CHAPTER 3 RESULTS AND DISCUSSION

3.1 Effect of pH on Sorption Efficiency of Cs-137 onto Dowex 50Wx10

From the results of the study in section 2.7 (Table 3.1 and Figure 3.1), it was found that pH effect on sorption efficiency of the ion exchange resin was not observed in the range of pH 2 to 7.

Generally, it can be measured quantitatively from pH 2 to pH 8. It can be concluded that effect of pH (2-8) on sorption efficiency of the ion exchange resin is negligible.

Table 3.1-Effect of pH on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin in various media (100 ml) (batch system)

pH	Sorption efficiency (%)		
	Deionized water	NaCl (0.02 M)	Tap water
1	80	76	82
2	92	98	98
3	91	95	94
5	92	99	94
7	91	97	91
8	85	96	91

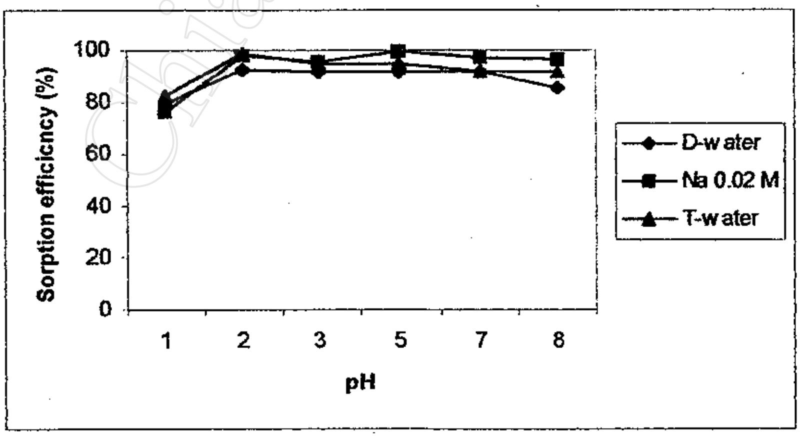


Figure 3.1- Effect of pH on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin in various media (100 ml) (batch system)

3.2 Effect of Sample Volume on Sorption Efficiency of Ion Exchange Resin

3.2.1 Batch System

3.2.1.1 For I-131

From the results of the study in section 2.8 (Table 3.2 and Figure 3.2), it was found that effect of volume (10-1500 ml) on sorption efficiency of Dowex 1x2 resin for I-131 was not observed in deionized water. However, effect of a volume of ≥ 1000 ml in tap water can be seen. It could be due to the tap water contains some other ions. Generally, it can be measured quantitative sorption can be obtained for a sample volume of 10 to 1000 ml range.

Table 3.2- Effect of sample volume on sorption efficiency of I-131 onto Dowex 1x2 resin (batch system)

Volume	Sorption efficiency (%)	
(ml)	Deionized water	Tap water
10	94	93
100	96	89
500	94	99
1000	96	94
1500	95	65

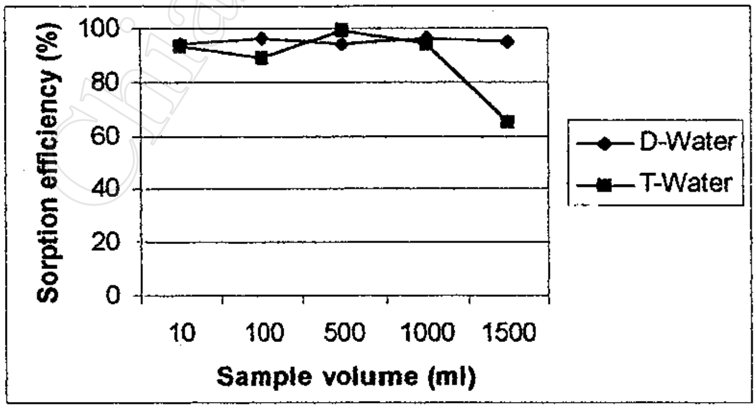


Figure 3.2- Effect of sample volume on sorption efficiency of I-131 onto Dowex 1x2 resin (batch system)

3.2.1.2 For Cs-137

From the results of the study in section 2.8 (Table 3.3 and Figure 3.3), it was found that the larger volume, the less sorption pronounced for Cs-137 in deionized water while in tap water less effect was observed. Qualitative sorption can be obtained only from a sample volume of a 10 ml. It is ratherly different from I-131. In this case, other effects, *i.e.*, surface absorption, should be considered.

