Assessment of groundwater quality of middle – Upper pleistocene aquifer in Ca Mau peninsula

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ABSTRACT

Groundwater quality is a matter of concern in Ca Mau Peninsula. There have been many organizations, domestic and foreign scientific researchersworking on the issue, and they have produced various results regardinggroundwater pollution (arsenic, heavy metal, minerals, or saltwater intrusion…). In this paper, the authors assess groundwater quality by using the water quality index (WQI) to transform complex data into simple indicators that are easy to understand, and let people in the studied areas be aware of the pollution issue of the water resources they are using. Groundwater samples are collected from national monitoring wells and from exploitation works in the area. Indicators such as pH, TDS (total dissolved solids), total hardness (TH), total alkalinity (Na ++ K +), sulfate (SO42-), chloride (Cl), and nitrate (NO3) are used to calculate WQI values.The WQI values of the middle Pleistocene aquifers of Ca Mau Peninsula range from 36.09 to 1,344. Based on these values, authors have classified groundwater samples into 5 groups of different qualities, from the very high quality to the unusable one. The very high quality accounts for 14% of the samples; good quality accounts for 49%, average quality accounts for 24%, poor quality accounts for 7%, and unusable accounts for 6% of the total samples.There is about 10% of the samples exceeding permissible limits of TDS, whereas the sulfate and chloride range from 20% to 21%. Samples of poor and unusable qualityare mainlyfrom Soc Trang province. Most of themhavethe TDS levels greater than 1, and some have an abnormally high level ofsulfatewhen compared with other samples in the area. The study hasyielded a more comprehensive assessment of groundwater quality, allowing regulators to plan water resources more reasonably and be able togive in time advices tothe people.

Keywords: *Groundwater quality index, groundwater in Ca Mau Peninsula, chemical composition of groundwater.*

1. INTRODUCTION

Water is an indispensable resource for life on Earth [4]. Though it covers most the Earth's surface area, the water that people can use for living is very limited. In developing countries, the use of water resources has not gained adequate and proper attention; and various research results about water chemical composition have not been used effectively. In recent studies in some countries, water quality indicators have been used to assess groundwater resources when providing water services to people, for example, in Tamil Nadu, India[8]and Dhar town, India [13].

In Vietnam, there have been some studies about hydro-geochemical characteristics of major groundwater aquifers in the Red River Delta, Vietnam [11] showingthe relationships between two aquifers by time and space. Authors of these. Works also studied the classification of sources that formed chemical composition of groundwater in the upper-middle Pleistocene aquifer (qp2-3) of the Ca Mau Peninsula[5], and on that basis, they have defined 4 types of groundwater origins and used analysis methods and charts to explain their formations.

In general, most of the studies in Viet Nam so far just evaluated groundwater quality by using separated factors, not an integrated assessment model, and without quantitative analysis; for example, these authors just used TDS levels to make the assessments. However, there have been some studies about arsenic pollution in the Mekong Delta [10], and about harmful effects of arsen in drinking water in this area [9]. Our research team argues that these types of analysis and assessments still not clearly evaluate the quality of groundwater at present project sites that have been currently in service for the people there.

There has also been a project to evaluate the impact of climate change in the Mekong Delta by the Division for Water Resources Planning and Investigation of Southern Vietnam, and that project has established a distribution map of salinity levels based on geophysical surveys. However, it is still not adequate to use just this map to indicate which areas that could be exploitable for human living.

As such, in this paper, the authors use the water quality index to make an integrated assessment of groundwater quality by analyzing water elementsthat may affect human health, such as: pH, total hardness, total dissolved solids, total alkalinity, chloride, sulfate and nitrate. Based on the National Technical Regulations on Drinking Water Quality of Vietnam Ministry of Health, the authors assign weights to these elements according to health hazardous levels and show out areas with very good, good, or poor water quality, and the authors, finally, conclude with necessary recommendations.

