

Appendix 1 Standard Calibration for Single Channel γ Counter

(A) Energy calibration for NaI-Probe

NaI-Probe

BERTHOLD LB 5320

Date/Time: 31/07/97 16:34:07

Elap. Time (s): 1

Cal. Window 1: 662 to 1999 keV

Preset Time (s): 5

Cal. Window 2: 31 to 662 keV

HV - Operation point found [V]: 670.0

Energy calibration for NaI-Probe

NaI-Probe

BERTHOLD LB 5320

HV [V]: 667.0

Energy window: 20 keV

HV (Volt)	count rate (CPS)
630	26.20
634	35.90
638	40.00
642	43.40
646	55.70
650	60.60
654	68.60
658	148.63
662	1646.00
666	5853.00
670	4282.00
674	1449.00
678	669.00
682	449.67
686	419.00
690	433.33
694	473.67
698	583.00
702	643.00
706	643.00

HV - Operation point [V]: 667.0

Area ratio: = 0.371

Adjust factor: = 15.592

(B) Pulsheight Spectrum for NaI-Probe

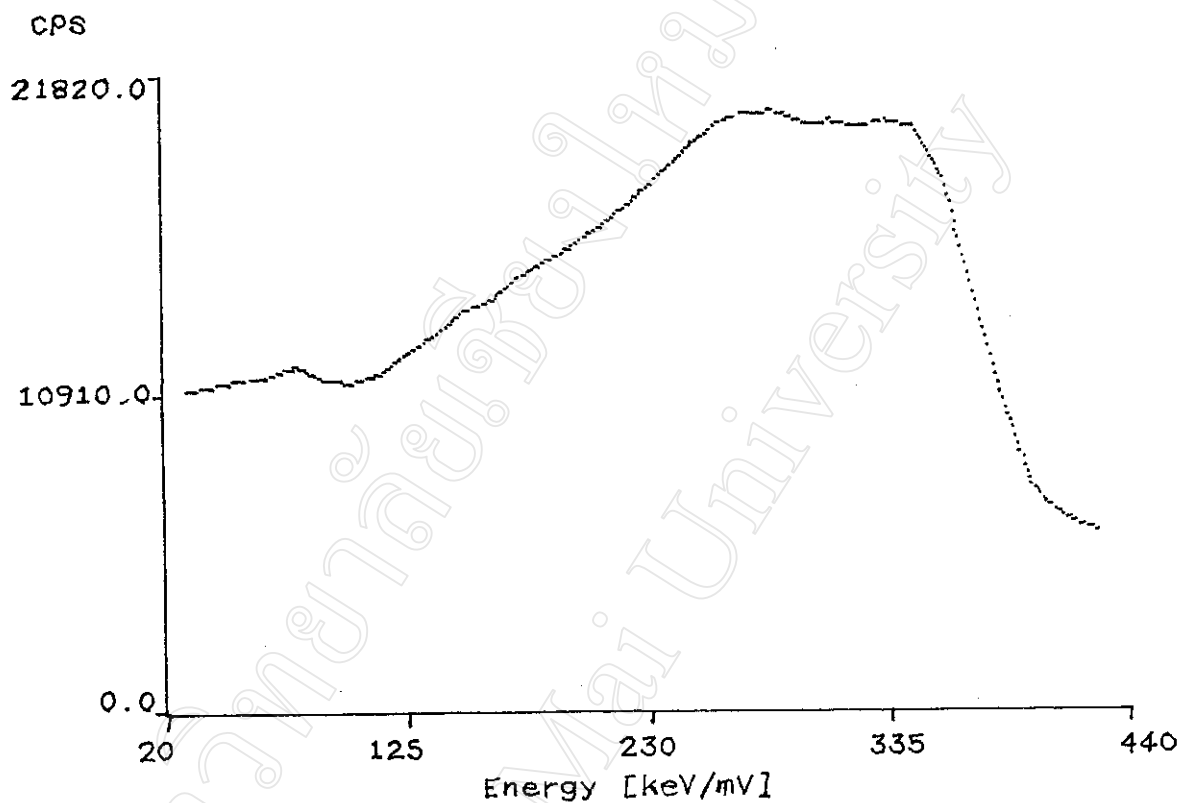


Figure - Plot of I-131 spectrum for NaI probe

Background

NaI-Probe

BERTHOLD LB 5320

Date/Time: 05/08/97 11:24:00

Elap. Time (s): 600

Preset Time (s): 600

HV [V]: 667.0

Energy pos. (keV): 230

Window (keV): 200

Count rate (CPS)	Stat. err (1-sig) (CPS)
6.898	0.107

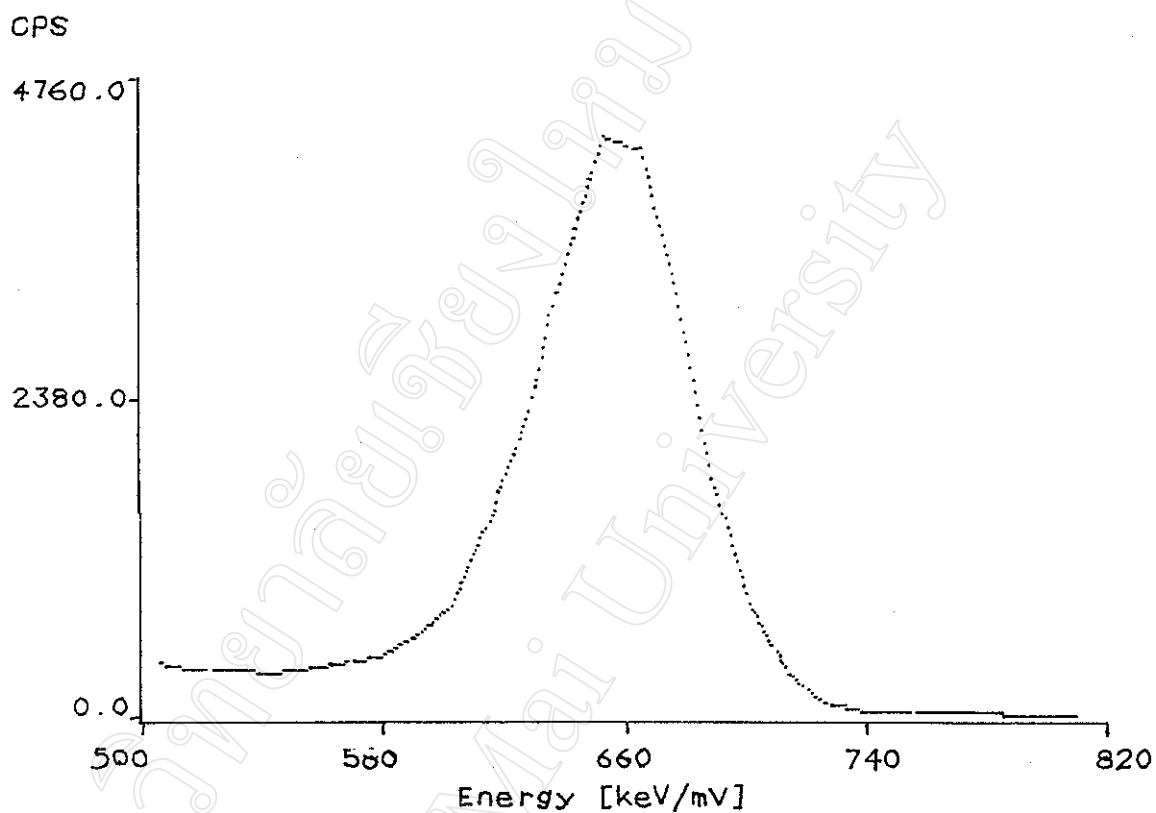


Figure – Plot of Cs-137 spectrum for NaI probe

Background

NaI-Probe

BERTHOLD LB 5320

Date/Time: 31/07/97 16:57:04

Elap.Time (s): 600

Preset Time (s): 600

HV [V]: 667.0

Energy pos. (keV): 662

Window (keV): 12

Countrate (CPS)	Stat.err (1-Sig) (CPS)
0.182	0.017

Appendix 2 Standard Radioactivity Determination in Batch Type

(A)-Radioactivity determination in batch type (I-131)