Table 3.3-Effect of sample volume on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin (batch system)

Volume	Sorption efficiency (%)	
(ml)	Deionized water	Tap water
10	90	94
100	81	84
500	71	90
1000	65	75
1500	59	83

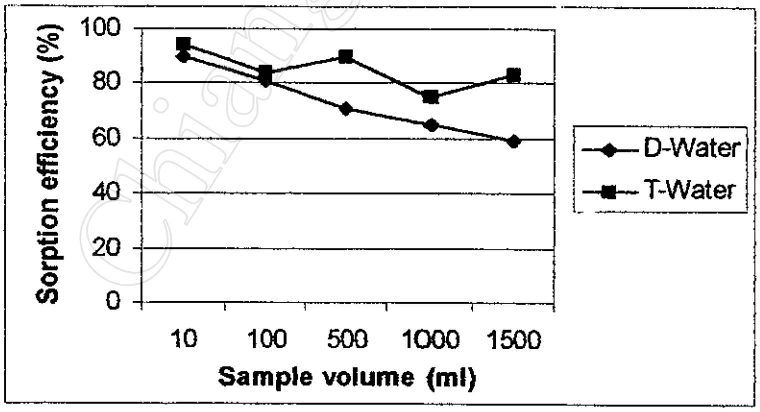


Figure 3.3- Effect of sample volume on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin (batch system)

3.2.2 Continuous System

For Cs-137, opposite observed results were found. From the results (Table 3.4 and Figure 3.4), only sorption of 1500 ml can be obtained quantitatively. It is very different from batch system study. In this case, not only the effect of volume, but also the other effects, flow-rate can affect the system. For continuous system, constant flow-rate (5 ml / min) was used. However, in batch type, flow-rate may be varied (1 – 10 ml / min) in terms of gravity force to sample volume and column backpressure.

Table 3.4-Effect of sample volume on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin (continuous system)

Volume	Sorption efficiency (%)	
(ml)	Deionized water	Tap water
10	55	54
100	44	59
500	43	59
1000	83	61
1500	98	70

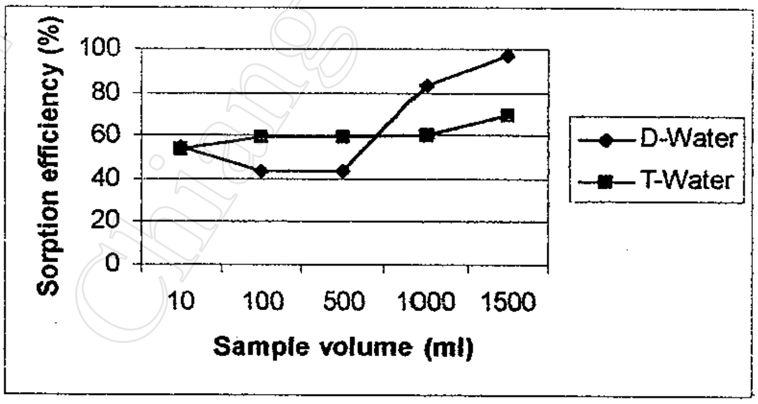


Figure 3.4-Effect of sample volume on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin (continuous system)

3.3 Effects of Some Other Ions on Sorption Efficiencies of the Ion Exchange Resins

In batch system, effect of iodide ion on sorption efficiency of Dowex 1x2 and effect of sodium ion on Dowex 50W were studied. Effect of sodium ion on Dowex 50Wx10 was studied in continuous system.

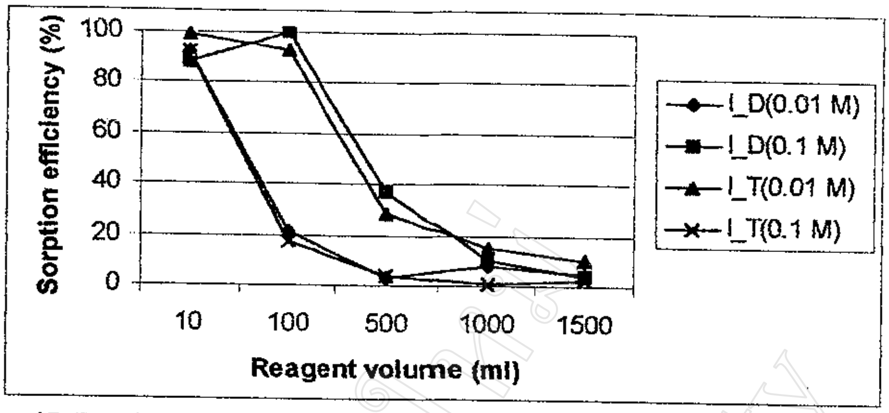
3.3.1 Batch System

3.3.1.1 For I-131

From the results (Table 3.5 and Figure 3.5), effect of iodide ion solution volume on Dowex 1x2 resin can be seen clearly. Sorption efficiency decreased when iodide ion volume increased. Effect of iodide ion concentration should also be considered. In 0.1 M iodide in deionized water, unexpected results for a sample volume of 100 ml was obtained in comparison to others. It may be because of random errors such as excess addition of isotope (I-131), voltage fluctuation, *etc.*

