VNU Journal of Science, Earth Sciences 28 (2012) 1-10

Geochemical characteristics of Quaternary sediments in the Hanoi area

Dang Mai[1,*], Nguyen Thuy Duong[1], Tong Thi Thu Ha[2], Dang Quang Khang[1], Nguyen Van Niem[2], Dinh Xuan Thanh[1]

[1]*Falculty of Geology, VNU University of Science, 334 Nguyen Trai, Hanoi, Vietnam*
[2]*Vietnam Institute of Geosciences and Mineral Resources*

Received 12 May 2011; received in revised form 14 June 2011

Abstract. 17 samples collected from two drill holes (QO.01 and QO.03) at Quoc Oai (Hanoi) were analysed the main chemical compositions in oxides SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O by XRF method and some trace metal elements such as As, Cu, Pb, Zn, Sb, V, Cr, Ni, Cd by AAS method. According to these results, content of SiO_2, Al_2O_3, Fe_2O_3 are the highest, the next is K_2O, TiO_2 and the other oxides are very low. The sediments in the Vinh Phuc formation have rich Fe_2O_3 by laterization, whereas those in the Hai Hung formation have rich K_2O by the potassium-absorption in the organic matters. In the sediments, there are close relationship between the alkaline and alkaline earth elements, and the titan oxide is positively correlative with Al_2O_3 and Fe_2O_3.

The arsenic content in almost samples is higher than 10mg/kg, somewhere else up to 41 mg/kg, exceeding many folds compared to the average level found in the earth's crust and in the clay sedimentary. The antimony content (Sb) is also increased high with the clark index from 8.06 to 125.6 mg/kg. The behaviors of As, Cu, Pb, Zn are very similar to each other in the samples of 02 holes QO.01 and QO.03, that is highly concentrated in the upper sediments of the Vinh Phuc formation and in the rich-organic lower sediments of the Hai Hung formation. It seem probable that As is existed as sulfur phases and absorbed by the organic materials. It is able to infer sedimentary source and accumulated arsenic content from the linear correlation coefficient between siderophile and Cu, As, which, as a basic for judging the cause pollution of Hanoi groundwater.

Keywords: Vinh Phuc formation; arsenic, antimony, copper; siderophile elements; drill hole; Hanoi area

1. Introduction

According to finding of researcher at Vietnam and abroad, arsenic concenstrations in the groundwaters of the Holocene and Pleistocene layers in Hanoi is very high, at many sites higher than the level permitted by the World Health Organization (WHO) (Do Trong Su, 2000; Pham Hung Viet, 2001; Nguyen Van Dan, 2004; Nguyen Kim Dung, 2006; Berg.M., 2008: Norman J., 2008). Arsenic concenstrations in water well in Hoai Duc, Phu Xuyen, Thuong Tin is more than 100µg/l that is exceeded 10 time comparing to

* Corresponding author. Tel: 84-934276782.
E-mail: maigeo47@gmail.com

WHO's criteria. According to Bui Huu Viet (2010) soil in the west of Hanoi has been polluted by heavy elements, such as As, Cu, Ni, Mn, Cr, Zn, Cd. Content of trace elements found in the soil and the water have a close relationship with the host rocks that first of all is the Quaternary sedimentary. Indeed, on the causes of arsenic contamination, most researchers cling to the point of view that, the arsenic found in groundwater originated from the Quaternary sediments [1, 3, 5, 6, 9, 10]

In order to find more evidences and to know geochemical characteristics at the soil of the Quaternary sediments in the Hanoi, arsenic and heavy metal elements concentration were researched in Quaternary sediments of Quoc Oai (Hanoi).

2. Methods

The sediment samples were collected in 3 deep drill holes, which belonged to project VINOGEO. One of 3 drill holes that names QO.03 was in Tam village, Thach Than commune, Quoc Oai district (Ha Noi) and the othes were ịn Quoc Oai district (Ha Noi). The depths of the drill holes were 48, 53 and 42 m. The drill hole samples were collected about 300gr for each 1m depth and packaged in the polypropylene bags at the sites.