Time (min)	Activity (cpm)
1	396
2	412
3	435
4	460
5	467
6	477
7	475
8	479
9	455
10	460

Parameter for Science application

High voltage (V) = 667
 Preset time (s) = 60
 Preset error (%) = 0
 Measuring unit = cpm
 Calibration factor = 60
 Dead time (μ s) = 0
 HV max. (V) = 1200
 Max. energy (keV/mV) = 2000
 Background (cps) = 5.175
 Background time (s) = 60
 Energy position (keV) = 230
 Energy window (keV) = 200

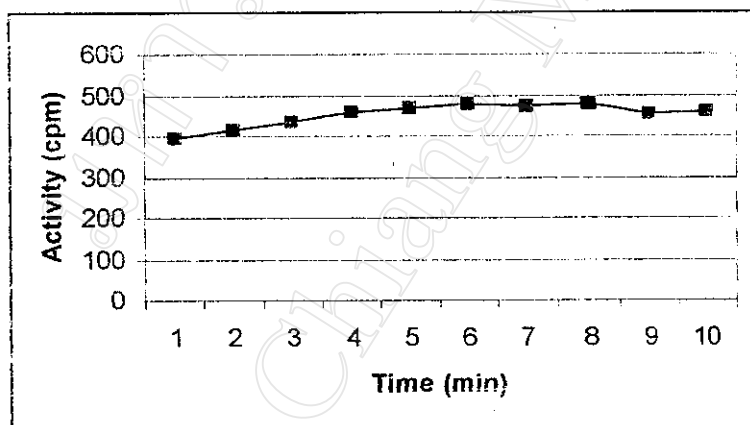


Figure 1-Activity vs. time for standard radioisotope I-131 (batch type)

(B)-Radioactivity determination in batch type (Cs-137)

Time (min)	Activity (cpm)
1	89
2	92
3	87
4	90
5	91
6	90
7	86
8	90
9	87
10	90

Parameter for Science application

High voltage (V) = 667
 Preset time (s) = 60
 Preset error (%) = 0
 Measuring unit = cps
 Calibration factor = 1
 Dead time (μ s) = 0
 HV max. (V) = 1200
 Max. energy (keV/mV) = 2000
 Background (cps) = 3.433
 Background time (s) = 600
 Energy position (keV) = 500
 Energy window (keV) = 300

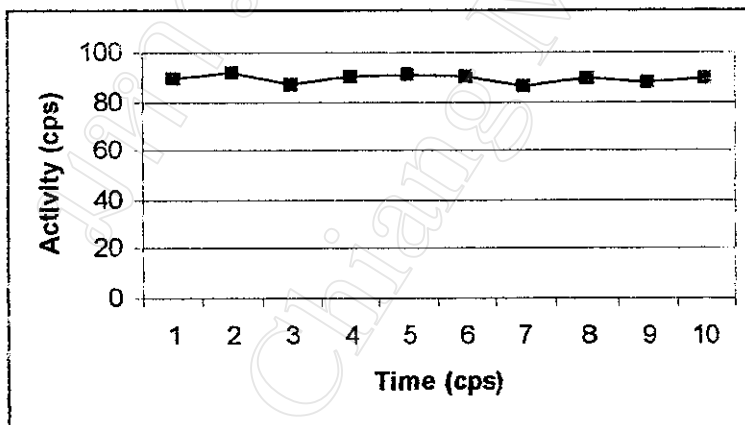


Figure 2- Activity vs. time for standard radioisotope Cs-137 (batch type)