Table 3.5-Effect of volume solution containing I-131 and iodide on sorption efficiency of I-131 onto Dowex 1x2 (batch system)

Volume (ml)	Sorption efficiency (%)			
	(0.01 M) Iodide in deionized water	(0.1 M) Iodide in deionized water	(0.01 M) Iodide in tap water	(0.1 M) Iodide in tap water
10	92	88	99	92
100	21	100	93	17
500	3	37	28	4
1000	8	10	15	1
1500	5	4	10	2



*I_D = iodide in deionized water, I_T = iodide in tap water

Figure 3.5-Effect of volume solution containing I-131 and iodide on sorption efficiency of I-131 onto Dowex 1x2 (batch system)

3.3.1.2 For Cs-137

From Table 3.6 and Figure 3.6, effect of sodium ion concentration on sorption efficiency of Dowex 50W resin is not pronounced for 0.01 and 0.02 M, but for 0.1 M. However, it can be seen that when the volume is increased, the sorption efficiency decreased. It can also be seen that effect of the ion concentration on sorption efficiency of resin is much more than the effect due to volume.

Table 3.6-Effect of volume solution containing Cs-137 and sodium chloride on sorption efficiency of Cs-137 onto Dowex 50Wx10 resin (batch system)

Volume (ml)	Sorption efficiency (%)					
	(0.01 M) Sodium in deionized water	(0.02 M) Sodium in deionized water	(0.1 M) Sodium in deionized water	(0.01 M) Sodium in tap water	(0.02 M) Sodium in tap water	(0.1 M) Sodium in tap water
10	79	85	89	75	77	77
100	80	87	86	75	76	79
500	84	82	66	71	71	82
1000	71	85	36	71	83	38
1500	84	64	27	66	68	34

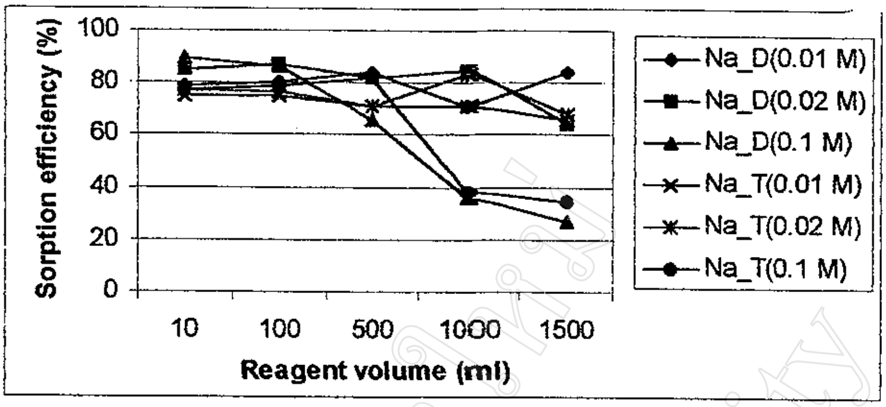


Figure 3.6- Effect of volume solution containing Cs-137 and sodium chloride on sorption efficiency of Cs-137 onto Dowex 50Wx10 Resin (batch system)

3.3.2 Continuous System

Only sorption efficiency of Cs-137 was studied. The results (Table 3.7 and Figure 3.7) indicated that only about 70-80% sorption can be obtained in a medium containing 0.02 or 0.1 M sodium ion when a sample volume of 10-500 or 10-100 ml respectively.