The major elements and some heavy metals (such as: V, Cu, Cr, Ni, Sr, Ba, Zn, Rb, Zr) chemical compositions of sedimentary were determined by X-ray Fluorescent (XRF Philips 2404). The heavy metals, such as As, Pb, Cu, Zn, Cd, were analyzed by atomic absorption spectrometry method (AAS). As was analysed on an atomic absorption spectrometry device employing a graphite burnt furnace (Perkin-Elmer 4110 ZL Zeeman), and the other elements were determined by a flame absorption spectrometry (Analytik Jena, AAS Vario 6).

3. General ideas on the Quaternary sediments at the Hanoi area

The Quaternary sediments in Ha Noi belong to 5 formations whose age were from early Pleistocene to Holocene, such as: 1) Le Chi formation; 2) Ha Noi formation; 3) Vinh Phuc formation; 4) Hai Hung formation and 5) Thai Binh formation (Ngo Quang Toan et al, 1998).

The Le Chi formation ($Q_1^1 lc$): includes early Pleistocene's fluvial deposits; was not appear in the surface and only found them in drill holes at depths from 45 to 80m. Their thickness was from 2.5 to 24.5m. The lithological compositions of the Le Chi formation include: pebble (quartz, silica, marble), gravel, sand, silt, brown-gray clay …

The Ha Noi formation ($Q_1^{2-3} hn$), that aged in middle-late Pleistocen, was formed from the fluvial and diluvial deposits. They were distributed in the edges of mounds, hills and plains of Ba Vi, Soc Son include Xuan Mai, Thach That, Hoa Lac, Ba Vi, Da Phuc, Kim Anh, Minh Tri areas. Their materials were cobble, pebble, gravel and yellow clay-silt layer at the upper part. In some areas around hills and mounds, the upper part of the sediment were hardly weathered to form a young laterite layer. The fluvial deposits could be found in almost drill holes and their thickness were from 9.9 to 34m. This formation could be considered as the main underground water containing object of the Hanoi. In relationship to other formations, the Ha Noi formation lies unconformable upon the Le Chi formation and was covered unconformable by the Vinh Phuc formation.

The Vinh Phuc formation (Q_1^3vp), which was formed in late-Pleistocene, occurred as the first bench (the area exposed on the surface) and widely distributed at Soc Son, Dong Anh, Thach That, Quoc Oai, Chuong My, Xuan Mai and Co Nhue. They were at the absolute altitude of 8-20m; whereas down in the plains, from South Dong Anh, Co Nhue to further south, they were appeared at 2-26.5 m deep of the drill holes. The sedimentary origin of the Vinh Phuc formation were fluvial, fluviolacustrine, fluviomarine. Material of fluvial deposit includes gravel, sand, quartz sand, silt, clay. Their structure was oblique lamination. The laterized sedimentary surface was mottled yellow-gray and brown-red. The fluviolacustrine was restrictedly distributed and includes silt, gray and dark-gray clay, white-gray kaolin clay containing late-Pleistocene floral relics. The composition of fluviomarine was silty clay mixed with gray sand. Their surface was weathered mottled.

In Hanoi area, the origin of Hai Hung formation ($Q_2^{1-2}hh$) was bog lake, fluviomarine and marine. The bog lake sediment whose material was dark gray silty clay containing floral relics and lens-shaped peat, was formed before the Flandrian transgression. The components of the fluviomarine sediments mainly include silty clay fixed fine-grained sand, dark gray silty sand, peat containing floral relic and foraminifera that was appeared in the early-middle Holocene. The marine sediments belong to lagoon phase mainly include clay, silty clay mixed with a little fine-grained sand that is green gray or yellow gray, plastic and smooth. The clay mineral association are: hydromica, kaolinite, montmorilonite, chlorite

The Thai Binh formation (Q_2^3tb) includes the modern sediments that was formed after the marine regression period. The formation's deposits belong to the inner-dyke and outer-dyke alluvial facies. Their composition was sand, silt, clay, gravel, pebble, grit.

