CHAPTER 3

RESULTS AND DISCUSSION

Due to the whole course of the experiment dealt with the measurement of fluoride ion by an ion selective electrode, therefore an evaluation of the electrode condition that still be usable for the measurement is necessary in order to ensure the obtained result.

3.1 Performance evaluation of fluoride ion selective electrode.

An evaluation for the effectiveness of the electrode performance must be checked for the first use and later on from time to time. The least time consuming method is the two-point measurement of which the potentials of two fluoride standard solutions are measured and the difference of their potentials would indicate how good the response condition of the electrode in its present state. Table 3.1 shows the voltage response of the electrode at different concentrations of fluoride ion.

Table 3.1 The voltages of the standard solutions and the slope

Fluoride concentration (mg/l)	Voltage (mV)	Slope (mV)
1	118	118-60=58
10	60	

It can be seen from the difference of the voltage which is 58 mV. This figure conforms to the value of the slope which derived from the Nernst equation that can be presented as E_{ISE} = k-0.059log[F]. Therefore, at tenfold difference of the concentration, the potential difference would be equal to 0.059 V or 59 mV. Thus, the value obtained in this evaluation will certainly show that the electrode used in this experiment is still in a good condition. However, it was noticed that the response of the electrode to the solution of low concentration was slightly more sluggish than the higher concentration. So throughout the experiments in this research work the electrode was allowed to be equilibrated for 3 minutes before reading was taken.

3.2 Preparation of a calibration graph

In order to determine the concentration of fluoride in all studied solution, a calibration graph was established by plotting the logarithmic concentration of the fluoride and its corresponding potential measurement. Table 3.2 and Figure 3.1 represent a data set and a calibration curve for fluoride determination.

Table 3.2 Logarithm of the concentration and the voltage of the standard fluoride solutions

Concentration of standard fluoride solution (mg/l)	Log of concentration	Voltage (mV)
0.2	-0.699	152
0.4	-0.398	135
0.8	-0.097	117
1.2	0.079	106
2	0.301	93
4	0.602	75

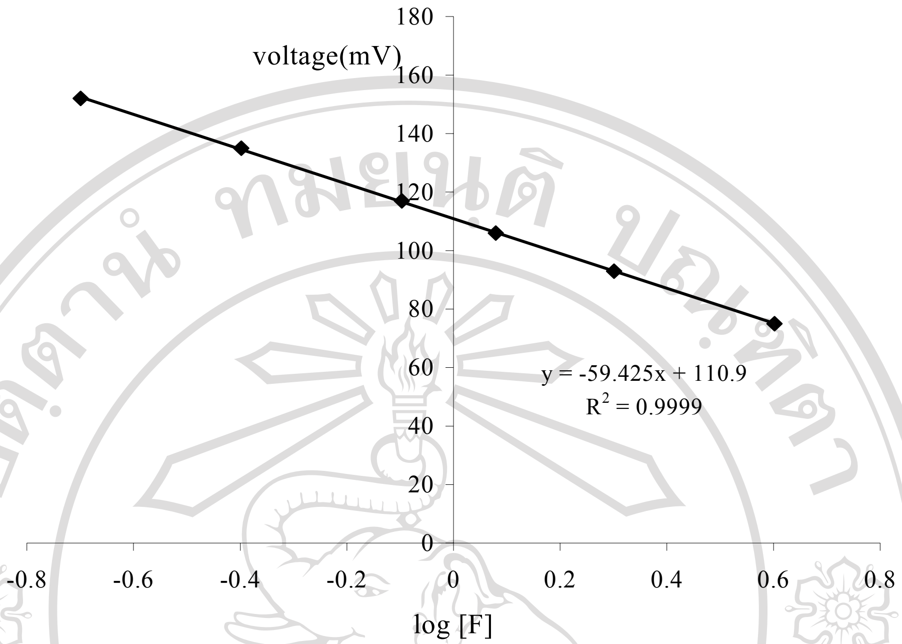

Figure 3.1 Calibration graph of the standard fluoride solutions

From the calibration curve, its slope also confirms how good the condition of the electrode. The value of slope obtained this time is also 59.425 mV which agrees well with the value obtained from the two-point measurement method.

3.3 Determination of the equilibration time for fluoride adsorption on firebrick

Normally, the study of the optimum equilibration time was necessary to be carried out in order to know the time required for equilibrating fluoride solution with the firebrick. In this research, the times allowed for equilibrium to be established were selected as the interval of 0.5, 1, 1.5, 2, 2.5 and 3 hours, respectively. The results are illustrated in Table 3.3 and Figure 3.2.

Table 3.3 Residual fluoride concentration remained after equilibrating at different time intervals

Time (hr.)	Voltage 1 (mV)	Voltage 2 (mV)	Voltage 3 (mV)	Average (mV)	Residual fluoride concentration (mg/l)
0.0	N/A	N/A	N/A	N/A	10.00
0.5	123	125	122	123.3	0.618
1.0	134	135	133	134.0	0.409
1.5	135	134	135	134.6	0.398
2.0	136	135	136	135.6	0.383
2.5	138	137	135	136.6	0.368
3.0	138	136	136	136.6	0.368

Remark: The potential of the fluoride solution with initial concentration of 10 mg/l was not measured in the experiment (N/A= not available)