Table 3.7-Effect of volume solution containing Cs-137 and sodium chloride on sorption efficiency of Cs-137 onto Dowex 50Wx10 (continuous system)

Volume (ml)	Sorption efficiency (%)		
	(0.01 M) Sodium in deionized water	(0.02 M) Sodium in deionized water	(0.1 M) Sodium in deionized water
10	60	71	75
100	57	80	77
500	60	72	57
1000	57	64	36
1500	63	30	27

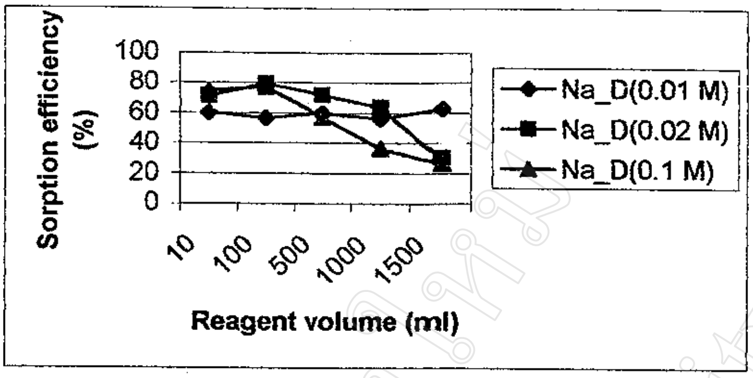


Figure 3.7-Effect of volume solution containing Cs-137 and sodium chloride on sorption efficiency of Cs-137 onto Dowex 50Wx10 (continuous system)

3.4 Determination of Specific Activity by Using Continuous System

In this work, results of specific activity and difference (%) between known activity (expected activity) and experimental or observed value of the activity were performed by using the following equations:

Detector efficiency (η) = 12 %

Expected activity in 100% (A_I) = $[A_m/(\eta \times 60 \times I_{Cs\text{-}137})] \times 10^3$ (Bq/l)

Where A_I = expected activity, A_m = observed activity, $I_{Cs\text{-}137}$ = Intensity of Cs-137

A_m = 6141.82 cpm→ $A_I \cong 10 \times 10^5$ Bq / l, A_m =5991.03 cpm → $A_I \cong 10 \times 10^5$ Bq / l

In the experiment, various solutions containing the same activity, but different volumes (10,100, 500, 1000 and 1500 ml), *i.e.*, different specific activities (1×10^5, 1×10^4, 1×10^3, 1×10^2 and 7×10^2 Bq/l were tried.

It can be derived for the following relationships:

Slope = ΔActivity / ΔTime, Flow rate = 5 ml/min

Specific Activity = slope • 1 / (Flow rate) • 1 / (Eff. of column) • 1 / (Eff. of detector)

Difference (%) = 100 (Expected Activity – Specific Activity) / Expected Activity

From the results (Tables 3.8-3.9 and Figure 3.8), different values were found to be high for most of all solutions with a volume in the range of (10-1500 ml) in deionized water (pure Cs-137 solution without carrier) and in 0.1 M NaCl. The values of differences (%) were acceptable for the solutions with a volume in the range of 100-1000 ml of tap water (spiked with Cs-137 and of Cs-137 containing 0.01-0.02 M NaCl. It can be observed that efficiencies of column were in the range of 60 ± 20%.

Table 3.8- Specific activity determination for Cs-137 contaminated samples (continuous system)

(A) Deionized water

Sr.	ΔActivity (cpm)	ΔTime (min)	Slope (cpm/min)	Column efficiency (%)	Observed activity (Bq/l)
1(a)	1280	5	256.00	58	1.2×10^4
(b)	1097	5	219.40	51	1.2×10^4
2(a)	781	10	7.81	46	4.7×10^3
(b)	579	10	5.79	41	3.9×10^3
3(a)	684	5x10	13.68	44	0.9×10^3
(b)	765	5x10	15.30	43	1.0×10^3
4(a)	1178.3	10x10	11.78	87	3.7×10^2
(b)	934.7	10x10	9.35	79	3.3×10^2
5(a)	774.8	10x10	7.75	100	2.2×10^2
(b)	778.8	10x10	7.79	95	2.3×10^2

(B) Tap water

Sr.	ΔActivity (cpm)	ΔTime (min)	Slope (cpm/min)	Column efficiency (%)	Observed activity (Bq/l)
1(a)	2578	5	515.60	44	3.2×10^4
(b)	4117	5	823.40	62	3.7×10^4
(c)	3454	5	690.80	56	3.4×10^4
2(a)	1492	10	149.2	56	7.4×10^3
(b)	1998	10	199.8	62	9.0×10^3
3(a)	1968	5x10	39.36	58	1.9×10^3
(b)	2004	5x10	40.08	60	1.9×10^3
4(a)	2038.71	10x10	20.39	61	9.2×10^2
(b)	2158.85	10x10	21.59	60	10.0×10^2
5(a)	2152.60	10x10	21.53	71	8.5×10^2
(b)	1818.11	10x10	18.18	69	7.3×10^2