4. Results and discussion

Major compositions

Table 1. Oxide contents (% wt.) of Quaternary sediments in Hanoi area

Samples	Drill hole	Depth (m)	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
NH.07	QO-01	9.2	61.96	0.90	17.77	7.29	0.04	1.46	0.29	0.58	3.09
NH.10	QO-01	11.7	46.92	2.79	21.82	16.79	0.03	0.45	0.17	0.10	0.88
NH.17	QO-01	20.2	75.61	1.26	6.31	11.63	0.03	0.12	0.03	0.01	0.34
NH.21	QO-01	25.7	43.57	4.02	30.42	8.39	0.01	0.43	0.11	0.07	1.23
NH.25	QO-01	35.7	48.16	2.80	21.63	16.06	0.06	0.49	0.11	0.08	1.46
NH.30	QO-01	44.7	60.03	1.97	19.33	8.49	0.06	0.58	0.18	0.08	1.66
NH.65	QO-03	3.7	71.96	0.67	10.20	7.21	0.10	0.94	0.44	0.73	2.00
NH.66	QO-03	4.3	57.00	0.86	21.43	6.19	0.08	1.67	0.34	0.45	3.32
NH.69	QO-03	8.3	60.10	0.88	17.32	5.03	0.04	1.72	0.49	0.61	2.94
NH.71	QO-03	9.8	68.26	0.74	14.28	6.77	0.03	0.64	0.22	0.13	1.97
NH.72	QO-03	12.3	75.76	0.62	11.08	4.45	0.03	0.49	0.14	0.12	1.91
NH.75	QO-03	19.2	72.20	1.85	15.25	2.07	0.02	0.53	0.08	0.10	1.40
NH.76	QO-03	20.8	68.54	1.91	16.90	3.44	0.02	0.56	0.10	0.10	1.43
NH.77	QO-03	22.0	23.67	1.59	10.93	51.67	0.12	0.21	0.19	0.07	0.41

High contents were SiO_2, Al_2O_3 and Fe_2O_3, next was K_2O, TiO_2 the other oxides were very low, especially MnO (table 1). In average, SiO_2 was the highest in the Thai Binh formation (71.96%), next was in the Hai Hung formation (62.06%) and was the lowest in the Vinh Phuc formation (54.1% - table 3). Al_2O_3 was from 6.31% to 30.42%. This constituent in average was the highest in the Vinh Phuc formation (18.12%) and the lowest in the Thai Binh formation (10.20%). The average of Fe_2O_3 was highest in Vinh Phuc formation (10.46%) relating to the laterization; the lowest in gray-green clay of the Hai Hung formation (6.45%) and reached average in the Thai Binh formation (7.21%).

K_2O in the Hai Hung formation was surpassed the other formations because of relating to the potassium absorption of organic materials. The collected samples of the Hai Hung formation had K_2O from 1.91 to 3.32%. in average 2.87% (table 3). whereas in the Vinh Phuc formation. K_2O was from only 0.34 to 1.66%. and within the Thai Binh formation. the average content of K_2O was just 2%. The other alkali and alkaline earth elements were very low but they were close correlated close each other with a linear correlation coefficient higher than 0.8 (table 4). TiO_2 that was also importance in the Quaternary sediments varied from 0.62 to 4.02% (table 1). It was the highest in the Vinh Phuc formation with an average value of 1.94%; next was in the Hai Hung formation (0.86%). and the lowest in the Thai Binh formation (0.67%). TiO_2 was correlated positively to Al_2O_3 and then Fe_2O_3 (table 4)

Trace elements

The trace elements that were researched consisted of the chalcophile elements such as Cu. Zn. Sb. As. Pb. Cd and the siderophile elements such as V. Cr. Ni. Their components are displayed in table 2. The following describes in detail their behaviors that are influential hardly in soil and water.

Arsenic

The arsenic content of drill hole QO.01 was varied from 10.1mg/kg in mottled clay layer of Vinh Phuc formation to 41.5 mg/kg in greenest gray mixed-clay layer of Hai Hung formation. According to Smedley P.L. Kinniburgh D.G. (2002). the average As level of the friable sediments was ranged from 3 to 10 mg/kg. and then As content of research area was so much higher. If compared to the average As level of the earth's crust. which was 1.7 mg/kg (Vinogradop. 1962) then it was 8 to 24 times higher. So. this thing show that regional sedimentary could be source to pollute Hanoi underground water.