Ca Mau Peninsula is one of four areas in the Mekong River Delta (MRD)surrounded by the East Sea in the east - southeast, west coast in the west - southwest, Hau river system in the north and Rach Soi Vam Cong canal in the northwest (Figure 1). In recent years, agriculture and aquaculture activities in this area have made its canal system highly polluted. Besides, being surrounded by the East Sea and the West Sea, in combinationwith a tide regime, the surface flow systems in the region are mostly polluted, salinized, and hence inappropriate for human use. The main water supplies for the people here are groundwater resources. Currently, in the Mekong River Delta in general, or in the Ca Mau Peninsula in particular, there have been many domestic and foreign organizations researchingabout the problems of groundwater resources under the impact of human activities and climate changes; and about problems related to groundwater exploitation operations, the declination of water level, sea level rise and land subsidence.

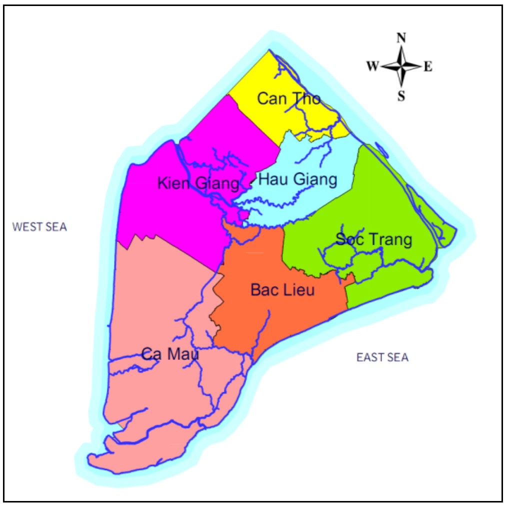

Figure 1. Administrative map of Ca Mau Peninsula area

There are seven aquifers in Ca Mau Peninsula: Holocene (qh), upper Pleistocene (qp_3), middle-upper Pleistocene (qp_{2-3}), lower Pleistocene (qp_1), middle Pliocene (n_2^2), lower Pliocene (n_2^1), upper Miocene (n_1^3). As the middle-upper Pleistocene aquifer is the most exploited regarding both industrial and household consumption scale, authors in this article focus only on the assessment of water quality in this aquifer.

2. MATERIALS AND METHODS

Groundwater samples for the study are extracted from the middle-upper Pleistocene aquifer (qp_{2-3}) of Ca Mau Peninsula. A total of 80 samples were collected from the national monitoring wells and from water exploitation works in the region (Figure 2). In some areas of Kien Giang province and Ca Mau city, the density of sample distribution is limited because these areas have sparse population and the groundwater resources there are mostly salinized. Water samples were taken by being pumped from monitoring wells; and 10 minutes after the pump time, pH levels and temperatures are measured, samples are taken, stored in plastic bottles and then transported to the laboratory for experiments. Each chemical element of the sampleswas measured three times to compute the average values. The pH level was tested based on Vietnam ISO standard 6492:1999; hardness level TH was tested with Vietnam Standard 6224-1996; arsenic concentration was measured by using AFS (Atomic Fluorescence Spectroscopy) and the Vietnam Standard 6626: 2000. Cd, Co, Cr, Cu, Ni, Pb, Sb, Se and Zn were measured using HR ICP-MS (High Resolution Inductively Coupled Plasma-Mass Spectrometry); Ba, Ca, Fe, K, Mg, Mn and Na were measured using ICP-OES (Inductively Coupled Plasma-Optical Emission Spectroscopy, Spectro, Kleve, Germany); ammonium and phosphate were measured using photometry; nitrate, chloride and sulfatewere measured using chromatography; and alkalinity was measured using titration 0.

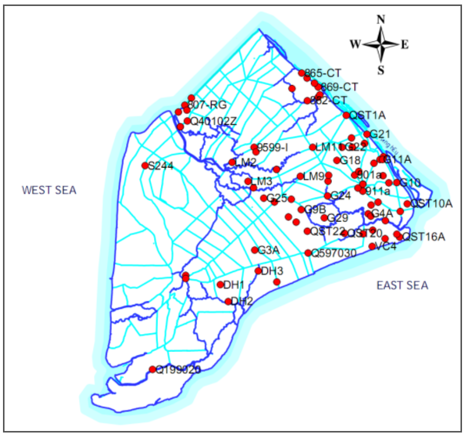

Figure 2. Locations of sampling points of the middle – upper Pleistocene aquifer (qp_{23}) in Ca Mau Peninsula