Table 3.8- (Continued)

(C) NaCl (0.01 M)

Sr.	ΔActivity (cpm)	ΔTime (min)	Slope (cpm/min)	Column efficiency (%)	Observed activity (Bq/l)
1(a)	3597.10	5	719.42	59	$3.4 x 10^4$
(b)	3644.07	5	728.81	58	$3.5 x 10^4$
(c)	2934.13	5	586.83	63	$2.6 x 10^4$
2(a)	1556.71	10	155.67	53	$8.2 x 10^3$
(b)	1694.35	10	169.43	61	$7.8 x 10^3$
3(a)	1991.19	5x10	39.82	58	$1.9 x 10^3$
(b)	2078.99	5x10	41.58	62	$1.9 x 10^3$
4(a)	1898.37	10x10	18.98	56	$9.3 x 10^2$
(b)	1910.22	10x10	19.10	56	$9.4 x 10^2$
5(a)	1559.56	10x10	15.60	63	$6.9 x 10^2$
(b)	1500.75	10x10	15.01	63	$6.7 x 10^2$

(D) NaCl (0.02 M)

Sr.	ΔActivity (cpm)	ΔTime (min)	Slope (cpm/min)	Column efficiency (%)	Observed activity (Bq/l)
1(a)	4058.71	5	811.74	66	$3.4 x 10^4$
(b)	4507.66	5	901.53	75	$3.3 x 10^4$
(c)	4266.15	5	853.23	73	$3.3 x 10^4$
2(a)	2414.24	10	241.42	79	$8.5 x 10^3$
(b)	2520.48	10	252.05	80	$8.8 x 10^3$
3(a)	2779.11	5x10	55.58	75	$2.1 x 10^3$
(b)	2154.65	5x10	43.09	69	$1.7 x 10^3$
4(a)	2275.43	10x10	22.75	63	$10.1 x 10^2$
(b)	2350.85	10x10	23.51	65	$10.1 x 10^2$
5(a)	1008.71	10x10	10.09	35	$7.9 x 10^2$
(b)	771.68	10x10	7.72	25	$8.5 x 10^2$

(E) NaCl (0.1 M)

Sr.	ΔActivity (cpm)	ΔTime (min)	Slope (cpm/min)	Column efficiency (%)	Observed activity (Bq/l)
1(a)	3893.68	5	778.74	65	$3.3 x 10^4$
(b)	4530.23	5	906.05	74	$3.4 x 10^4$
2(a)	2209.40	10	220.94	74	$7.8 x 10^3$
(b)	2078.81	10	207.88	70	$8.2 x 10^3$
3(a)	2514.24	5x10	50.28	60	$2.3 x 10^3$
(b)	2364.67	5x10	47.29	50	$2.6 x 10^3$
4(a)	1617.22	10x10	16.17	34	$13.4 x 10^2$
(b)	1826.16	10x10	18.26	37	$13.8 x 10^2$
5(a)	1154.29	10x10	11.54	25	$12.9 x 10^2$
(b)	1202.58	10x10	12.03	25	$13.5 x 10^2$

Table 3.9–Differrence (%) between expected activity and specific activity for Cs-137 contaminated samples (continuous system)

(A) Deionized water

No.	Condition	Specific Activity (Bq/l)		Difference
		Observed	Expected	(%)
1(a)	10 ml	$1.2x10^4$	10×10^4	88
(b)		$1.2x10^4$		88
2(a)	100 ml	$4.7x10^3$	10×10^3	53
(b)		$3.9x10^3$		61
3(a)	500 ml	0.9×10^3	2×10^3	55
(b)		1.0×10^3		51
4(a)	1000 ml	3.7×10^2	10×10^2	63
(b)		3.3×10^2		67
5(a)	1500 ml	2.2×10^2	7×10^2	69
(b)		2.3×10^2		67

(B) Tap water

No.	Condition	Specific Activity (Bq/l)		Difference
		Observed	Expected	(%)
1(a)	10 ml	$3.2x10^4$	10×10^4	68
(b)		$3.7x10^4$		63
(c)		$3.4x10^4$		66
2(a)	100 ml	$7.4x10^3$	10×10^3	26
(b)		$9.0x10^3$		10
3(a)	500 ml	1.9×10^3	2×10^3	5
(b)		1.9×10^3		5
4(a)	1000 ml	9.2×10^2	10×10^2	8
(b)		10.0×10^2		0
5(a)	1500 ml	8.5×10^2	7×10^2	-21
(b)		7.3×10^2		4