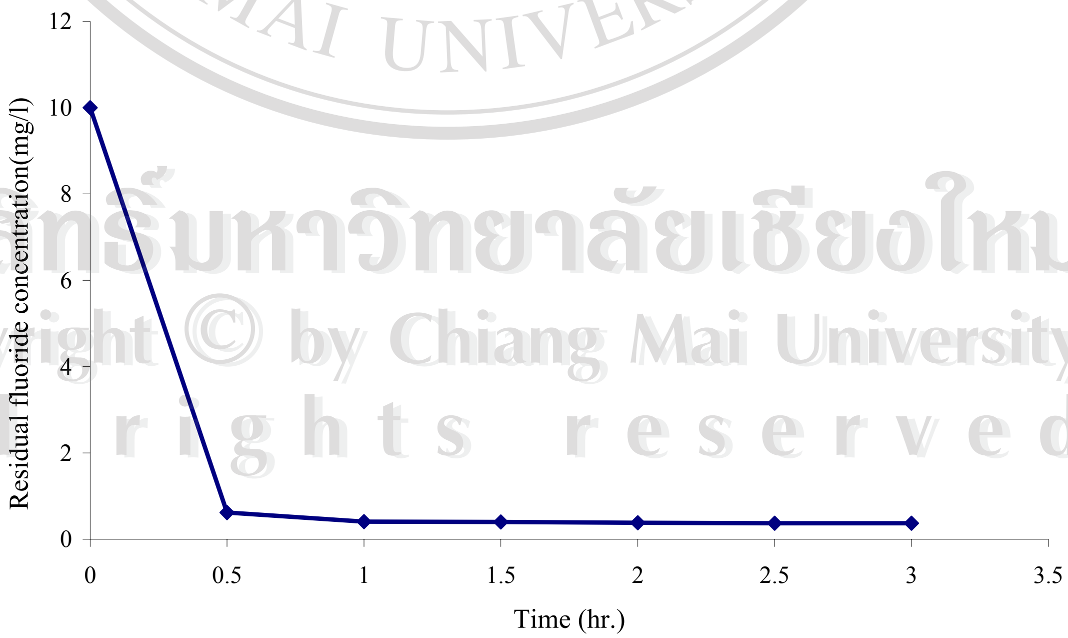

Figure 3.2 Residual fluoride concentration remained at different equilibrating periods

After 15g of firebrick was equilibrated with 15 ml of 10 mg/l NaF solution at different periods of time, the residual fluoride concentration was determined. The equilibration time for fluoride adsorption was then evaluated by monitoring the reduction of fluoride ion in the solution until the residual concentration remained nearly constant. The residual concentrations of fluoride at different equilibration time and its graph are presented in Table 3.3 and Figure 3.2. It can be clearly seen from the graph that with such adsorption condition, the fluoride concentration decreases drastically within the first half an hour of equilibration, then its decrease turns out to be very slightly afterward. Therefore, in order to ensure the equilibrium is reached, one hour of equilibration time seems to be appropriate for using throughout the course of the research. Time-dependent adsorption behavior of firebrick is a “no surprise” phenomenon like adsorption of other adsorbents.

The rate of fluoride adsorption can be explained by the movement of fluoride ion. The fluoride ions in the bulk solution can move to the bare surface of firebrick very swiftly at the early stage. After the fluoride ions have been built up at the adsorption site on the surface of firebrick, a further movement of fluoride ions from bulk solution would be retarded due to the negatively charge repulsion. However, the adsorption of fluoride can still linger on at a longer period of exposure due to the penetrating ability of the fluoride into the pore of the firebrick.

3.4 pH effect on fluoride adsorption on firebrick

The influence of the initial pH of fluoride solution on the amount of fluoride adsorption on firebrick was another interesting factor needed to be studied. This study was conducted to see the effect of pH ranging from 3 to 9 on the adsorption and to find the optimum pH that yields the maximum amount of fluoride removed. The adsorption experiment were carried out by putting 15 g firebrick into the fluoride solution of which the concentration was varied from 10-400 mg/l along with the variation of the pH in the range of 3-9. After equilibrating as described, the fluoride concentration was determined from its potential measurement. The results are shown in Table 3.4 and Figure 3.3.

Table 3.4 Residual fluoride concentrations and the amount adsorbed fluoride at different pH

Initial concentration (mg/l)	pH	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (μmol/g)
10	3	15.09	122	0.851	0.479
	4	15.45	124	0.820	0.469
	5	15.33	144	0.567	0.486
	6	15.05	140	0.610	0.493
	7	15.04	149	0.518	0.497
	8	15.14	144	0.567	0.492
	9	15.01	149	0.518	0.499
20	3	15.17	137	0.646	1.007
	4	15.47	134	0.682	0.986
	5	15.04	129	0.748	1.011
	6	15.32	132	0.708	0.994
	7	15.15	134	0.682	1.007
	8	15.29	134	0.682	0.997
	9	15.28	130	0.734	0.954

Table 3.4 (continued)

Initial concentration (mg/l)	pH	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (μmol/g)
50	3	15.15	114	4.391	3.348
	4	15.12	126	3.953	2.404
	5	15.02	127	9.880	2.424
	6	15.54	130	3.672	2.353
	7	15.15	121	3.672	2.379
	8	15.81	120	4.415	2.276
	9	15.21	126	3.953	2.390
70	3	15.34	115	4.841	3.353
	4	15.79	115	4.841	3.257
	5	15.21	106	5.714	3.336
	6	15.09	112	5.116	3.394
	7	15.50	113	5.023	3.309
	8	15.32	115	4.841	3.357
	9	15.17	113	5.023	3.381
100	3	15.04	101	12.532	4.591
	4	15.17	103	12.079	4.575
	5	15.13	96	13.742	4.509
	6	15.57	100	12.765	4.339
	7	15.15	99	13.003	4.339
	8	15.23	103	12.079	4.557
	9	15.58	98	13.244	4.396

Table 3.4 (continued)

Initial concentration (mg/l)	pH	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (μmol/g)
150	3	15.36	96	27.484	6.297
	4	15.88	87	32.442	5.844
	5	15.67	94	28.516	6.120
	6	15.63	91	30.136	6.054
	7	15.22	90	30.136	6.188
	8	15.18	84	34.286	6.018
	9	15.65	86	33.045	5.899
300	3	15.60	106	45.717	12.86
	4	15.04	91	60.273	12.58
	5	15.27	98	52.979	12.77
	6	15.12	109	43.258	13.40
	7	15.69	101	50.130	12.57
	8	15.06	94	57.032	12.73
	9	15.41	103	48.316	12.89
400	3	15.56	96	68.710	16.88
	4	15.34	98	66.224	17.17
	5	15.15	95	69.662	17.19
	6	15.51	101	63.827	17.17
	7	15.36	100	63.827	17.27
	8	15.21	99	65.015	17.38
	9	15.31	95	69.988	17.01