Water quality index is an effective tool to assess groundwater quality by analyzing the quality of chemical elements in the water. Based on the water quality standard, weights are assigned to chemical elements, and then weighted percentages are calculated against the total score. WQI reflects the interaction among elements that define water quality and is calculated on a sustainable standpoint about human health. In this paper, authors use chemical elements of groundwater that can negatively affect human health, such as pH, TDS, TH, Na+, K+, Cl-, SO42-, NO3-, and use the Standard QCVN 01: 2009/ BYT of the Vietnam Ministry of Health as a measure to assess these elements.

WQI values of water samples are calculated in three steps [4]:

Step 1: Each chemical element was assigned a weight (w_i) based on its impact to human health; the weight ranges from 1 to 5 (Table 1).

Step 2: Relative weight (w_i) of each elementis computed using the following formula:

$$Rw_i = \frac{w_i}{\sum_1^n w_i} \quad (1)$$

Where:

Rw_i : the relative weight of the i^{th} chemical element, in percentage

w_i : the weight of the i^{th} chemical element

$\sum_1^n w_i$: The total score of all elements

Step 3: quality rating scale, q_i, is computed for each element using the following formula:

$$q_i = \frac{C_i}{S_i} \times 100 \quad (2)$$

Where:

q_i: the quality ratio of the i^{th}chemical element

C_i: laboratory concentration value of the i^{th} chemical element, in milligram per liter (mg/l, except for pH).

S_i: permissible concentration value of the i^{th} chemical element according to the Standard QCVN 01:2009/BYT, in milligram per liter (mg/l, except for pH).

The quality of a chemical element was then determined by multiplying the equivalent weight ratio RWi with the quality ratio qi using the following formula:

$$SI_i = Rw_i \times q_i \quad (3)$$

Water quality index is calculated as a total quality of all water chemical elements:

$$WQI = \sum_1^n SI_i \quad (4)$$

The computed WQI values are finally classified into 5 types of different quality levels as in Table 1.

Table 1. Classification of Water Quality Index

WQI range	Category of water
<50	Very Good water
50-100	Good water
100-200	Average water
200-300	Very Poor water
>300	Unsuitable for drinking purpose

3. RESULTS AND DISCUSSION

Water quality index is an integrated assessment of quality of ions in groundwater that are harmful to human health. In this study, assessment results of 80 water samples from middle-upper Pleistocene aquifers in Ca Mau Peninsula are shown in Table 2.

Hydrogen ion concentration of groundwater (pH): the pH level of groundwater changes due to microbial activities or pollution sources from industrial activities. Among 80 samples collected from the aquifers qp2-3, most are in permissible limits [14], except for five samples (accounted for 6% of total samples) exceeding the allowed limit, in which one sample is from Hau Giang province, one from Soc Trang, two from Can Tho and one from Bac Lieu province.

Total Alkalinity (Na^+ + K^+): The concentration of alkali in groundwater is due to weathering in rocksthat contain water. Alkalinity concentration contributes to the sour and salty taste of the water. Alkalinity concentration ofthe samples ranges from 9.21 mg/l to 7420 mg/l. There areseven samples (accounted for 8% of total samples) having alkalinity concentration exceeding permissible limits, in which two samples are from Rach Gia city, two from Ca Mau province, onefrom Can Tho city, one from Hau Giang province and one from Bac Lieu province.

Nitrate (NO_3^-): Nitrate concentration indicates the self-cleaning ability of the groundwater. The formation of nitrate is due to decomposition of plants and animals. In the studied areas, nitrate concentration of all samples is from 0.24 mg/l to 12.16 mg/l, within permissible limits.

