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MICROELEMENTS IN GROUNDWATER AND GROUNDWATER MONITORING IN THE SOUTH OF VIETNAM PLAIN

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ABSTRACT

Hydrogeological investigations in the South Viet Nam Plain (Nam Bo Plain) have shown the microelements (Cu, Pb, Zn, Hg, Cd, Cr, Mo, As, Mn, F) concentration ranging in large amplitude. Especially the high arsenic concentration have been observed in some places, such as Ho Chi Minh City, Tan An, Cao Lanh, Tra Vinh. Mercury concentration has been also observed in some places with higher criteria concentration.
Groundwater monitoring network in Nam Bo Plain has been conducted by DHES since 1990. It is designed for monitoring groundwater regime.
Groundwater levels have been measured over than 13 years in large number of observation wells spread over Nam Bo Plain. Observation wells are grouped in cluster of individual, each monitors a different aquifer. There are 198 wells at 98 locations.
Groundwater quality monitoring is carried out bi-annually. Samples are taken in dry and wet seasons.
Raise and fall of groundwater levels in different aquifers have been observed in some places not only for fresh but also for saline water in Nam Bo Plain. Also the fluctuation of groundwater quality, increasing and decreasing tendency have been monitored. The change of groundwater levels may lead to salt intrusion, pollution and land subsidence.

INTRODUCTION

South Viet Nam Plain (Nam Bo Plain) is very important area in economy of Vietnam. Nam Bo Plain covers about 54,000 km2 with 18 provinces and cities. It comprises the delta of Mekong, Vam Co, Sai Gon and Dong Nai rivers. Although surface water is abundant in the Plain, but a part of this is brackish, saline and low quality. So groundwater is main source for drinking water in many provinces, especially where surface water is with low quality.
Groundwater occurs in 5 aquifers (see Table 1) as follow:

- Holocene (Q_2)
- Upper-Middle Pleistocene (Q_1^{2-3})
- Lower Pleistocene (Q_1^{1})
- Pliocene (N_2)
- Upper Miocene (N_1^{3})

Groundwater has been studied systematically since 1975. DHES has been carried out many investigation projects, among them Hydrogeological mapping in different scales, prospecting, exploration, urban geological investigation and groundwater monitoring. Microelements have been analyzed in these projects in this report microelement in groundwater are studied in urban geological and groundwater monitoring projects. The microelement data are shown in Tables 2,3,4,5. For more than 13 years monitoring groundwater regime, the change of water level and quality of different aquifers have been studied. Groundwater levels in April of 1995 and 2002 for different aquifers are shown in Figs. 1, 2, 3, 4, 5, 6, 7, 8 basing on which we can find out the different level in 7 years.

METHODS

Hydrogeological investigations in Nam Bo Plain have shown the microelement (Cu, Pb, Zn, Hg, Cd, Cr, Mo, As, Mn, F) concentration, ranging in large amplitude. Especially the high arsenic concentration has been observed in some places. Mercury concentration has been also observed in some places with higher criteria concentration. For 10 years DHES has carried out

urban geological investigations in main cities and towns (14) since 1993. As and Hg concentrations have been shown in tables 2, 3, 4, 5.
Groundwater monitoring network in the South Plain has been conducted by DHES since 1990. It is not designed for monitoring the impact of groundwater abstraction or learning more about recharge but groundwater level, temperature and quality. Groundwater regime has been measured over than 13 years in large number of observation wells spread over the South Plain. Observation wells are grouped in cluster of individual, each monitors a different aquifer. There are 198 wells at 98 locations. Water levels are recorded 2 hourly in areas with tidal and 24 hourly in areas without tidal influence.
A numbers of microelement samples were analyzed in Urban Geological Investigation and Groundwater Monitoring Project as follow:

Aquifer	Q2	Q12-3	Q11	N2	N13
Number of samples in Urban Inv.Projects	21	34	2	66	5
Number of samples in Gr.Morn.Project	2	18	14	60	13

Groundwater quality monitoring is carried out bi-annually. Samples are taken in dry and wet seasons.