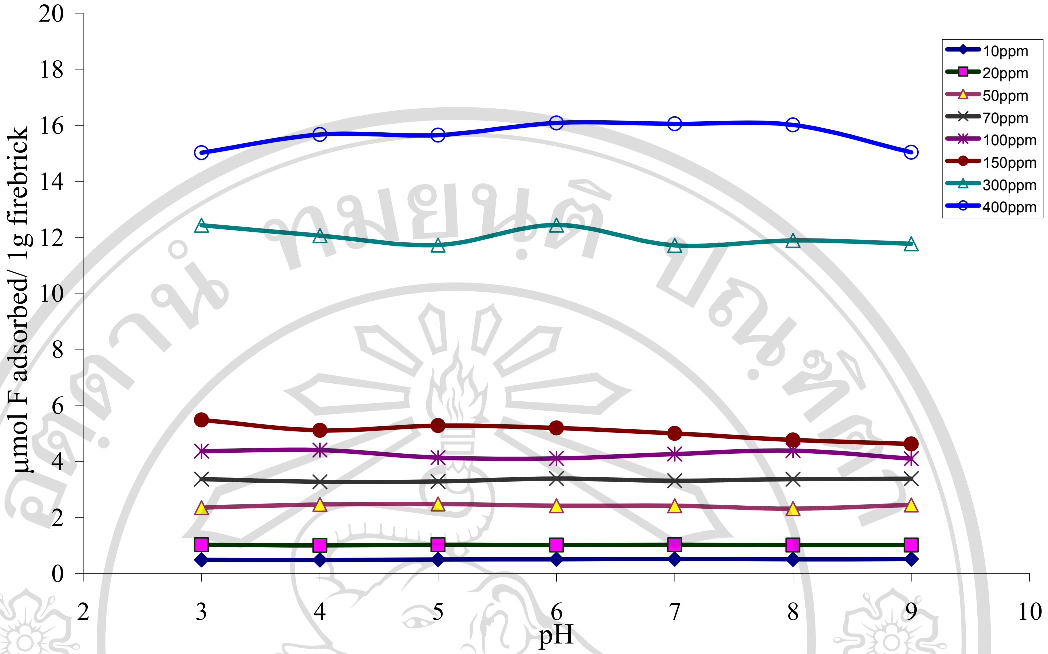

Figure 3.3 Effect of pH on fluoride adsorption at different initial fluoride concentrations

From Table 3.4 and Figure 3.3, it reveals definitely that pH of the fluoride solution posed no effect on the fluoride adsorption by the firebrick throughout the pH range studied. Eventhough, at high initial concentration, slight variation on the adsorbed amount of fluoride on the firebrick as the pH change occurred, but this may be due to the error in measuring the high concentration of ion by fluoride electrode. This pH independent effect of fluoride adsorption on firebrick therefore demonstrates the nature of fluoride removal which is quite conclusive to be purely adsorption because no matter what forms of fluoride will be present in the solution, the adsorption still occurs. Comparing to the removal process that occurs with the bone char, the pH-dependent adsorption phenomena proves its ion exchange nature where less removal appears at low pH due to the existence of unadsorbed molecular HF form.

3.5 Adsorption Isotherm

In order to understand the nature of adsorption occurring on the surface of firebrick, adsorption isotherm at different temperatures was aimed for a study. In this research work, there different temperatures, i.e. 30, 40 and 50 ^oC were selected for the isotherm study. This was done by adding a fixed amount of firebrick into the standard fluoride solution of which its initial concentration was varied from 10 to 400 mg/l. The equilibrium (or residual) concentration of fluoride for each equilibration was then measured and the results obtained at each temperature are presented in Table 3.5-3.8 and Figure 3.4-3.7.

Table 3.5 Adsorption isotherm data at 50 ^oC

Initial concentration (mg/l)	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (μmol/g)
10	15.25	142	0.356	0.499
20	15.51	131	0.579	0.988
50	15.42	136	2.319	2.441
70	15.38	130	2.953	3.496
100	15.52	121	8.509	4.654
150	15.51	121	17.38	6.748
300	15.45	106	62.44	12.13
400	15.23	103	86.31	16.26

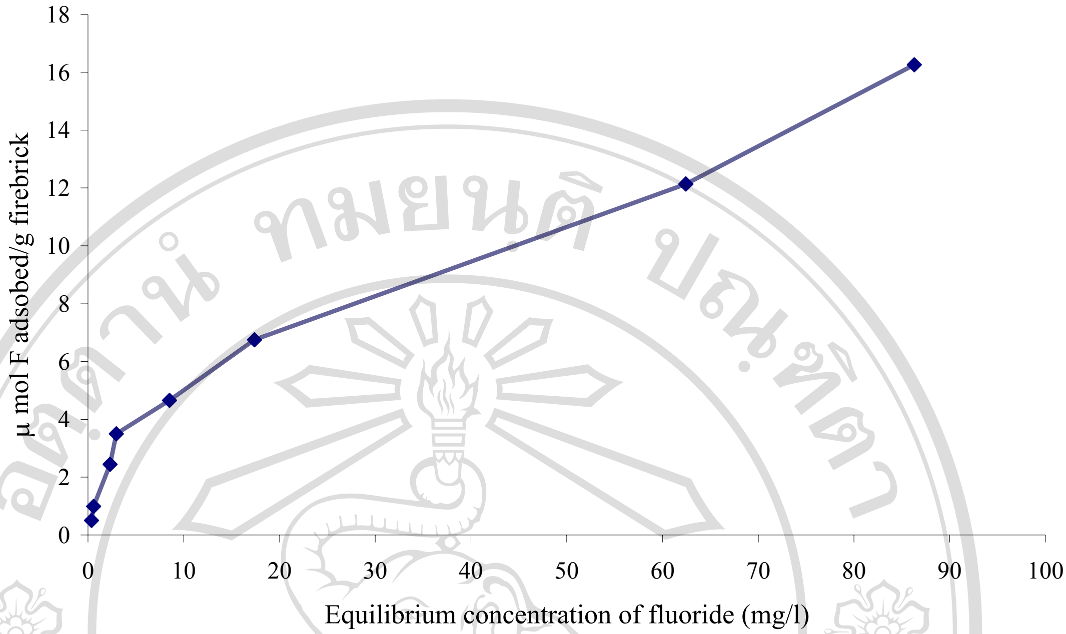

Figure 3.4 Adsorption isotherm of fluoride on firebrick at 50 ^{o}C

Table3.6 Adsorption isotherm data at 40 ^{o}C

Initial concentration (mg/l)	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (μmol/g)
10	15.52	139	0.410	0.487
20	15.33	130	0.579	0.998
50	15.53	140	1.972	2.440
70	15.24	128	3.205	3.450
100	15.25	119	9.036	4.709
150	15.63	122	15.37	6.800
300	15.28	104	66.31	12.07
400	15.47	101	93.73	15.62