In the drill hole QO.03. As content was from 5.77 mg/kg at 19.3 m depth in mottled clay of Vinh Phuc formation to 14.8 mg/kg at 4.3 m depth in greenest gray, dark gray clay-mud of Hai Hung formation (tab. 1). In comparison to the clay deposits. the As maximum was 2.2 times higher and 9 times higher than the average level in the earth's crust. It is possible that the source of arsenic of underground water in Ha Noi area could be from sedimentary layers. In variation charts. As content decreased with depth (Fig. 1a. 2a)

Table 2. Trace element contents (mg/kg) of Quaternary sediments in Hanoi area

Sample	Drill hole	Depth (m)	Cu	Zn	Sb	As	Pb	Cd	V	Cr	Ni
NH.07	QO-01	9.2	35.2	102.0	12.4	18.7	35.2	0.048	135	104	56
NH.10	QO-01	11.7	92.8	94.1	6.6	41.5	47.6	<0.01	456	339	64
NH.17	QO-01	20.2	62.7	55.8	4.4	13.7	6.1	<0.01	122	174	71
NH.21	QO-01	25.7	116.0	130.0	62.8	15.3	22.2	<0.01	279	248	137
NH.25	QO-01	35.7	112.0	173.0	4.8	21.1	25.9	<0.01	336	246	125
NH.30	QO-01	44.7	70.8	118.0	4.0	10.1	16.6	<0.01	204	129	95
NH.65	QO-03	3.7	20.1	63.0	7.1	12.2	16.1	0.057	78	87	42
NH.66	QO-03	4.3	42.8	124.0	4.7	14.8	34.1	0.18	167	120	71
NH.69	QO-03	8.3	35.8	152.0	3.9	13.3	29.4	0.12	139	113	58
NH.71	QO-03	9.8	30.0	139.0	3.1	10.9	18.2	<0.01	110	90	42
NH.72	QO-03	12.3	105.0	69.3	8.0	13.6	21.5	<0.01	84	74	30
NH.75	QO-03	19.2	43.4	63.8	5.6	5.8	23.1	<0.01	183	130	38
NH.76	QO-03	20.8	49.6	78.3	11.0	6.5	25.1	<0.01	197	129	44

Table 3. The mean of chemical component contents of Quaternaary sediment formations in Hanoi area (*)

Formations	Oxides (%)								
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MnO	MgO	CaO	Na_2O	K_2O
Thai Binh	71.96	0.67	10.20	7.21	0.10	0.94	0.44	0.73	2.00
Hai Hưng	68.04	0.75	14.23	5.42	0.03	0.95	0.28	0.29	2.27
Vinh Phuc	54.84	2.27	17.82	14.82	0.04	0.42	0.12	0.08	1.10
Ha Nôi	80.78	0.20	9.48	2.28	0.38	0.85	0.50	0.21	1.31
Le Chi	78.59	0.28	9.12	2.85	1.44	0.97	0.65	0.17	1.39
	Trace elements (mg/kg)								
	Cu	Zn	Sb	As	Pb	Cd	V	Cr	Ni
Thai Binh	20.10	63.00	7.10	12.20	16.10	0.06	78.00	87.00	42.00
Hai Hưng	49.76	117.26	6.42	14.26	27.68	0.12	127.00	100.20	51.40
Vinh Phuc	78.19	101.86	14.17	16.29	23.80	<0.01	253.86	199.29	82.00
Ha Nôi	-	-	-	-	-	-	-	-	-
Le Chi	-	-	-	-	-	-	-	-	-

(*) The data of Ha Noi and Le Chi formations from [12]

Copper

In the drill hole QO.01. the lowest of Cu content was 35.2 mg/kg in the top soil layer and the highest was 116 mg/kg at 25.7 m depth in mottled clay of Vinh Phuc formation. In the drill hole QO.03. it was varied from 20 mg/kg at 3.7 m depth in silt sand layer of Thai Binh formation to 105 mg/kg at 22.5 m depth in clay layer of Vinh Phuc formation. Copper component was trended to increase with depth (Fig. 1b. 2b). With the average level in sedimentary of the world [6]. copper content in this area reaches approximately and has clark index from 0.62 to 2.04.