Total Dissolved Solids (TDS): According to the Standard QCVN 01:2009/BYT of Vietnam Ministry of Health, the maximum permissible TDS content of drinking water is 1000 mg/L. This content is due to the formation of chemical composition and the resting time of the water in rocks and soils. As analysis results of chemical composition shown in table 2, TDS content of groundwater in the middle-upper Pleistocene aquifer qp2-3 in Ca Mau Peninsula is the combination of major chemical elements in groundwater such as HCO3-, Cl-, SO42-, Ca2+, Na+, Mg2+. Groundwater with high TDS can cause heart and kidney diseases and often contains many Cl^-. However, the middle-upper Pleistocene aquifers qp2-3 in Ca Mau Peninsula have a high level of TDS due to Cl-, HCO3-, SO42, and Ca2+, Mg2+, Na+. In the qp2-3 aquifers, TDS concentration ranges from 0,3 g/L to 24,75 g/L. In 80 studied samples, there are 8 (accounted for 10% of total samples) with TDS exceeding permissible limits, in which three are from Soc Trang province, two from Ca Mau province, one from Rach Gia city, one from Hau Giang province, and one from Can Tho city.

Total hardness (TH): The hardness of groundwater is attributed to calcium and magnesium salts. These contents are formed from waste water sources from industrial and human activities. Hardness in water can cause cardiovascular disease. The total hardness of 80 samples of the middle - upper Pleistocene aquifers (qp_{2-3}) range from 52.50 mg/l to 7355.36 mg/l. There are 50 samples (accounted for 44% of total samples) exceeding permissible limits, in which 41 samples are from Soc Trang province, three from Hau Giang province, two from Rach Gia city, one from Ca Mau province, two from Can Tho city and one from Bac Lieu province.

Sulfate (SO_4^{2-}): The main formation sources of sulfates in groundwater are gypsum and minerals in rocks and soils. A sulfate concentration that exceeds 1000 mg/g can cause irritation in stomach and intestines. In the studied areas, there are 17 samples (accounted for 21% of total samples) exceeding permissible limits, and all is from Soc Trang province.

Chloride (Cl^-): The main sources of Cl in water are from domestic sewage, industrial wastes, agriculture pesticides and sea water intrusion. In the studied areas, chloride concentration range from 0.7 mg/l to 14534.5 mg/l. There are 16 samples (accounted for 20% of total samples) exceeding permissible limits, in which nine are from Soc.

Trang province, one from Can Tho city, two from Rach Gia city, two from Hau Giang province and two from Ca Mau province. The computed WQI values of groundwater in the middle – upper Pleistocene aquifers (qp_{2-3}) are shown in Table 2.

Figure 3 describes the amounts and spatial distributions of fivetypes of groundwater quality in Ca Mau Peninsula. There are 11 samplesof very good water quality (WQI <50) accounted for 14% of total samples.These samples are represented as blue points in the chart, and they are mainly in areas of the light water distribution of Can Tho, Hau Giang, Rach Gia - Kien Giang, Bac Lieu, and scattered in some areas of Soc Trang province.There are 39 samples of good water quality (50 <WQI <100) accounted for about 49% of total samples. These are represented as green points in the chart and they focus in the fresh water distribution areas in all provinces of Ca Mau Peninsula. 19 samples are ofaverage water quality (100 <WQI <200), represented as red points in the chart, accounted for about 24% of total samples, and mainly concentrated in Soc Trang province.6 samples are ofvery poor water quality (200 <WQI <300), represented as pink points, accounted for about 7% of total samples, and concentrated in Soc Trang city. There are 5 samples (accounted for 6% of the total samples) considered as unsuitable for drinking (WQI>300) and represented as brown points, concentrated in some areas of Soc Trang province.

Analysis results of groundwater quality and the spatial distribution of different quality types in Figure 3a show that: groundwater samples from very good quality to good quality are mostly concentrated in areas with TDS levels less than 1; those from average quality to very poor quality are concentrated in areas with TDS levels greater than 1; and there are some samples in Soc Trang city, though in the fresh water region (with TDS < 1) but still have poor quality because of the sudden increase of sulfate ion concentration.