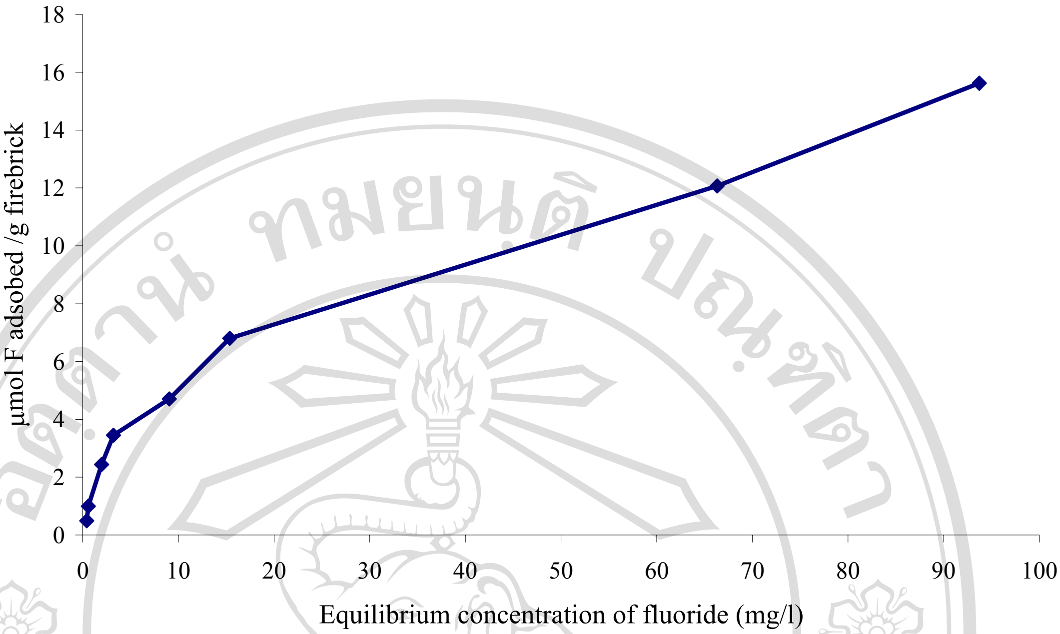

Figure 3.5 Adsorption isotherm of fluoride on firebrick at 40 °C

Table 3.7 Adsorption isotherm data at 30°C

Initial concentration (mg/l)	Average weight of firebrick (g)	Average voltage (mV)	Equilibrium fluoride concentration (mg/l)	Specific amount of adsorbed fluoride (µmol/g)
10	15.62	136	0.463	0.481
20	15.36	125	0.708	0.991
50	15.35	135	2.369	2.452
70	15.14	125	3.616	3.406
100	15.14	119	9.226	4.733
150	15.17	118	19.595	6.786
300	15.28	103	70.503	11.85
400	15.26	100	101.47	15.47