Lead

The lead content in the sedimentary layers in drill hole QO.01 was ranged from 6.13 mg/kg at 20.2 m depth in Vinh Phuc formation to 47.6 mg/kg at 11.7 m depth in Hai Hung formation. In general. it was very close to the average level of the world. In drill hole QO.03. variation of lead content was from 16.1 mg/kg at 3.7 m depth in silt-sand sedimentary layer of Thai Binh formation to 34.1 mg/kg at 4.3 m depth in clay layer of Hai Hung formation. The concentration coefficient of lead in clay layers is fluctuated from 0.27 to 1.71. and it's clark index is from 1 to 2. So. in researched area. lead content is the same as the average level of the world. Like arsenic. lead tends to decrease with depth. (Fig. 1c. 2c)

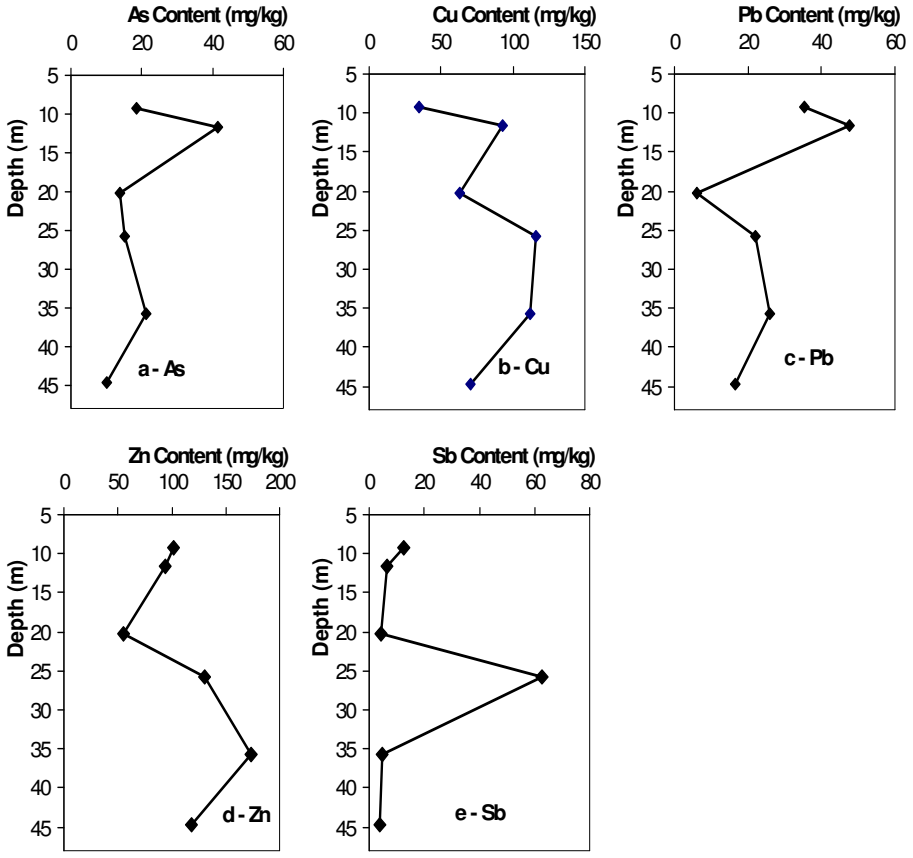

Figure 1. The variation of trace element contents with depth in drill holes QO.01 (longitude:$105^0$38'11,46"; latitude: $20^0$59'41,03")

Zinc

The variation of zinc contents trends to differ at the 2 drill holes a little bit. The zinc tends to increase in drill holes QO.01 (fig. 1d) and decrease in drill hole QO.03 (fig. 2d) with the depth. In the drill hole QO.01. Zn content was varied from 55.8 mg/kg at 20.2m depth in sediments of Hai Hung formation to 173 mg/kg in sedimentary layers of Vinh Phuc formation. In drill hole QO.03. it was ranged from 63 mg/kg at 3.7 m depth in sediments of Thai Binh formation to 152 mg/kg at 8.3m depth in sediments of Hai Hung formation. In comparison to the general level of the world. the Zn content in Hanoi friable sediments was reached the average level and its concentration coefficient in clay layers was from 0.7 to 2.16 and its clark index was 0.79 to 1.83.