(C) NaCl (0.01 M)

No.	Condition	Specific Activity (Bq/l)		Difference
		Observed	Expected	(%)
1(a)	10 ml	$3.4x10^4$	10×10^4	66
(b)		$3.5x10^4$		65
(c)		$2.6x10^4$		74
2(a)	100 ml	$8.2x10^3$	10×10^3	18
(b)		$7.8x10^3$		22
3(a)	500 ml	1.9×10^3	2×10^3	5
(b)		1.9×10^3		5
4(a)	1000 ml	9.3×10^2	10×10^2	7
(b)		9.4×10^2		6
5(a)	1500 ml	6.9×10^2	7×10^2	1
(b)		6.7×10^2		4

Table 3.9– (Continued)

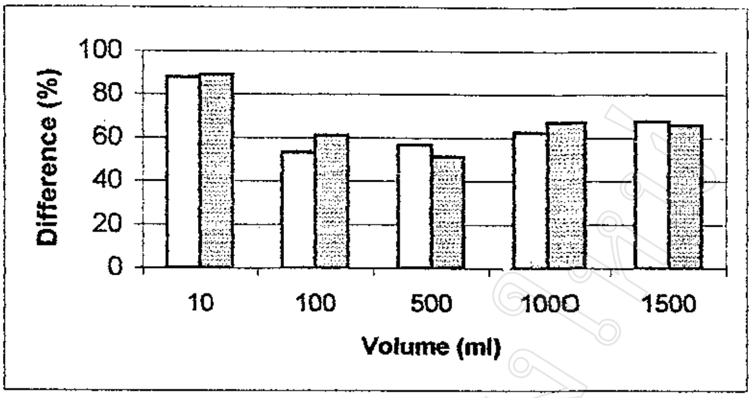
(D) NaCl (0.02 M)

No.	Condition	Specific Activity (Bq/l)		Difference (%)
		Observed	Expected	
1(a)	10 ml	$3.4x10^4$	10×10^4	66
(b)		$3.3x10^4$		67
(c)		$3.3x10^4$		67
2(a)	100 ml	$8.5x10^3$	10×10^3	15
(b)		$8.8x10^3$		12
3(a)	500 ml	$2.1x10^3$	2×10^3	-5
(b)		$1.7x10^3$		15
4(a)	1000 ml	$10.1 x10^2$	10×10^2	-1
(b)		$10.1 x10^2$		-1
5(a)	1500 ml	$7.9 x10^2$	7×10^2	-13
(b)		$8.5 x10^2$		-21

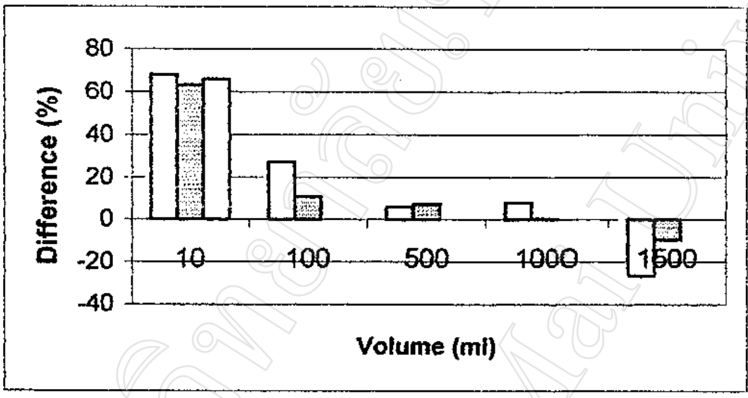
(E) NaCl (0.1 M)

No.	Condition	Specific Activity (Bq/l)		Difference (%)
		Observed	Expected	
1(a)	10 ml	$3.3x10^4$	10×10^4	67
(b)		$3.4x10^4$		66
2(a)	100 ml	$7.8x10^3$	10×10^3	22
(b)		$8.2x10^3$		18
3(a)	500 ml	$2.3 x10^3$	2×10^3	-15
(b)		$2.6 x10^3$		-30
4(a)	1000 ml	$13.4 x10^2$	10×10^2	-34
(b)		$13.8 x10^2$		-38
5(a)	1500 ml	$12.9 x10^2$	7×10^2	-84
(b)		$13.5 x10^2$		-93