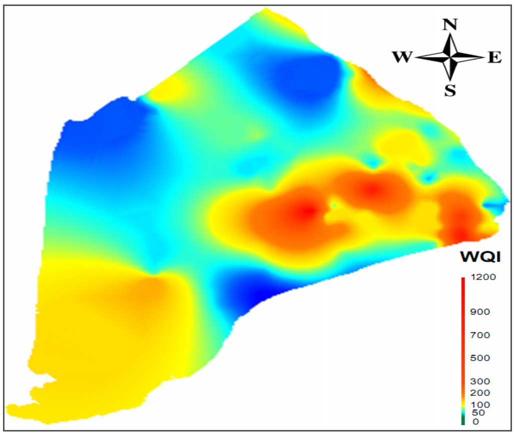

Figure 3. Distributed map of water quality index WQI of middle - upper Pleistocene aquifers (qp_{23})

Figure 3b is built using interpolation technique with 80 water quality indexes calculated in Table 2. The interpolation results show that areas with dark yellow and red are regions with water quality from poor to unusable, and they account for almost all areas of Ca Mau and Soc Trang province. The blue and green regions are areas with water quality from good to very good, so suitable for human use.

3. CONCLUSION

Of the 80 samples used forcomputing groundwater quality indexes, there are some chemical elements which are harmful to human health exceeding the permissible limits according to the Standard QCVN 01: 2009 / BYT of Vietnam Ministry of Health.

Specifically, TH hardness accounts for 44%, hydrogen ion concentration (pH) accounts for 6%, TDS accounts for 10%, alkalinity (Na + K) accounts for 8%, sulfate (SO42-) accounts for 21% and chloride (Cl) accounts for 20%. If taking TDS separately, there are only 10% of the total samples exceeding the permissible limit, whereas this ratio is 20% and 21% for sulfate and chloride.

Based on the calculation results, authors have divided the samples into five groups of water quality, including: very good water (WQI <50) accounted for 14% of the total samples, good water (50 <WQI <100) accounted for 49%, poor water (100 <WQI <200) accounted for 24%, very poor water (200 <WQI <300) accounted for 7% and unusable water (WQI> 300) accounted for 6% of the total samples.

According to the partitioning map, Ca Mau and Soc Trang provinces need to conduct assessments of groundwater quality in their current exploitation projects more often to have appropriate solutions that meet health demands of people in the region.

Assessment results of groundwater quality in the middle Pleistocene aquifersin Ca Mau Peninsula area show that: water samples of poor and unusable quality, mainly from Soc Trang province, are largely due to having the total hardness TH, sulfates, chlorides, TDS much higher than the allowed limits of Vietnam Ministry of Health. Most of these samples arelocated in areas with TDS greater than 1 g/L, but a few samples with TDS less than 1/L but with the sulfate concentrations exceeding permissible limits. For locations with unusual levels of sulfate ions, furtherresearches are needed to determine their causes then to have appropriate treatment solutions.

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TÓM TẮT

Chất lượng nước dưới đất đang là vấn đề được quan tâm ở bán đảo Cà Mau. Đã có nhiều tổ chức, các nhà khoa học trong và ngoài nước nghiên cứu, đánh giá chất lượng nước ở khu vực này, và đã cho ra nhiều kết quả khác nhau về vấn đề ô nhiễm nước dưới đất (As, các kim loại nặng, các nguyên tố vi lượng, hoặc xâm nhập mặn,…). Trong bài báo này, nhóm tác giả đánh giá chất lượng nước dưới đất thông qua chỉ số chất lượng nước dưới đất WQI (water quality index), nhằm mục đích chuyển các dữ liệu chất lượng nước phức tạp thành các chỉ số dễ hiểu, và cho người dân trong khu vực dễ dàng hiểu và nhận định về các vấn đề ô nhiễm nguồn nước đang sử dụng trong ăn uống và sinh hoạt hàng ngày. Các mẫu nước được thu thập từ mạng lưới quan trắc Quốc Gia và trong các công trình khai thác trong khu vực nghiên cứu. Các thông số được phân tích bao gồm: pH, TDS (total dissolved solids), Tổng độ cứng (TH), Tổng lượng kiềm (Na^++K^+), Sunfat (SO_4^{2-}), Chloride (Cl^-), và Nitrate (NO_3^-) sử dụng để tính chỉ số WQI. Giá trị WQI các tầng chứa nước pleistocene giữa trên trong vùng bán đảo Cà Mau phân bố trong khoảng từ 36,09 đến 1344. Dựa vào giá trị WQI nhóm nghiên cứu phân ra 5 loại nước có chất lượng nước khác nhau, từ rất tốt đến không thể sử dụng ăn uống được, trong đó: loại 1, nước có chất lượng rất tốt chiếm 14%, nước có chất lượng tốt chiếm 49%, nước có chất lượng trung bình chiếm 24%, nước có chất lượng nước kém chiếm 7%, nước không thể sử dụng trong ăn uống chiếm 6% trong tổng số mẫu nghiên cứu. Nếu xét riêng lượng cặn khô TDS thì chỉ có 10 phần trăm số lượng mẫu vượt giới hạn cho phép, trong khi đó các ion như sunfate, Chloride chiếm từ 20% đến 21%. Các mẫu nước dưới đất có chất lượng từ xấu đến không thể sử dụng ăn uống tập trung chủ yếu ở khu vực tỉnh Sóc Trăng, các mẫu này hầu hết đều có hàm lượng TDS lớn hơn một, tuy nhiên có một số mẫu có hàm lượng ion sunfate cao bất thường so với các mẫu khác trong khu vực. Kết quả nghiên cứu này đã đánh giá chất lượng nước nước dưới đất toàn diện hơn, giúp cho các nhà quản lý quy hoạch nguồn tài nguyên nước dưới hợp lý hơn, đồng thời đưa ra các khuyến cáo kịp thời cho người dân trong việc khai thác, sử dụng nguồn tài nguyên nước dưới đất.

