75	18.0b	14.8

Different charcter in the average data means a siginificant difference in P<0.01
No siginificant difference between two types of shallow well

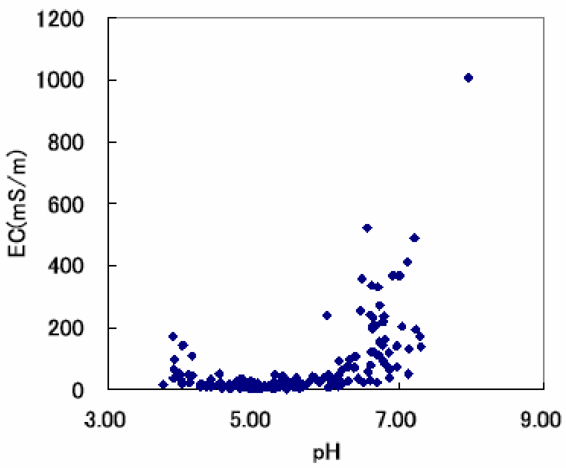

Fig.2 Relationship between pH and EC of all well water samples

The pH and EC values of well water samples from three types of well were summarized in Tables 1 and 2, respectively. In both 2004 and 2005, the average pH value of SSW was significantly ($p<0.01$) lower than those of DW and SCW. Also, the average pH of SCW tended to be lower than that of DW. These results indicate that the shallow groundwater is more acidic than deep groundwater. The EC data show a significant difference between DW and SSW in 2004 and between DW and SSW or SCW in 2005. These data imply that groundwater from deep layer contains larger amount of ions than that from shallow layer.

Figure 2 shows the relationship between EC and pH for whole data. From this figure, it is observed that well waters with neutral or alkali pH contain a large amount of ion, and that acidic well waters also contain more ions than the waters with pH of 5 to 6.

Table 3 Concentrations of anions and cations in well waters from three types of well (2004)

(meq/L)

Sample	n		Cl	NO_3	SO_4	HCO_3cal*	Na	K	Mg	Ca
DW	23	Mean	2.15	0.05	0.26	7.39	3.32	0.12	2.19	4.20
		Max	17.3	0.31	1.84	30.6	27.93	0.58	25.65	13.07
		Min	0.01	n.d.	n.d.	0.10	0.10	0.01	n.d.	0.11
		Std	3.76	0.10	0.48	6.42	5.73	0.14	5.01	3.31
SCW	16	Mean	0.30	0.02	0.11	2.71	0.78	0.06	0.46	1.84
		Max	1.91	0.08	0.49	8.73	3.89	0.14	1.43	5.87
		Min	0.02	n.d.	0.01	0.15	0.04	n.d.	0.01	0.09
		Std	0.47	0.03	0.14	2.53	1.03	0.05	0.45	1.67
SSW	39	Mean	0.34	0.07	0.04	0.64	0.40	0.11	0.16	0.40
		Max	2.12	0.49	0.35	6.65	2.02	0.85	1.19	4.34
		Min	0.03	n.d.	n.d.	0.01	0.03	n.d.	n.d.	0.01
		Std	0.49	0.11	0.06	1.15	0.49	0.19	0.22	0.77

*HCO_3 concentration was estimated by the following equation;

HCO_{3cal} = [total cation] – ($[Cl^-]+[NO_3^-]+[SO_4^{2-}]$)

Table 4. Results of significant test for Na, Cl (a) and Ca,Mg and HCO_3(b)

(a)

		Na		
		DW	SCW	SSW
Cl	DW		*	**
	SCW	*		
	SSW	**		

(b)

		Ca(Mg)		
		DW	SCW	SSW
HCO_3	DW			**(**)
	SCW			**
	SSW	**	*	

*: p <0.05 **:p <0.01

The chemical constituents of well waters were shown in Table 3 with the results of significant tests (Table 4a and 4b). From these results it is obvious that DW waters significantly contain a larger amount of Na and Cl than shallow well waters (SCW and SSW). Also, the concentrations of Ca, Mg and bicarbonate ions in DW waters were higher than those in SSW waters. On the other hand, the concentrations of these ions in SCW waters showed no significant difference with DW water but with SSW water. Considering these results with the data of pH, acidic pH found in SSW might be neutralized by concrete materials in SCW, which contain Ca,Mg and carbonate.