Raise and fall of groundwater levels in different aquifers have been observed in some places not only for fresh but also for saline water in Nam Bo Plain. Also the fluctuation of groundwater quality, increasing and decreasing tendency have been monitored.
In comparing aquifer groundwater levels in two period of time (April 1995 and April 2002) the values of decreasing depths (Figs 1, 2, 3, 4) were determined.

RESULTS AND DISCUSSION

Microelement concentration in groundwater

Basing on urban investigation we have found out the ranging values of As and Hg as follow:
- **As concentration** (see table 2)

+ Aquifer Q_2: Low As concentration in 14 towns
+ Aquifer Q_1^{2-3}: High values of As concentration in Long Xuyen (An Giang Province), Ha Tien (Kien Giang)
+ Aquifer Q_1^{1}: Low value of As concentration
+ Aquifer N_2 : High value in Tan An (Long An), Long Xuyen (An Giang)
+ Aquifer N_1^{3}: Low value of As concentration

- **Hg concentration** (see table 3)

+ Aquifer Q_2: Low Hg concentration in 14 towns
+ Aquifer Q_1^{2-3}: High Hg concentration in Long Xuyen (An Giang Province), Higher Vietnam Standard in 4 towns (Tay Ninh, Long Xuyen, Rach Gia, Ha Tien)
+ Aquifer Q_1^{1}: Higher Vietnam Standard in My Tho
+ Aquifer N_2: Highest Hg in My Tho, Tan An; Higher Vietnam Standard in 5 other towns (Tay Ninh, Ben Tre, Long Xuyen,Vinh Long, Soc Trang and Ca Mau)
+ Aquifer N_1^{3}: Low value of Hg concentration

Basing on Groundwater Monitoring data we have found out the ranging values of As and Hg as follow:
- **As concentration** (see table 4)**:**

+ Aquifer Q2: Low As concentration in most towns, high As concentration in Tra Vinh
+ Aquifer Q1 2-3: Low values of As concentration in 4 towns
+ Aquifer Q1 1: Low value of As concentration
+ Aquifer N2: High value in Dong Thap and Dong Nai
+ Aquifer N13: High value of As concentration in Long An

- **Hg concentration** (see table 5)**:** Low values in all aquifers

Groundwater monitoring regime

The change of water quality is not so clearly as some remarks follow:

- In Upper-middle Pleistocene: Area with stable TDS is far from recharge area, decreasing TDS area receiving directly rainfall water and increasing TDS area because of coming higher TDS water
- In Lower Pleistocene: Area with stable TDS is far from recharge area, decreasing TDS area receiving lower TDS water and increasing TDS area is influence by seawater coming.
- In Pliocene: In eastern part is decreasing TDS area because of rainfall and seepage from QI, increasing TDS area because of coming higher TDS water and stable TDS
- In Upper Miocene: Area with stable TDS in eastern part, decreasing TDS area receiving lower TDS water and increasing TDS area is influence by seawater coming, increasing TDS area because of coming higher TDS water and decreasing TDS area because of lower TDS water coming from the East Sea.

The recorded groundwater levels show significant fluctuations, predominantly due to the following hydrogeological reasons:

- Seasonal fluctuation of rainfall
- Seasonal fluctuation of water in rivers and canal
- Annual flooding
- Tidal fluctuation
- Influence of groundwater exploitation

We can clearly identify specific zones of structurally lowering water levels and areas with stable ones

In the southwest of the Plain and around groundwater abstraction centers (like HCMC, Soc Trang, My Tho, Ca Mau, etc.) the groundwater is steadily lowering. In the northeast, in the border with Cambodia groundwater is stable.