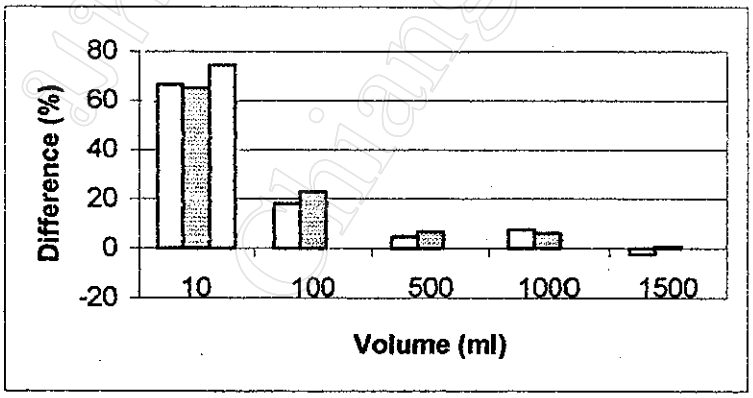
The differences were summarized as Figure 3.8.



(A) Deionized water

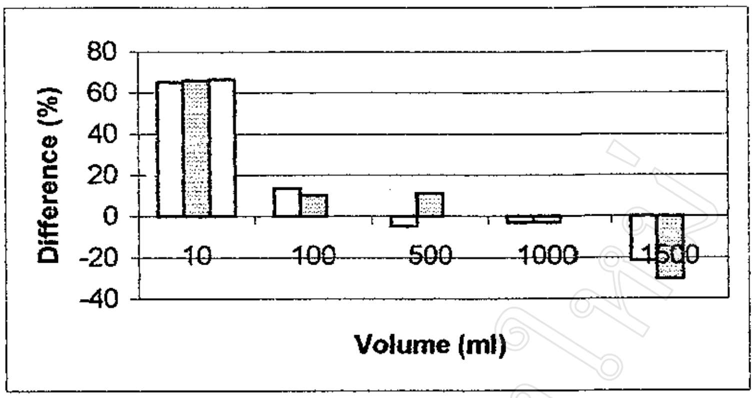


(B) Tap water

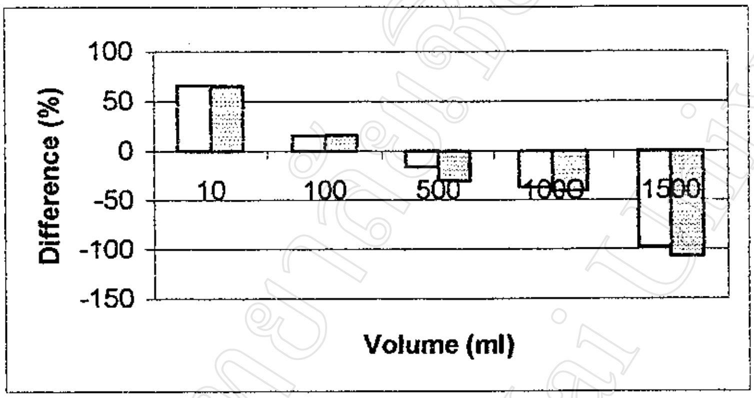


(C) 0.01 M NaCl

Figure 3.8– Difference (%) between expected activity and specific activity for Cs-137 contaminated samples (continuous system)



(D) 0.02 M NaCl



(E) 0.1 M NaCl

Figure 3.8– (continued)

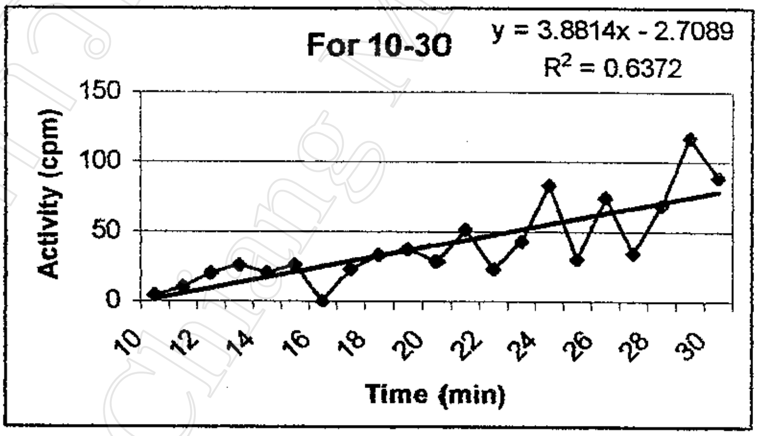
3.5 Radioactivity of an Unknown Sample

From the analysis (Table 3.10, Figure 3.9), activity of an unknown sample is 180 Bq/l (a 300 ml of sample passing through the column with 5 ml/min flow rate). In this case efficiency of column used is 60%. The sample was also analyzed by γ-spectrometry and found to be 160 Bq/l.