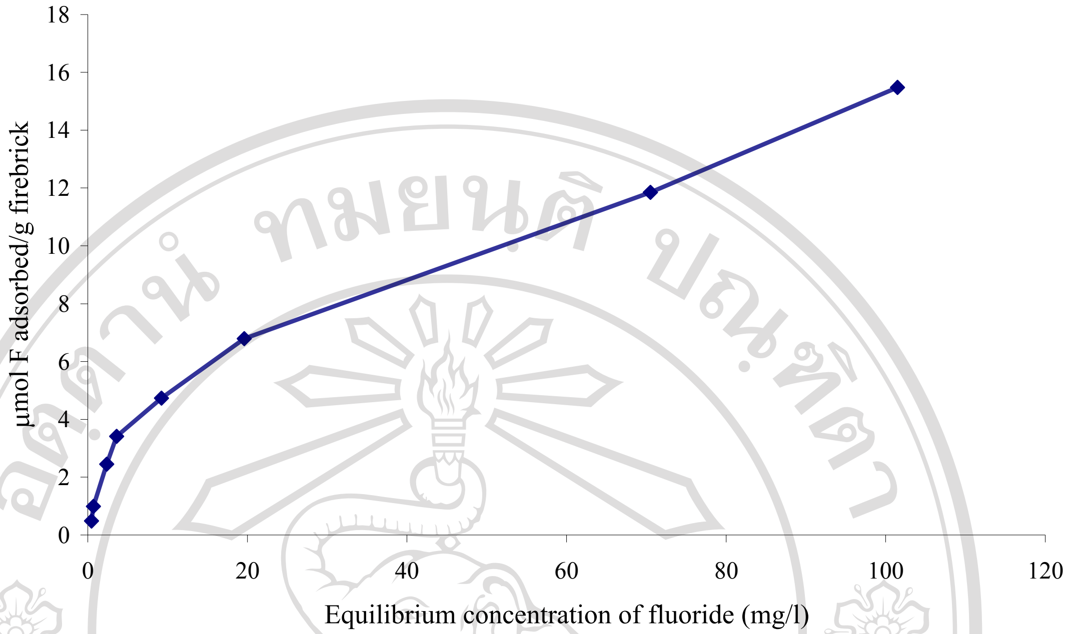

Figure 3.6 Adsorption isotherm of fluoride on firebrick at 30 °C

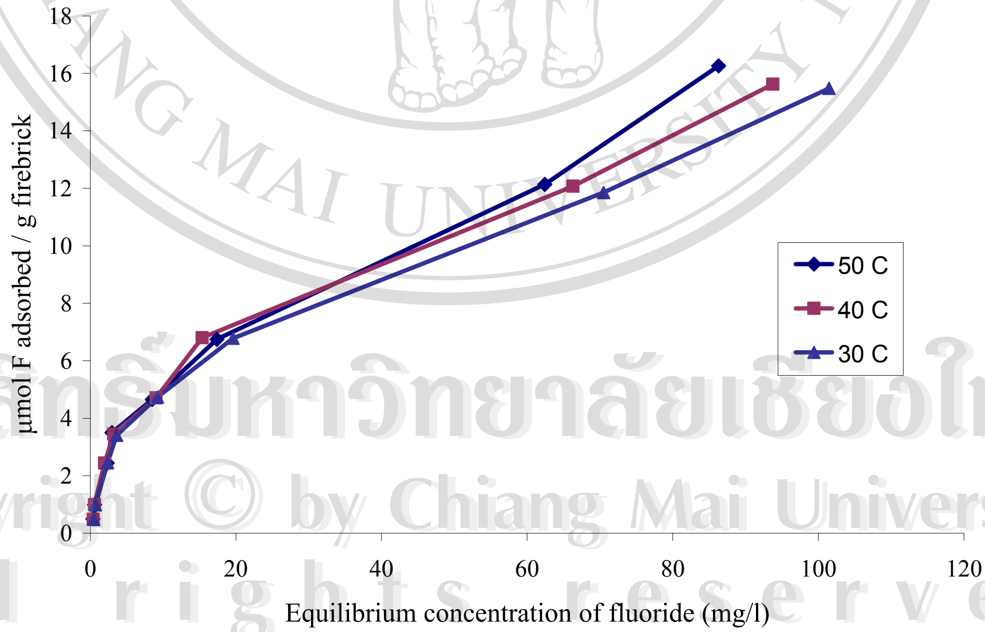

Figure 3.7 Adsorption isotherms at 30, 40 and 50 °C

From the Table 3.5-3.8 and Figure 3.4-.3.7, it reveals that the temperature of adsorption posed a slight effect on fluoride adsorption by firebrick. When the initial fluoride concentration was increased, the amount of adsorbed fluoride on firebrick was also increased. From the characteristic of the adsorption isotherm curve indicates that the adsorption on the surface of firebrick is not a monolayer type because the amount of adsorbed fluoride did not reach any saturation with the increase of the initial fluoride concentration. So, it can be concluded that the fluoride adsorption behavior of the firebrick was found not to be a Langmuir type.

Based on the adsorption isotherm of fluoride at various temperatures, if we assume that, at the point of inflection of the curve, the monolayer adsorption on the first layer of firebrick is depleted. The capacity of the firebrick for fluoride adsorption will be about 3.6 μmol/g.

Table 3.8 Logarithm of the residual fluoride concentration at various temperatures (lnC) and the reciprocal of temperature (1/T)

Temperature (^oC)	Temperature (K)	1/T ($10^{-3}K^{-1}$)	Concentration (10^{-3}M)	ln C
30	303	3.30	0.190	-1.65
40	313	3.19	0.169	-1.77
50	323	3.09	0.155	-1.86

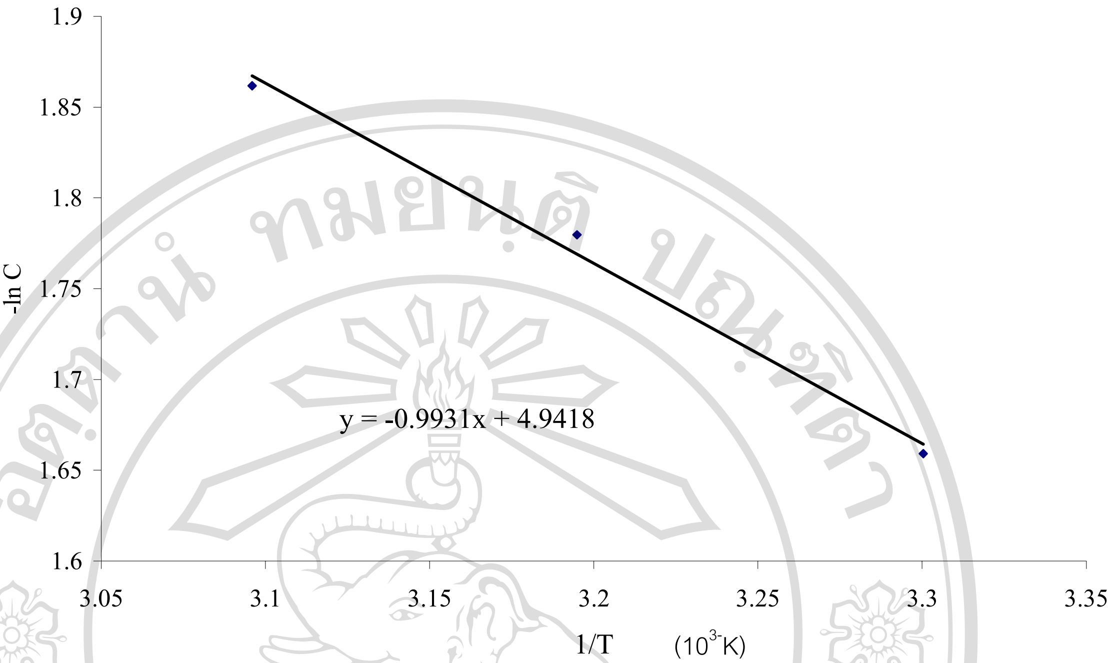

Figure 3.8 The relationship between logarithm of the residual fluoride concentration and the reciprocal of temperature

From Figure 3.8, the slope is +0.9931. The heat of adsorption ($\triangle H_{ads}$) can be calculated by using the slope of the graph. The heat of adsorption on firebrick is 8.26 $kJmol^{-1}$. Heat of adsorption is positive, so the adsorption should be endothermic. Since the heat of adsorption is lower than 20 $kJmol^{-1}$, therefore, the type of adsorption should be classified as physical adsorption.

3.6 The study of interfering ion on the adsorption of fluoride on firebrick.

Due to the nature of most adsorbents that they are not selective on adsorption of any particular type of ions, especially those involving with physical adsorption. Therefore, in the case of firebrick, it is not an exceptional that the adsorption of fluoride amidst other ions present in the solution may possibly have some competitive effects among one another. Thus, the adsorption of fluoride on firebrick in the presence of both cations and anions at different weight ratio ranging from 1:1 to 1:100 was studied and result are shown in Table 3.9 and Figure 3.9.

Table 3.9 Residual fluoride concentration in solution at various mass ratios of other ions and fluoride

Ratio of fluoride:other ions (by weight)	Residual fluoride concentration (mg/l)						
	SO_4^{2-}	NO_3^-	Cl^-	PO_4^{3-}	Na^+	Mg^{2+}	Ca^{2+}
1:0	0.34	0.34	0.34	0.34	0.34	0.34	0.34
1:1	0.42	0.48	0.47	0.38	0.46	0.320	0.25
1:10	0.43	0.37	0.39	0.42	0.42	0.29	0.26
1:25	0.40	0.38	0.42	0.42	0.37	0.27	0.25
1:50	0.37	0.37	0.42	0.43	0.373	0.24	0.26
1:100	0.44	0.35	0.45	0.40	0.37	0.21	0.22