By comparing two maps in different years (1995 and 2002) for four aquifers (see Figs. 1, 2, 3, 4, 5, 6, 7, 8) we can find the decreasing depth of groundwater as follow:

- Aquifer Q_1^{2-3}: in Ca Mau the draw down depth was 6.15 m (average 0.9 m/year)
- Aquifer Q_1^{1}: in Ca Mau the draw down depth was 6.57 m (average 0.93 m/year), in Soc Trang - 4.82m (average 0.69 m/year), Ho Chi Minh City- 7.01 m (average 1.0 m/year)
- Aquifer N_2: in Ca Mau the draw down depth was 6.19 m (average 0.89 m/year), in Soc Trang - 1.54m (average 0.22 m/year), in Vinh Long - 1.57 m (average 0.22 m/year) and in Ho Chi Minh City - 7.79 m (average 1.11 m/year)
- Aquifer N_1^{3} : in Vinh Long - 1.39 m (average 0.22 m/year) and in Ho Chi Minh City - 6.,43 m (average 0.92 m/year)

From abovementioned data we have found out that because of groundwater exploitation the water levels of four main aquifers are lowering.

CONCLUSIONS

- Arsenic concentration have been found with higher values (WHO standard) in Long Xuyen- An Giang province (Q_1^{2-3}, N_2), Ha Tien - Kien Giang province (Q_1^{2-3}), Tra Vinh (Q_2), Tan An - Long An province (N_2).
- Mercury concentration has been found with higher values (Viet Nam standard) in Long Xuyen- An Giang some provinces. The results must be checked by modern laboratory.
- Decreasing groundwater levels are monitored in Ca Mau (Q_1^{2-3},Q_1^{2-3}, N_2 and N_1^{3}), Soc Trang (Q_1^{2-3},Q_1^{2-3}), Ho Chi Minh City (Q_1^{2-3},Q_1^{2-3}, N_2 and N_1^{3}).
- The change of groundwater levels may lead to salt intrusion, pollution and land subsidence in Ca Mau, Soc Trang and Ho Chi Minh City.