Từ khóa: *Chỉ số chất lượng nước dưới đất, nước dưới đất BĐCM, thành phần hóa học nước dưới đất.*

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Table 2. Groundwater quality index WQI in middle – upper Pleistocene aquifer (qp_{23})

TT	CTQT	TH, mg/l (tính theo $CaCO_3$)			pH			TDS (g/l)		
		TN	qi	SIi	TN	qi	SIi	TN	qi	SIi
1	DH1	90.0	30.0	2.4	8.46	99.5	15.9	0.70	70.0	11.2
2	DH2	89.5	29.8	2.4	8.38	98.6	15.8	0.57	57.0	9.1
3	DH3	86.5	28.8	2.3	7.63	89.8	14.4	0.55	55.0	8.8
4	DH4	52.5	17.5	1.4	8.41	98.9	15.8	0.50	50.0	8.0
5	Q597030	349.0	116.3	9.3	8.61	101.3	16.2	0.70	69.7	11.1
6	Q177020	150.0	50.0	4.0	7.83	92.1	14.7	0.65	65.3	10.5
7	Q188020	460.0	153.3	12.3	7.56	88.9	14.2	2.51	250.6	40.1
8	Q199020	150.0	50.0	4.0	8.40	98.8	15.8	1.67	167.3	26.8
9	862-CT	146.0	48.7	3.9	8.41	98.9	15.8	0.49	48.9	7.8
10	863-CT	110.0	36.7	2.9	8.80	103.5	16.6	0.42	42.0	6.7
11	865-CT	169.0	56.3	4.5	7.81	91.9	14.7	0.46	46.5	7.4
12	866-CT	407.5	135.8	10.9	8.57	100.8	16.1	0.96	95.7	15.3
13	867-CT	442.5	147.5	11.8	7.82	92.0	14.7	0.91	91.0	14.6
								…		
71	QST24	5306.7	1768.9	141.5	7.40	87.1	13.9	10.35	1034.9	165.6
72	QST25A	1104.2	368.1	29.4	8.30	97.6	15.6	1.84	183.8	29.4
73	QST26A	628.3	209.4	16.8	7.50	88.2	14.1	1.52	151.8	24.3
74	S112	105.0	35.0	2.8	7.12	83.8	13.4	0.38	38.0	6.1
75	S113	175.0	58.3	4.7	8.19	96.4	15.4	0.48	48.1	7.7
76	S115	122.5	40.8	3.3	7.86	92.5	14.8	0.45	44.9	7.2
77	VC1	315.0	105.0	8.4	6.87	80.8	12.9	1.24	123.9	19.8
78	VC2	320.0	106.7	8.5	8.37	98.5	15.8	1.10	110.2	17.6
79	VC3	112.5	37.5	3.0	8.11	95.4	15.3	0.66	66.3	10.6
80	VC4	238.0	79.3	6.3	8.24	96.9	15.5	0.81	80.5	12.9
Si		**300.00**			**8.50**			**1000.00**		
wi		**2.00**			**4.00**			**4.00**		
Rwi		**0.08**			**0.16**			**0.16**		