Antimony

In drill hole QO.01. the antimony content was ranged from 4.03 mg/kg to 62.8 mg/kg. It was higher 2.4 to 31.4 times than the average level in clay stones and 8.1 to 125.6 times than the average Sb level in the earth's crust. Unlike other elements. it was difficult to find the Sb content variation (fig. 1c. 2c). In the top and bottom sedimentary layers. the Sb content was very low and about the same but in the middle layer at 25.7 m depth. the Sb content was increased to 62.8 mg/kg. In drill hole QO.03. the Sb content was varied from 3.07 mg/kg at 9.8 m depth in Hai Hung formation to 11 mg/kg at 20.8 m depth in Vinh Phuc formation. However. in the average level. Sb content in the sediments of Vinh Phuc formation was higher than its of Hai Hung and Thai Binh formation. The concentration coefficient of Sb was reached to 1.54 - 5.5. and the clark index was from 6.14 to 22. Thus. the Sb content in research area was much higher than its common situation in the world.

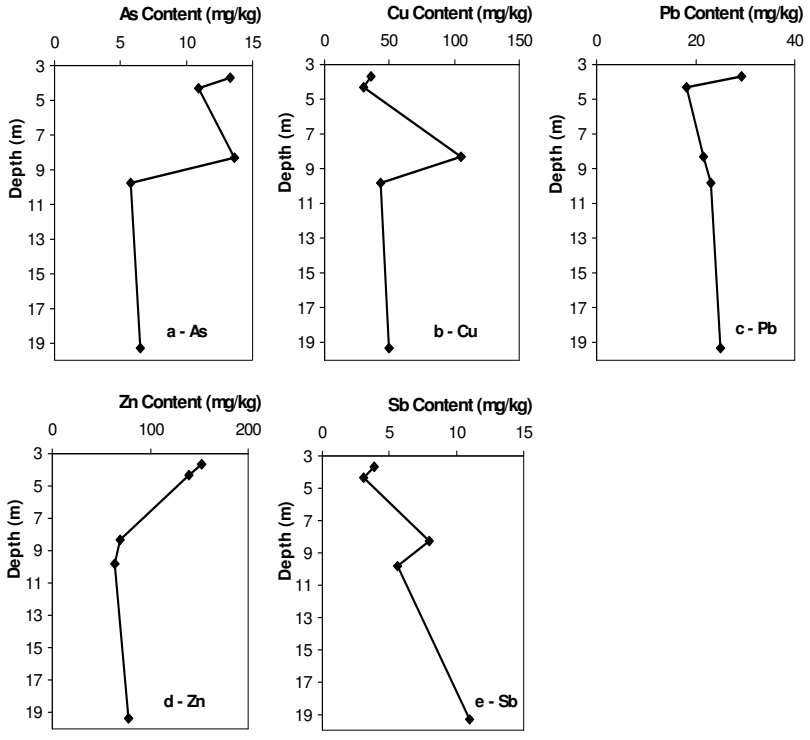

Figure 2. The variation of trace elements with depth in drill holes QO.03 (longitude:$105^0$37'43,16"; latitude: $20^0$59'33,93").

The siderophile elements

The siderophile elements that was analysed include V. Cr. Ni and Ti. In almost samples. their contents were very low and below the average level in the global sedimentary. Therefore. they had non-significant roles to the researched area environment.

The correlation between the chemical components

Researching the correlation between the chemical components enabled to define sedimentary origin and behavior of the elements.