Fig 1: MAP OF G.W LEVEL ISOLINES H_1 FOR 1995

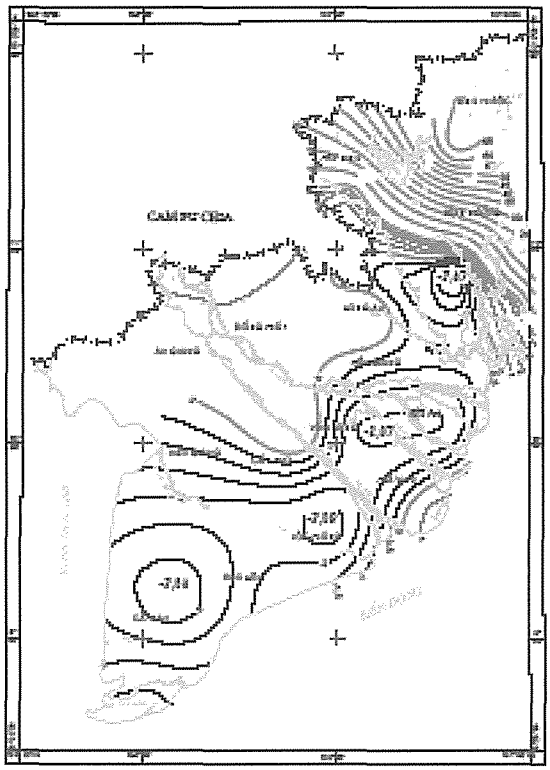

Fig 2: MAP OF G.W LEVEL ISOLINES H_2 FOR 2002

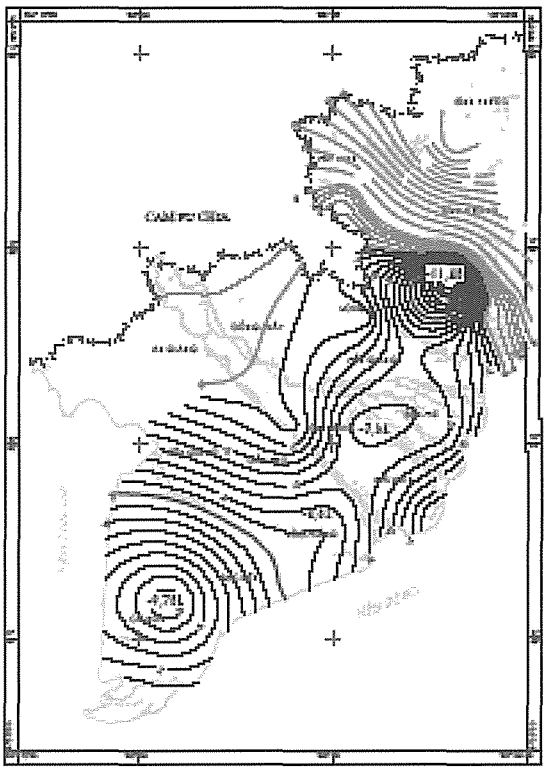

Fig 3: MAP OF G.W LEVEL ISOLINES H_1^3 FOR 1995

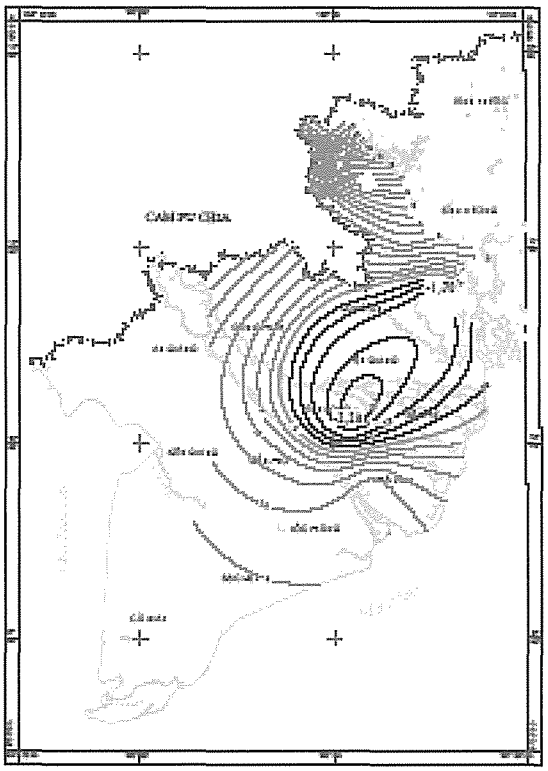

Fig 4: MAP OF G.W LEVEL ISOLINES H_2^3 FOR 2002

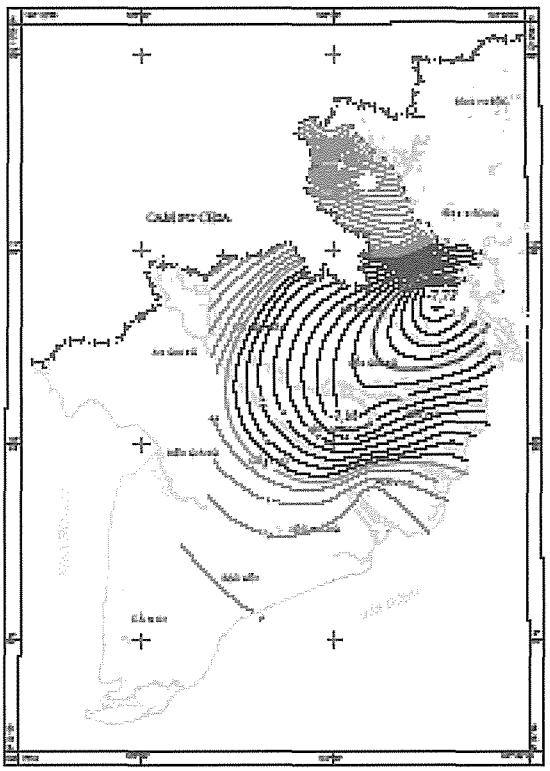

Fig 5: MAP OF G.W LEVEL ISOLINES Q_1^{2-3} FOR 1995

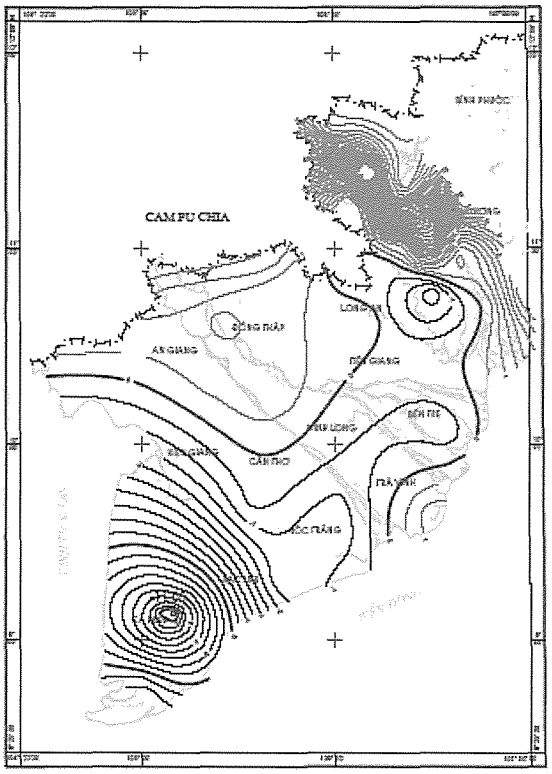

Fig 6: MAP OF G.W LEVEL ISOLINES Q_1^{2-3} FOR 2002

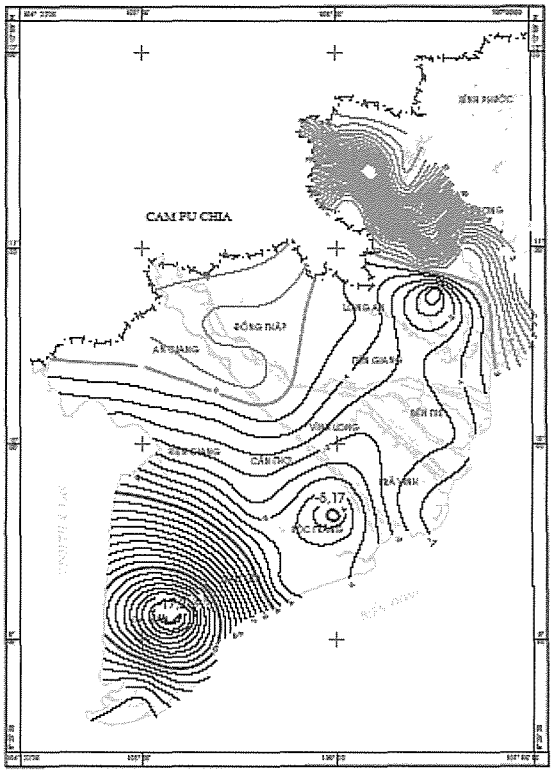

Fig 7: MAP OF G.W LEVEL ISOLINES Q_1^3 FOR 1995

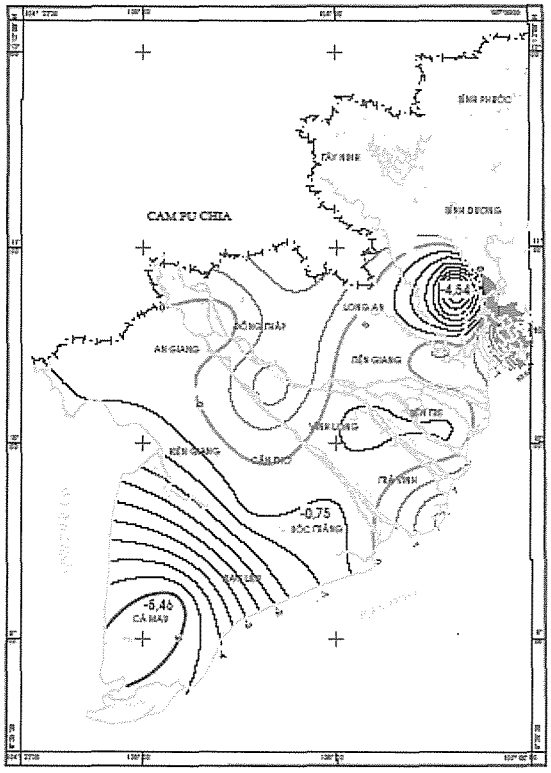

Fig 8: MAP OF G.W LEVEL ISOLINES Q_1^3 FOR 2002

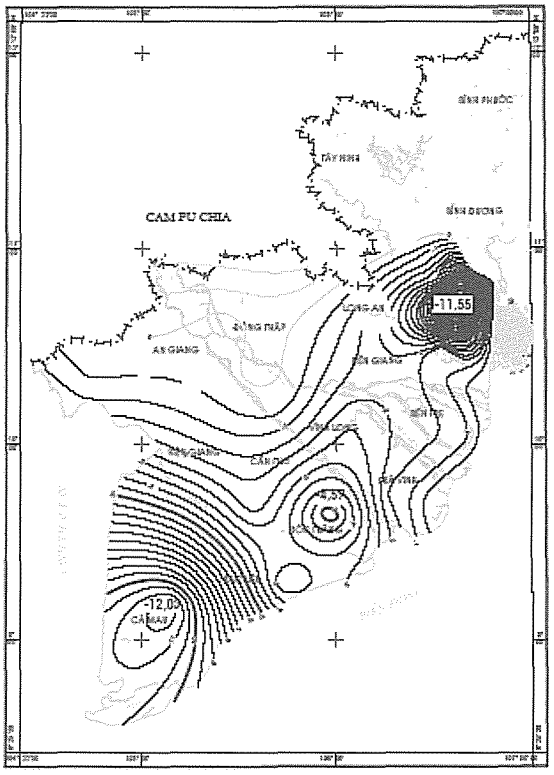

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Table 1. Geological characteristics of the major aquifer systems of Nam Bo Plain