Table 3. Groundwater quality index WQI in middle – upper Pleistocene aquifer (qp_{23})

TT	CTQT	Các Ion (mg/l)												WQI
		Na+K	qi	SIi	Cl^-	qi	SIi	SO_4^{2-}	qi	SIi	NO_3^-	qi	SIi	
1	DH1	232.73	116.4	9.3	31.91	10.6	1.3	62.44	25.0	5.0		0.0	0.0	**45**
2	DH2	180.56	90.3	7.2	33.68	11.2	1.3	30.26	12.1	2.4		0.0	0.0	**38**
3	DH3	180.00	90.0	7.2	15.95	5.3	0.6	26.42	10.6	2.1	0.80	1.6	0.3	**36**
4	DH4	178.95	89.5	7.2	15.95	5.3	0.6	12.01	4.8	1.0	0.85	1.7	0.3	**34**
5	Q597030	115.56	57.8	4.6	104.58	34.9	4.2	118.63	47.5	9.5	4.50	9.0	1.8	**57**
6	Q177020	195.54	97.8	7.8	175.48	58.5	7.0	7.20	2.9	0.6	1.51	3.0	0.6	**45**
7	Q188020	783.33	391.7	31.3	1240.75	413.6	49.6	57.64	23.1	4.6	2.04	4.1	0.8	**153**
8	Q199020	620.00	310.0	24.8	558.34	186.1	22.3	21.61	8.6	1.7	3.74	7.5	1.5	**97**
9	862-CT	64.08	32.0	2.6	40.77	13.6	1.6	33.14	13.3	2.7	1.17	2.3	0.5	**35**
10	863-CT	73.74	36.9	2.9	25.88	8.6	1.0	2.40	1.0	0.2	1.88	3.8	0.8	**31**
11	865-CT	63.00	31.5	2.5	74.45	24.8	3.0	12.01	4.8	1.0	0.71	1.4	0.3	**33**
12	866-CT	98.00	49.0	3.9	17.02	5.7	0.7	367.43	147.0	29.4	4.79	9.6	1.9	**78**
13	867-CT	124.00	62.0	5.0	44.31	14.8	1.8	393.85	157.5	31.5	0.80	1.6	0.3	**80**
71	QST24	32.46	16.2	1.3	5847.00	1949.0	233.9	2586.05	1034.4	206.9	0.40	0.8	0.2	**763**
72	QST25A	37.87	18.9	1.5	27.00	9.0	1.1	1002.50	401.0	80.2	1.80	3.6	0.7	**158**
73	QST26A	41.33	20.7	1.7	77.00	25.7	3.1	1001.50	400.6	80.1	1.80	3.6	0.7	**141**
74	S112	56.67	28.3	2.3	71.96	24.0	2.9	5.76	2.3	0.5	0.49	1.0	0.2	**28**
75	S113	44.29	22.1	1.8	32.97	11.0	1.3	12.01	4.8	1.0	0.41	0.8	0.2	**32**
76	S115	64.60	32.3	2.6	70.90	23.6	2.8	12.01	4.8	1.0	2.06	4.1	0.8	**32**
77	VC1	220.00	110.0	8.8	24.82	8.3	1.0	506.72	202.7	40.5	4.68	9.4	1.9	**93**
78	VC2	157.50	78.8	6.3	21.27	7.1	0.9	355.42	142.2	28.4	1.05	2.1	0.4	**78**
79	VC3	131.67	65.8	5.3	74.45	24.8	3.0	9.61	3.8	0.8	0.51	1.0	0.2	**38**
80	VC4	115.00	57.5	4.6	15.95	5.3	0.6	142.17	56.9	11.4	0.81	1.6	0.3	**52**
Si		**200.00**			**300.00**			**250.00**			**50.00**			
wi		**2.00**			**3.00**			**5.00**			**5.00**			
Rwi		**0.08**			**0.12**			**0.20**			**0.20**			