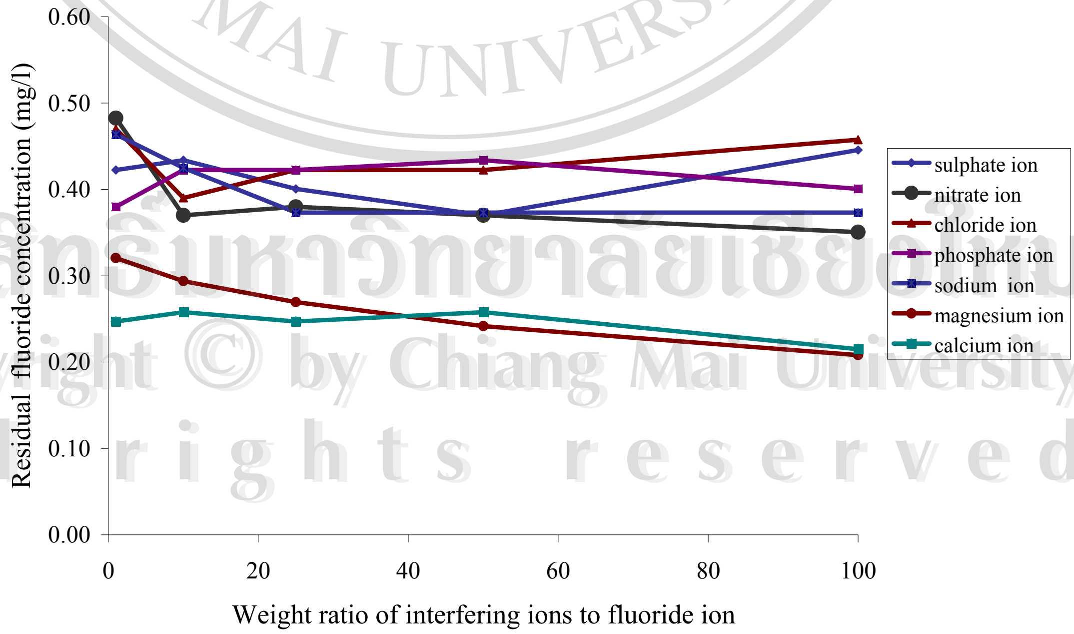

Figure 3.9 The effect of interfering ions on fluoride adsorption on the firebrick

Considering the results presented in the graphical form as the interfering ions posed the effect on the fluoride adsorption, it can be seen that once the ions are present, especially the anions and sodium ion, they can be slightly influential in competing with fluoride but not significantly. The residual fluoride concentration; which is reduced from the initial concentration of 10 mg/l, remaining in the solution is still considered to vary minimally and it is regarded to be almost constant except in the presence of Mg^{2+} and Ca^{2+}. These two doubly charged cations interfered the adsorption by causing the ion-pair formation or even forming the compounds of MgF_2 and CaF_2. Therefore, more fluoride ions were diminished from the solution when more amounts of the cations were added into the fluoride solution. The presence of these cations on the amount at a hundred times of the fluoride evidently shows its interfering effect. However, the graphical presentation in Figure3.9 may be slightly exaggerated due to the exploded scaled on Y axis for the sake of a clear depiction.

Regarding an insignificant influence of the interesting anions and Na^{+}, all the potential readings obtained from the ISE measurement that show the change in the residual fluoride concentration may not arise from these interfering ions, but it may be due to the interfering effect of the ions to the response of the electrode itself.

3.7 Estimation of the appropriate amount of firebrick for packing in the column.

The quantity of the adsorbent significantly influenced the extent of defluoridation, so the evaluation of fluoride adsorption performance of the firebrick in a flow through system has been done. To conduct the experiment with a packed column, a glass column (I.D. 8cm. and height 75 cm.) was filled with 400, 800 and 1200g of firebrick, respectively. The fluoride solution with a concentration at 10 mg/l was allowed to flow down the column with a flow rate of 3 ml/min. Sample of the effluent were periodically collected and analyzed for the remaining concentration of fluoride. The results are shown in Table 3.10 and Figure 3.10.

Table 3.10 The residual concentration of fluoride solution after passing through the packed column of firebrick.

Volume (ml)	Firebrick 400g		Firebrick 800g		Firebrick 1200g	
	Voltage (mV)	Residual fluoride concentration (mg/l)	Voltage (mV)	Residual fluoride concentration (mg/l)	Voltage (mV)	Residual fluoride concentration (mg/l)
100	152	0.312	147	0.386	148	0.370
200	145	0.420	138	0.564	137	0.589
300	144	0.438	140	0.519	138	0.564
400	140	0.519	143	0.457	139	0.542
500	141	0.497	148	0.370	144	0.438
600	140	0.519	150	0.340	147	0.386
700	138	0.564	152	0.312	150	0.340
800	135	0.641	154	0.287	152	0.312
900	131	0.759	155	0.275	152	0.312
1000	127	0.899	155	0.275	154	0.287
1200	122	1.110	154	0.287	156	0.264
1400	117	1.372	152	0.312	156	0.264
1800	100	2.813	144	0.438	156	0.264
2000	96	3.332	140	0.519	155	0.275
2250	95	3.475	134	0.668	154	0.287
2500	95	3.475	128	0.862	154	0.287

Table 3.10 (continued)

Volume (ml)	Firebrick 400g		Firebrick 800g		Firebrick 1200g	
	Voltage (mV)	Residual fluoride concentration (mg/l)	Voltage (mV)	Residual fluoride concentration (mg/l)	Voltage (mV)	Residual fluoride concentration (mg/l)
2750	94	3.625	121	1.158	154	0.287
3000	90	4.293	114	1.557	153	0.299
3500	87	4.873	106	2.183	152	0.312
4000	82	6.020	100	2.813	150	0.340