Appendix 3 Standard Radioactivity Determination in Continuous Type

Standard radioactivity determination for Cs-137 (continuous)

Time (min)	Activity (cpm)
1	83
2	126
3	157
4	214
5	403
6	487
7	571
8	598
9	702
10	776
11	817
12	938
13	963
14	1019
15	1125
16	1219
17	1253
18	1191
19	1224
20	1217

Parameter for Science application

High voltage (V) = 667
 Preset time (s) = 60
 Preset error (%) = 0
 Measuring unit = cpm
 Calibration factor = 60
 Dead time (μ s) = 0
 HV max. (V) = 1200
 Max. energy (keV/mV) = 2000
 Background (cps) = 3.592
 Background time (s) = 600
 Energy position (keV) = 500
 Energy window (keV) = 300

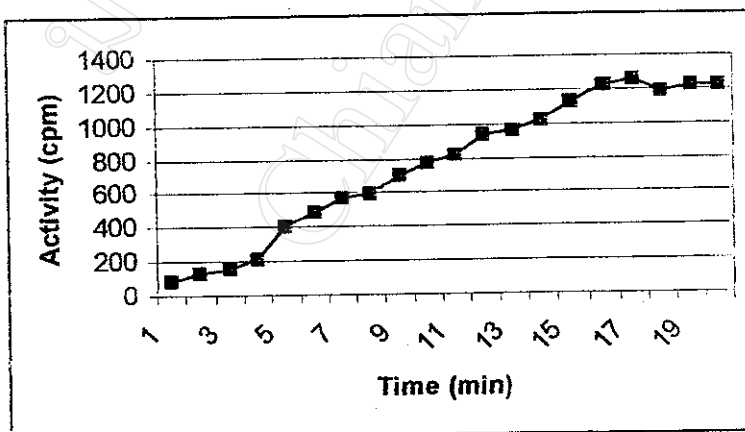


Figure 1- Activity vs. time for standard radioisotope Cs-137 (continuous type)

(A) Standard radioactivity measurement of Cs-137 by using continuous flow system (Deionized water)

Table 1 Original activity of Cs-137 Std. (1 ml)

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
1	55	55
2	255	1327
3	255	2370
4	846	2342
5	1927	2370
6	1948	2292
7	1842	2219
8	2166	2290
9	2503	2201
10	2456	2236
11	2362	2186
12	2252	

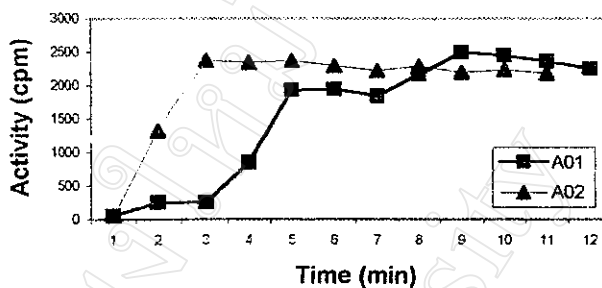


Table 2 Cs-137 in Deionized water (1:9) 10 ml

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
1	54	67
2	225	236
3	1127	1109
4	1417	1287
5	1426	1321
6	1505	1333
7	1469	1270
8	1538	1323
9	1418	1295
10	1421	1294
11	1505	1381