Period	Division		Symbol		Lithology	Thickness (m)	Type	Productivity
Quaternary	Holocene		Q_2	qhb	Silt, clay and sand	0-10	Unconfined	Poor
				qha	Silt, clay and sand	20-77	Unconfined	Poor
	Pleistocene	Upper-Middle	Q_1^{2-3}	qp2-3b	Fine-coarse sand and gravel	0-80	Confined	Very good
				Qp2-3a	Fine-coarse sand	10-30	Confined	Good
		Lower	Q_1^1	qp1	Sand and gravel	0-115	Confined	Very good
Neogen	Pliocene		N_2	m4b	Sand and gravel	25-120	Confined-Artesian	Good
				m4a	Sand and gravel	50-120	Confined-Artesian	Good
	Miocene	Upper	N_1^3	m3	Sand and gravel	0-100	Confined-Artesian	Good

Table 2: Concentration As after results of urban geological investigation (mCg/l)

NN	Investigation area	Q_2				Q_1^{2-3}				Q_1^{1}				N_2				N_1^{3}			
		N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max
1	THU DAU MOT					7	1.13	0.62	1.91					7	1.33	1.10	1.78				
2	TAY NINH					9	1.80	0.60	2.84					5	1.83	0.54	3.96				
3	BEN TRE													7	8.35	1.53	14.50	1	3.38	3.38	3.38
4	MY THO									2	0.90	0.78	1.02	7	9.88	0.40	24.85	4	0.96	0.27	2.68
5	TAN AN													10	18.29	0.85	56.78				
6	CAO LANH													10	4.85	1.47	8.31				
7	LONG XUYEN					7	14.10	0.79	32.01					3	16.28	14.52	19.11				
8	VINH LONG	10	4.26	0.50	12.09									6	3.37	1.20	8.18				
9	RACH GIA					5	1.46	1.05	2.40												
10	HA TIEN					4	12.82	0.54	48.41												
11	SA DEC	4	5.49	2.53	7.99									2	1.97	0.23	3.71				
12	SOC TRANG													1	0.12	0.12	0.12				
13	TRA VINH	7	1.99	0.60	3.65	2	1.85	1.10	2.59												
14	CA MAU													8	4.44	0.60	8.76				

VIETNAM STANDART: 50 mCg/l (0.05 g/l)

Table 3: Concentration Hg after results of urban geological investigation (mCg/l)