It has been demonstrated that determination of radioactivity using the continuous procedure developed in this work could be applied for radioactivity monitoring in water with an error % of $\pm$ 20.

Table 3.10-Radioactivity of an unknown sample

Time (min)	Activity (cpm)	Time (min)	Activity (cpm)	Time (min)	Activity (cpm)	Time (min)	Activity (cpm)
1	23.98	20	28.35	39	155.95	58	109.89
2	0	21	52.14	40	60.84	59	116.99
3	0.34	22	22.98	41	116.04	60	138.6
4	0	23	43.54	42	115.93	61	127.66
5	33.43	24	83.31	43	121.7	62	181.55
6	33.67	25	29.71	44	84.35	63	160.74
7	17.67	26	74.09	45	46.88	64	131.1
8	0	27	34.34	46	68.75	65	122.39
9	0	28	67.88	47	145.51	66	146.04
10	4.35	29	117.11	48	209.64	67	119.55
11	9.65	30	88.4	49	149.82	68	156.87
12	19.73	31	91.34	50	127.09	69	120
13	26.03	32	91.61	51	165.01	70	133.26
14	20.2	33	98.1	52	124.2	71	128.79
15	25.18	34	102.48	53	132.19	72	168.34
16	0	35	78.82	54	147.94	73	145.61
17	22.42	36	130.32	55	155.39	74	142.71
18	32.7	37	83.61	56	134.07		
19	37.61	38	127.2	57	134.91		



η = 12%, slope = 3.8814 (From the time of 10 to 30 min), $C_{Eff.}$ = 60%

Specific activity = 180

Figure 3.9-Radioactivity of an unknown sample

3.6 A Survey of Radioactivity in Water of Chiang Mai Municipality

From the results (Table 3.11 and Figure 3.10), it was found that activities of the samples taken from the sites in Chiang Mai Municipality were of the background value.

Table 3.11-A survey of radioactivity in water of Chiang Mai Municipality

Time (x10 min)	Site 1 (cpm)	Site 2 (cpm)	Site 3 (cpm)	Site 4 (cpm)	Site 5 (cpm)	Site 6 (cpm)
1	0	1.8	0	10.68	0	0
2	15.18	0	38.17	0	0	0.8
3	0	31.27	0.61	2.99	0	0
4	24.67	4.69	0	15.11	0	23.99
5	0	51.97	36.29	0	0	0
6	10.78	0	27.63	0	0	0
7	0	9.26	0	35.37	0	11.53
8	0	12.3	0	6.17	0	8
9	22.28	10.05	8.3	59.43	0	20.39
10	0	32.73	0	26.16	0	0
11	4.41	14.64	14.15	0	0	0
12	0	13.81	15.64	14.36	0	0
13	40.19	13.28	39.66	2.84	0	0
14	13.4	15.96	8.6	0	0	0
15	15.62	9.83	0.15	3.24	26.98	0

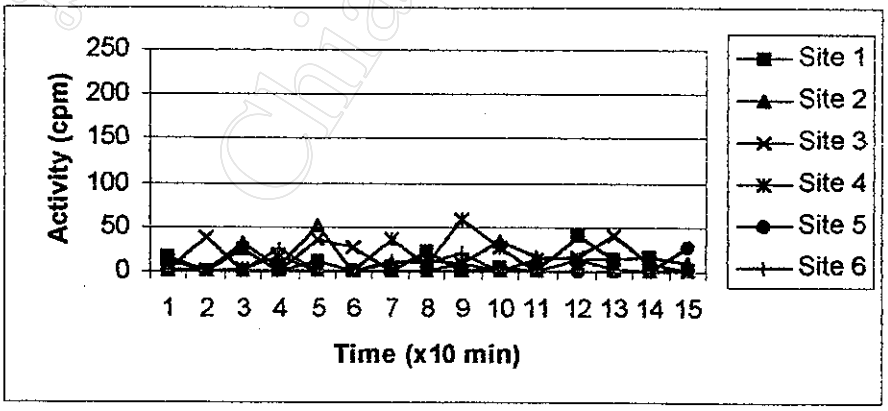


Figure 3.10-A survey of radioactivity in water of Chiang Mai Municipality