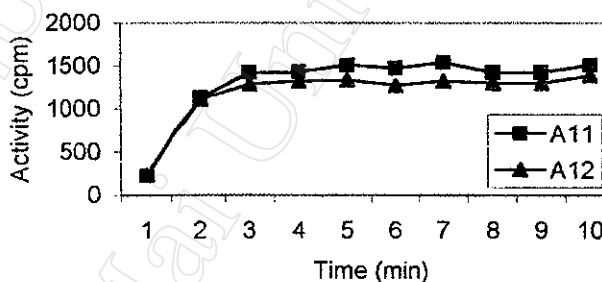


Table 3 Cs-137 in Deionized water (1:99) 100 ml

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
1	83	58
2	126	97
3	157	149
4	214	228
5	403	309
6	487	360
7	571	412
8	598	472
9	702	553
10	776	589
11	817	676
12	938	729
13	963	848
14	1019	891
15	1125	968
16	1219	990
17	1253	987
18	1191	1057
19	1224	1046
20	1217	976

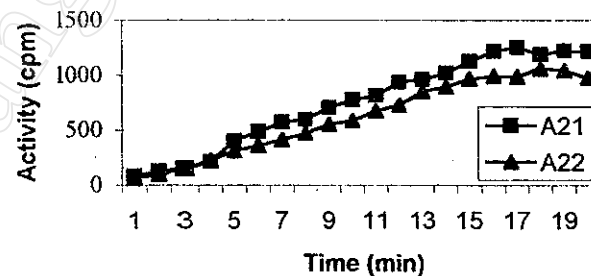


Table 4 Cs-137 in Deionized water (1:499) 500 ml

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
1	80	84
2	209	184
3	288	238
4	348	227
5	431	304
6	478	145
7	587	593
8	635	1091
9	741	708
10	869	797
11	861	898
12	939	893
13	1047	937
14	1076	1100
15	1132	1209
16	1203	1080

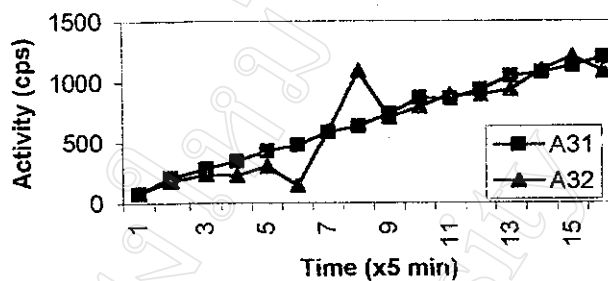


Table 5 Cs-137 in Deionized water (1:999) 1000 ml

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
1	75	67
2	213	71
3	67	70
4	326	407
5	344	382
6	416	458
7	539	575
8	663	657
9	787	765
10	919	860
11	1082	965
12	1209	1100
13	1320	1196
14	1468	1300
15	1595	1392
16	1722	1505
17	1844	1577
18	1984	1695
19	2132	1792
20	2172	1859
21	2150	1940
22	2174	1959
23	2246	1891
24	2205	1934
25	2131	1984
26	2222	1988
27	2291	2011
28	2176	1942

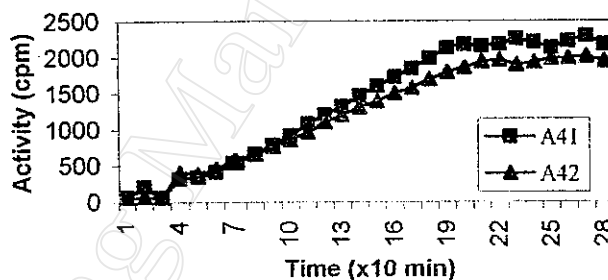


Table 6 Cs-137 in Deionized water (1:1499) 1500 ml

Sr. no.	Std. (a) (cpm)	Std. (b) (cpm)
10	79	94
20	68	80
30	67	81
40	488	471
50	420	487
60	598	536
70	669	625
80	773	690
90	856	770
100	936	869
110	996	936
120	1103	1088
130	1219	1161
140	1274	1236
150	1373	1315
160	1468	1409
170	1503	1486
180	1601	1575
190	1717	1662
200	1785	1729
210	1911	1818
220	1976	1906
230	2083	2013
240	2146	2097
250	2261	2158
260	2376	2294
270	2440	2356
280	2453	2400
290	2477	2382
300	2468	2379
310	2506	2406
320	2531	2394
330	2511	2439
340	2482	2415
350	2567	2440