NN	Investigation area	Q_2				Q_1^{2-3}				Q_1^{1}				N_2				N_1^{3}			
		N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max
1	THU DAU MOT					7	0.79	0.41	1.11					7	0.87	0.41	1.21				
2	TAY NINH					9	1.60	1.01	2.31					5	1.13	0.60	1.54				
3	BEN TRE													7	2.58	1.21	5.07	1	1.55	1.55	1.55
4	MY THO									2	1.65	1.10	2.20	7	10.07	0.99	58.00	4	39.73	1.26	116.00
5	TAN AN													10	4.04	1.43	5.51				
6	CAO LANH													10	0.42	0.00	0.81				
7	LONG XUYEN					7	2.42	1.61	3.31					3	2.21	1.81	2.81				
8	VINH LONG	10	0.94	0.61	1.50									6	1.11	0.61	2.04				
9	RACH GIA					5	1.38	0.81	1.81												
10	HA TIEN					4	1.20	0.71	1.86												
11	SA DEC	4	0.21	0.00	0.61									2	0.36	0.00	0.71				
12	SOC TRANG													1	2.22	2.22	2.22				
13	TRA VINH	7	0.77	0.00	1.61	2	0.91	0.20	1.61												
14	CA MAU													8	1.95	1.04	3.08				

VIETNAM STANDARD: 1 mCg/l (0.001 g/l)

Table 4: Concentration As after groundwater monitoring results (mCg/l)

NN	Investigation area	Q_2				Q_1^{2-3}				Q_1^{1}				N_2				N_1^{3}			
		N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max
1	BINH DUONG					2	1.44	0.00	2.88												
2	DONG NAI													5	3.84	0.00	17.10				
3	TAY NINH					2	0.355	0	0.71					5	3.83	0.00	9.00	2	5.00	0.00	10.00
4	HO CHI MINH CITY					12	1.934	0	7	7	1.34	0.00	4.00	5	4.06	0.00	10.00				
5	BEN TRE																	2	1.44	0.00	2.88
6	LONG AN					2	1.005	0	2.01									5	7.17	0.00	18.00
7	DONG THAP													5	13.44	0.00	29.03				
8	AN GIANG													4	1.61	0.07	3.00				
9	VINH LONG													2	0.57	0.00	1.14	2	1.28	0.00	2.55
10	HAU GIANG													5	1.36	0.00	4.00				
11	KIEN GIANG									2	0.895	0	1.79	5	4.40	0.24	9.38				
12	SOC TRANG									5	2.112	0	6	2	1.01	0.00	2.01	2	1.43	0.86	2.00
13	TRA VINH	2	33.41	0.31	66.50									7	1.60	0.00	4.08				
14	BAC LIEU													5	0.38	0.00	1.32				
15	CA MAU													10	0.36	0.00	2.00				

VIETNAM STANDARD: 50 mCg/l (0.05 g/l)

Table 5: Concentration Hg after groundwater monitoring results (mCg/l)

NN	Investigation area	Q_2				Q_1^{2-3}				Q_1^{1}				N_2				N_1^{3}			
		N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max	N samp.	Aver. value	Min	Max
1	BINH DUONG					2	0.10	0.09	0.11												
2	DONG NAI													5	0.22	0.00	0.52				
3	TAY NINH					2	0	0	0					5	0.09	0.00	0.35	2	0.16	0.11	0.20
4	HO CHI MINH CITY					12	0.103	0	0.56	7	0.19	0.00	0.56	5	0.16	0.00	0.56				
5	BEN TRE																	2	0.21	0.09	0.32
6	LONG AN					2	0.11	0	0.22									5	0.27	0.00	0.56
7	DONG THAP													5	0.27	0.00	0.87				
8	AN GIANG													4	0.32	0.00	0.70				
9	VINH LONG													2	0.16	0.09	0.22	2	0.19	0.17	0.21
10	HAU GIANG													5	0.13	0.00	0.56				
11	KIEN GIANG									2	0.1	0.09	0.11	5	0.29	0.00	0.52				
12	SOC TRANG									5	0.206	0	0.56	2	0.06	0.00	0.11	2	0.39	0.21	0.56
13	TRA VINH	2	0.22	0.00	0.43									7	0.16	0.00	0.56				
14	BAC LIEU													5	0.22	0.00	0.56				
15	CA MAU													10	0.20	0.00	0.56				

VIETNAM STANDARD: 1 mCg/l (0.001 g/l)