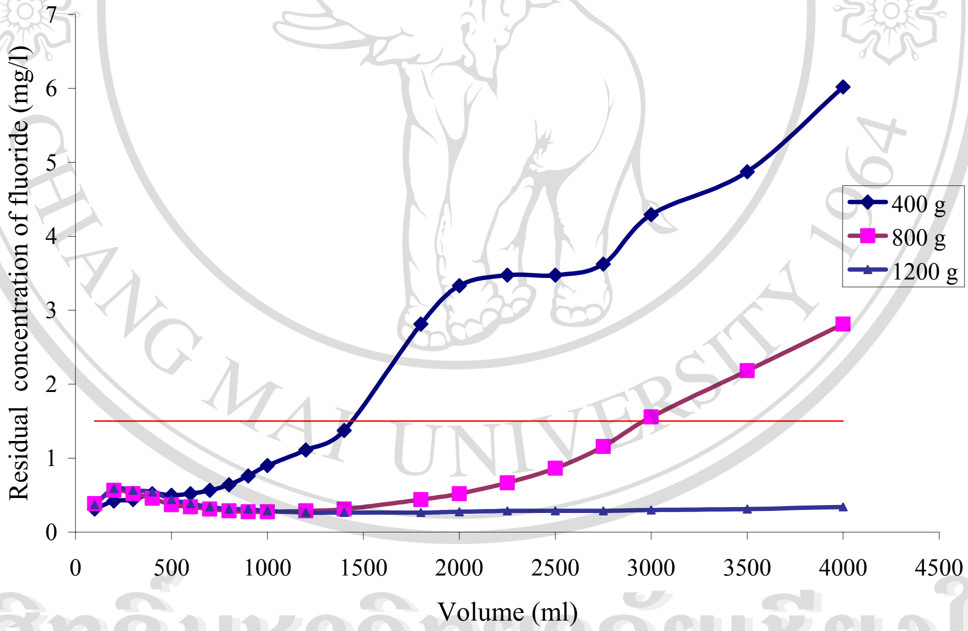

Figure 3.10 Variation of residual fluoride concentration in synthetic water sample by using different amount of firebrick

Inspection of the result presented in Table 3.10 and Figure 3.10 showed that the quantity of fluoride adsorption increases with the increasing amount of firebrick. When a solution with fluoride concentration of 10 mg/l was passed through the column, the amount of fluoride in the sample was reduced by the same extent within the first five hundred milliliters of the effluent. After this volume, the column with 400 g of firebrick started loosing its capability in removing the fluoride and the concentration of fluoride in the effluent began rising up until the threshold level of 1.5 mg/l was broken at the volume around 1.5 liters. For the column with higher amount of firebrick, its trend in fluoride removal was as expected.

The column with 800 g of firebrick, the level of fluoride in the effluent began departing from the low level of 0.28 mg/l and rising up till breaking the 1.5 mg/l barrier at the effluent volume of three liters which was twice the volume obtained from the 400 g column. Therefore, the column packed with 1200 g of firebrick was evidently capable of removing the fluoride to the level below 1.5 mg/l fore more than four liters and seem to be more than three time of the volume obtained with the 400 g column. This column operation on the effect of packing content proved to be a standard phenomenon because higher amount of packing should provide more capacity due to the increase of surface area.

3.8 Effect of the flow rate

The contact time is another important factor which would affect the adsorption. The effect of flow rate was therefore considered by making an investigation using a packed column of 1200 g firebrick. The water containing 10 mg/l of fluoride was allowed to flow down the column at the flow rate of 3, 5, 7 and 9 ml/min, respectively. Fraction sampling and assaying of the residual fluoride level were done and the results are shown in Table 3.11 and Figure 3.11.

Table 3.11 Residual concentration of fluoride in water after passing through the column

Volume (ml)	Residual fluoride concentration (mg/l) at a flow rate of			
	3 ml/min	5 ml/min	7 ml/min	9 ml/min
100	0.605	0.370	0.914	0.435
200	0.657	0.589	0.993	0.744
300	0.605	0.564	0.914	0.775
400	0.493	0.541	0.685	0.657
500	0.401	0.438	0.557	0.557
600	0.340	0.386	0.401	0.473
700	0.300	0.340	0.435	0.418
800	0.254	0.312	0.401	0.401
900	0.244	0.312	0.384	0.369
1000	0.225	0.287	0.369	0.354
1200	0.207	0.264	0.369	0.354
1400	0.207	0.264	0.369	0.369
1600	0.216	0.264	0.369	0.369
1800	0.225	0.264	0.384	0.493
2000	0.234	0.275	0.435	0.401
2250	0.244	0.287	0.535	0.557
2500	0.288	0.287	0.657	0.685
2750	0.354	0.287	0.744	1.035

Table 3.11 (continued)

Volume (ml)	Residual fluoride concentration (mg/l) at a flow rate of			
	3 ml/min	5 ml/min	7 ml/min	9 ml/min
3000	0.418	0.299	0.953	1.272
3500	0.493	0.477	1.221	1.500
4000	0.605	0.987	1.439	1.769
5000	0.990	1.431	2.174	2.564
5500	1.221	1.550	2.460	3.024
6000	1.563	1.923	2.672	3.024
6500	1.698	2.277	2.784	3.283
7000	2.002	2.478	3.151	3.827
7500	2.360	2.697	3.422	4.382
8000	2.564	2.813	3.716	4.566

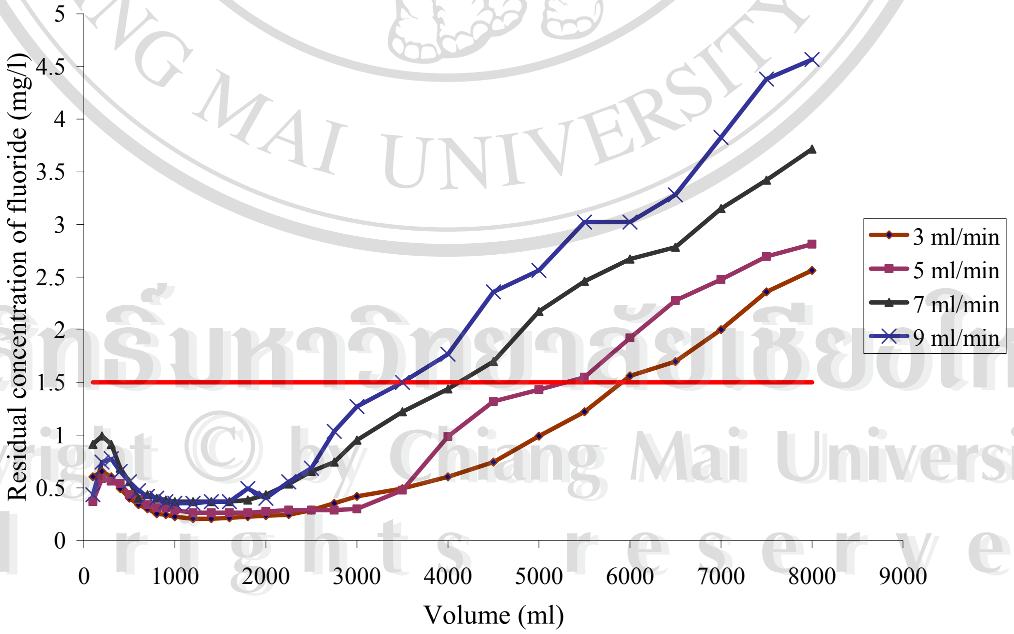

Figure 3.11 Variation of residual fluoride concentration in synthetic water sample by using different flow rate