That are similar for behaviours of As. Pb. Zn and Cu by their distribution in sedimentary layers. They gathered high content at 11.7 m depth in mottled clay layers of Vinh Phuc formation. That suggests that As element could be substitutional element remaining sulfur phases in the sediments. The correlative matrix of the chemical components is given in table 4. The data show that there are close combinations each other of siderophile elements such as Fe. V. Cr. Ni. Cu and their correlative coefficients are higher than 0.55. In the other side. As also has a very close relation to V (r = 0.74). Cr (r = 0.77). Fe_2O_3 (r = 0.8) and Ni (r = 0.23). So. in the Quaternary sediments of researched area. there is element assemblage including Fe. Cu. V. Cr. Ni. As. This element assemblage was determine in the weathering crust upon the mafic volcanic rocks of the Vien Nam formation belong to gold ore zone of Doi Bu (Luong Son – Hoa Binh) by Dang Mai et al (2000) [4]. These data show that the Quaternary sedimentary could be created from weathering mafic rocks of Vien Nam formation. This is source of As that pollutes Hanoi underground water.

Table 4. Correlate coefficients of chemical components

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	V	Cu	Cr	Ni	Zn	As	Pb
SiO_2	1,0	-0,7	-0,9	-0,6	-0,1	0,0	0,1	0,0	-0,8	-0,7	-0,8	-0,8	-0,8	-0,6	-0,6
TiO_2	-0,7(*)	1,0	0,7	0,5	-0,5	-0,5	-0,5	-0,5	0,8	0,9	0,8	0,8	0,5	0,3	0,2
Al_2O_3	-0,9	0,7	1,0	0,2	0,1	0,0	-0,1	0,1	0,7	0,6	0,6	0,7	0,7	0,3	0,5
Fe_2O_3	-0,6	0,5	0,2	1,0	-0,3	-0,2	-0,3	-0,4	0,7	0,7	0,8	0,6	0,4	0,8	0,2
MgO	-0,1	-0,5	0,1	-0,3	1,0	0,9	0,8	0,9	-0,3	-0,5	-0,4	-0,2	0,3	-0,1	0,4
CaO	0,0	-0,5	0,0	-0,2	0,9	1,0	0,9	0,8	-0,3	-0,5	-0,4	-0,3	0,1	0,0	0,3
Na_2O	0,1	-0,5	-0,1	-0,3	0,8	0,9	1,0	0,8	-0,4	-0,5	-0,4	-0,3	0,0	-0,1	0,2
K_2O	0,0	-0,5	0,1	-0,4	0,9	0,8	0,8	1,0	-0,4	-0,6	-0,6	-0,2	0,3	-0,2	0,4
V	-0,8	0,8	0,7	0,7	-0,3	-0,3	-0,4	-0,4	1,0	0,8	0,9	0,5	0,5	0,7	0,6
Cu	-0,7	0,9	0,6	0,7	-0,5	-0,5	-0,5	-0,6	0,8	1,0	0,9	0,9	0,6	0,5	0,1
Cr	-0,8	0,8	0,6	0,8	-0,4	-0,4	-0,4	-0,6	0,9	0,9	1,0	0,6	0,4	0,8	0,4
Ni	-0,8	0,8	0,7	0,6	-0,2	-0,3	-0,3	-0,2	0,5	0,9	0,6	1,0	0,8	0,2	0,0
Zn	-0,8	0,5	0,7	0,4	0,3	0,1	0,0	0,3	0,5	0,6	0,4	0,8	1,0	0,2	0,3
As	-0,6	0,3	0,3	0,8	-0,1	0,0	-0,1	-0,2	0,7	0,5	0,8	0,2	0,2	1,0	0,7
Pb	-0,6	0,2	0,5	0,2	0,4	0,3	0,2	0,4	0,6	0,1	0,4	0,0	0,3	0,7	1,0

(*) r: Significant corelation

5. Conclusions

In Hanoi Quaternary sediments. components that include SiO_2. Al_2O_3. Fe_2O_3 were high. then lower were K_2O. TiO_2 and other oxides were negligible. The sedimentary of Vinh Phuc formation was characterized by high Fe_2O_3 that was a result of laterization. whereas in Hai Hung formation. K_2O was high because of potassium absorption by organic materials. In researched sediments. there are close relationship between the alkaline and earth alkaline elements; TiO_2 is positively correlative with Al_2O_3 and Fe_2O_3.