An observation worthy of special mention was that there were well waters containing a high concentration of nitrate, utmost 0.49 meq/L, in SSW. The relationship between nitrate concentration and pH in SSW waters was shown in Fig.3, together with the relationship between sulfate and pH. This figure indicates that the concentration of nitrate in the water with low pH was high, while the waters containing high concentration of sulfate showed near neutral pH. A good correlation between pH and

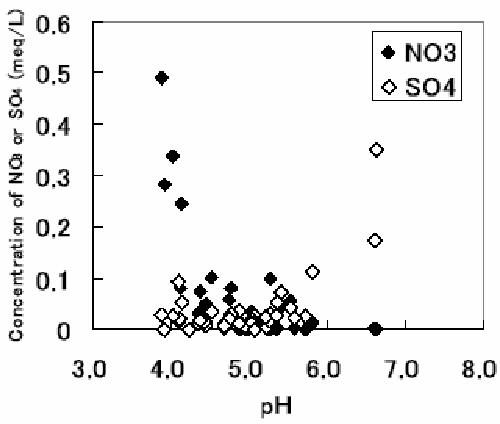

Fig.3 Relationship between pH and the concentrations of NO_3 or SO_4 in SSW waters

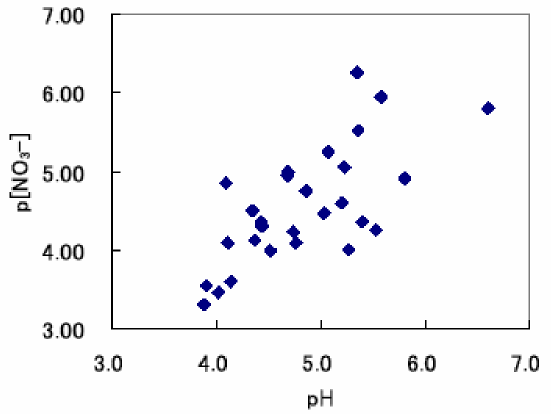

Fig.4 Relationship between pH and p[NO3] in SSW waters

$p[NO_3^-]$ ($-\log[NO_3^-]$) as shown in Fig.4, and it suggests that high acidity of well water might be derived from nitric acid.

The highest concentration of nitrate (0.49 meq/L) corresponds to 30 mg NO_3/L, which was close to the guideline of safety level for drinking by WHO (50 mg NO_3/L) (WHO,2006). Nitrate contamination of groundwater has been a serious problem in many countries in the world (Gallardo et al.,2005;Jin et al.,2004; Kass et al.,2005; Subramani et al.,2005), because high levels of nitrate in drinking waters can lead to health problems such as "blue baby" syndrome. In Japan, an application of a large amount of fertilizer in agricultural fields causes nitrate pollution in groundwater (Gallardo et al.,2005). Jin et al.(2004) reported that domestic wastewater was the major nitrate source of shallow groundwater in urban area, Hangzhou city, China. As the other sources of nitrate in groundwater, manure, industrial effluent, human water lagoons, animal feedlots, and native soil organic matter, as well as geologic sources have been listed (Jin et al. 2004). In this study, the well waters containing a high concentration of nitrate over 0.10 meq/L were found in some villages such as Vienkeo, Nonsengchen, and Bolek from shallow well and in Dongkhuai and Nonsengchen from deep well. The sources of high concentration of nitrate in well waters might relate with changes of life style or agricultural activity in rural villages. Further research on the source of nitrate in well water from various viewpoints such as isotopic composition of nitrogen should be necessary.

Conclusion

We analyzed three types of well waters collected from 28 villages in Xaythani district in rainy season of 2004 and 2005. We found that waters from deep well and shallow well have different chemical characteristics and that wall materials affects water quality in case of shallow well. The specific well waters showed high acidity accompanied with high concentration of nitrate.

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