From the result, when a packed column of 1200g firebrick was used to remove the fluoride at different flow rates (3, 5, 7 and 9 ml/min) and its content in the effluent was monitored. It was found that the effluent obtained with a flow rate of 3 ml/min resulting in the removal of fluoride content in solution from 10 mg/l to below 1.5 mg/l about 6 liters. While the operation at the flow rate of 5, 7 and 9 ml/min respectively, was able to defluoridate water up to the volume about 5.5, 4 and 3.5 liters respectively. This flow rate dependent performance of the firebrick column obviously proves that the slower the flow rate, the better the fluoride removing performance. This is because the contact time between fluoride ion and a firebrick for slower flow rate is longer allowing the adsorption to occur in a higher extent.

From the results of column study, it can also be seen that the fluoride removal capacity of the firebrick (3.6μmolF/g at 30 ^{0}C) is not high compared to bone char (225 μmol/g)[34] because firebrick used in the experiment has a bigger particle size and possibly possesses less porosity. So the surface area of 1 g bone char should be larger than 1g of firebrick. Comparing with the Padmasiri's column (I.D. 22.5 cm., height 95.0 cm.)[33] which was filled with burnt brick chip as an adsorption media staring with water with fluoride content of 3.0 mg/l, this filtering unit could keep a fluoride content below 1.0 mg making the capacity of the column at 15 liters/day. Hence the efficiency of the column in this experiment seems to be more than the Padmasiri's column due to the fact that initial concentration of fluoride in the experiment was higher and the size of column was smaller than the Padmasiri's defluoridator.

3.9 Defluoridation of potable water samples

In addition to evaluating the performance of a firebrick column on removing fluoride in the fluoride solution, an extension of applying this column to the potable water sample was attempted with the best operating condition of the column (1200g firebrick and flow rate 3ml/min) as listed in Table 3.12. Two water samples were collected from Ban Sankayom at Ma Khuea Chae Subdistrict, in Lamphun province, North of Thailand representing low and high fluoride content. The samples were analyzed for their fluoride and pH as shown in Table 3.13

Table 3.12 The condition for defluoridation of water samples

Item	condition
Column	8 cm.i.d. x 75 cm. height
Amount of firebrick	1200g
Flow rate	3 ml/min
Temperature	Room temperature

Table 3.13 Samples information

Sample No.	Initial concentration (mg/l)	pH	Remark
1	8.21	7.76	deep well
2	4.32	7.21	shallow well

After allowing the water sample to pass the defluoridating column, every one hundred milliliters of the effluent was collected for analyzing the residual fluoride concentration until the total volume reached 1 liter. Later on, the increment of 250, 500 and 1000 milliliters were collected respectively for every following 1 liter of the effluent. The result of such analyses was presented in Table 3.14 and Figure 3.12.

Table 3.14 Residual concentration of fluoride content in water after passing through the column of firebrick

Volume (ml)	Residual fluoride concentration(mg/l) Sample 1.	Residual fluoride concentration(mg/l) Sample 2.
100	0.432	0.242
200	0.512	0.255
300	0.380	0.255
400	0.270	0.255
500	0.200	0.255
750	0.292	0.261
1000	0.200	0.265
1250	0.200	0.268
1500	0.245	0.270
1750	0.292	0.276
2000	0.310	0.279
2500	0.450	0.281
3000	0.450	0.297

Table 3.14 (continued)

Volume (ml)	Residual fluoride concentration(mg/l) Sample 1.	Residual fluoride concentration(mg/l) Sample 2.
3500	0.450	0.320
4000	0.450	0.396
4500	0.534	0.421
5000	0.931	0.450
6000	1.153	0.972
7000	1.393	1.058
8000	1.882	1.173

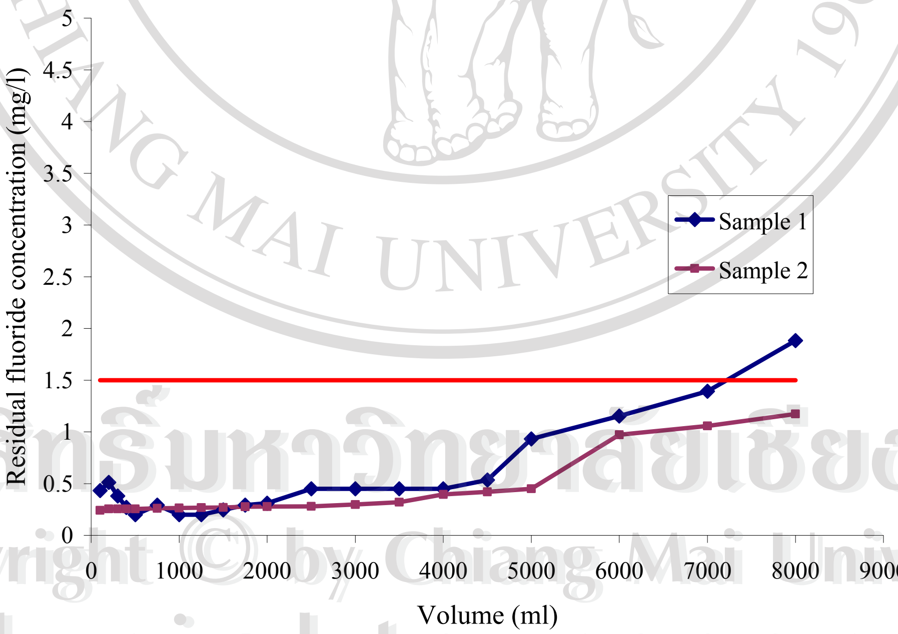

Figure 3.12 Residual fluoride concentration in water samples

It can be clearly seen from the graph that the firebrick column was again capable for removing fluoride in potable water, its tolerant level of the column was broken down after the treated water sample were collected cumulatively up to 7 and more than 8 liters for sample number 1 and 2, respectively. The qualities of the treated water are visually clear without any unpleasant smell. Therefore, the treated water is readily in suitable condition for consuming.