In the Hanoi Quaternary sediments. the arsenic content that pollutes underground water was much higher than average level of the earth's crust. Like arsenic. antimony was also high concentrated. its clark index was higher than 20. The behaviors of As. Cu. Pb. Zn were same. Their contents were high in the upper sediments of Vinh Phuc formation and low layer of Hai Hung formation where organic material remainders gather. Those events suggest that. arsenic which is dangerous polluting Hanoi underground water could be in sulfide phases and absorption forms of organic substances of Hai Hung formation.

The close relationship between Fe. V. Cr. Ni. Cu. As show that mafic rocks in Vien Nam formation were a source to have a part in forming the Quaternary sediments in Hanoi and to rich As there. However. there are more detailed researches on sedimentology and mineralogy.

Acknowledgements

This current research was supported by Vietnam National University. Hanoi in project QGTĐ.10.03. We deeply appreciate the heading board of the Project VINOGEO allow to collect the hole drill samples and Geochemistry and Mineralogy Institute. University of Freiburg (Germany) help to analyse chemical compositions by XRF and AAS.

References

[1] Berg.M., Pham Thi Kim Trang, Caroline Stengel, Johanna Buschmann, Pham Hung Viet, Nguyen Van Dan, Walter Giger, Doris Stüben. Hydrological and sedimentary controls leading to arsenic contamination of groundwater in the Hanoi area. Vietnam: The impact of iron-arsenic ratios. peat. river bank deposits. and excessive groundwater abstraction. Chemical Geology 249 (2008) 91-112.

[2] Bui Huu Viet, Mai Trong Tu, Pham Hung Thanh, Nguyen Van Niem, Do Duc Nguyen, Pham Thi Nhung Ly, Doan Thi Ngoc Huyen, Nguyen Van Luyen. *Reports on the pollution status and reason of the soil and water in Hatay province and proposing solutions to reducte the pollution impact on community life.* Archives of Vietnam Institute of Geosciences and Mineral Resources (2010)

[3] Dang Mai, Hoang Minh, Do Van Phi. Mathematical modeling of Secondary Geochemical Anomalies (Case Study of Doibu Area). Jounal of Geology 256 (2000) 28-38.

[4] Dang Mai. *Potential of pollution of arsenic in doibu gold ore area*. Proceeding International Workshop. As pollution (2000) 49-54. Ha Noi.

[5] Do Trong Su. *The status of water pollution by arsenic in Hanoi and some surrouning areas*. Proceeding International Workshop. As pollution (2000) 49-54. Ha Noi.

[6] Krauskopf K.B and Dennis K. Bird. *Introduction to Geochemistry*. Mc Graw Hill Inter Edition (1995)

[7] Ngo Quang Toan et al. *Geology and Mineral resources of Ha Noi on 1:200.000 scale.* Departement of Geology and Minerals of Vietnam (1993)

[8] Nguyen Van Dan, Nguyen Thi Dung. *Current status of groundwater pollution in Hanoi area.* Jounal of Geology 280 (2004) 48-57

[9] Norrmal.J., Charlotte J. Sparrenbom, Michael Berg, Dang Duc Nhan, Pham Quy Nhan, Håkan Rosqvist, Gunnar Jacks, Emma Sigvardsson, David Baric, Johanna Moreskog,Peter Harms-Ringdahl, Nguyen Van Hoan. *Arsenic mobilisation in a new well field for drinking water production along the Red River, Nam Du, Hanoi*. Applied Geochemistry 23 (2008) 3127-3142

[10] Pham Hung Viet et al. *Preliminary surveys for evalution arsenic level in ground and supply water in Ha Noi area*. Proceeding International Workshop. As pollution (2000) 49-54. Ha Noi.

[11] Smedley P.L.. Kinniburgh D.G. A review of the source. behaviour and distribution of arsenic in natura waters. Applied Geochemistry 17 (2002) 127-3142

[12] Tran Nghi, Ngo Quang Toan. *Depositional characteristics and geology development history during Quarternary of the Ha Noi and adjacent areas*. Geology Map magazine. the issue celebrating 35 years of Geology map field of study (1994) 154-161.