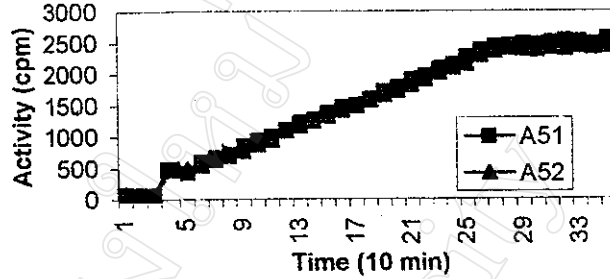
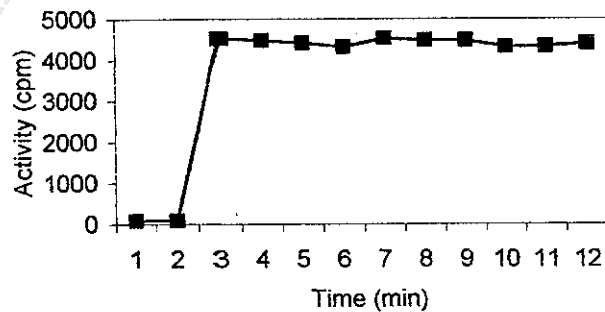


Table 7 Standard Cs-137 isotope

Sr. no	Activity (cpm)
1	86
2	94
3	4529
4	4473
5	4415
6	4327
7	4532
8	4477
9	4482
10	4316
11	4330
12	4400



(B) Standard radioactivity measurement of Cs-137 by using continuous flow system (Tap water)

Table 1 Data for 10 ml standard solution

Sr. no.	A11	A12	A13
1	0	0	0
2	0	0	0
3	529.75	0	805.75
4	2398.73	1933.65	2990.82
5	2578.25	4117.37	3454.07
6	2823.23	4133.67	3465.39
7	2541.06	4174.76	3417.7
8	2717.11	4416.85	3335.27
9	2736.32	4103.47	3389.65
10	2781.26	3331.1	3400.35
11	2748.28	3013.03	3495.73
12	2924.64	3050.18	3525.34

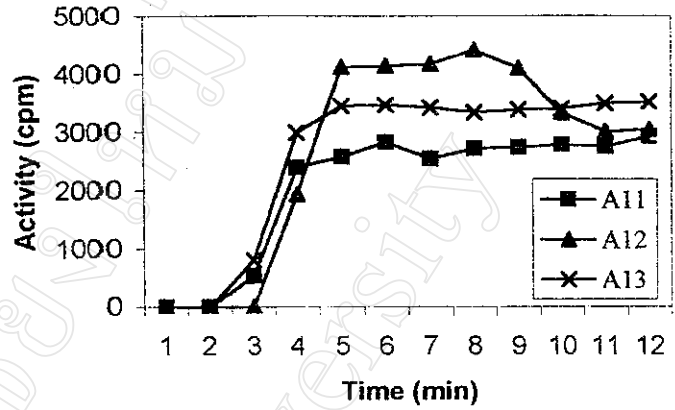


Table 2 Data for 100 ml standard solution

Sr. no.	A21	A22
1	0	0
2	0	0
3	0	244.13
4	105.8	463.66
5	349.03	667.97
6	612.39	906.56
7	907.86	1193.21
8	1230.08	1506.74
9	1197.34	1655.7
10	1491.95	1998.37
11	1653.24	2210.85
12	1867.36	2677.77
13	2002.76	2772.2
14	2591.75	2926.91
15	2567.55	3462.79
16	2819.55	3474.38
17	2932.48	3607.22
18	3244.45	3803.82
19	3337.56	3864.36
20	3437.82	3877.2
21	3655.2	3979.36
22	3603.45	3675.81
23	3493.81	3724.94
24	3478.32	3696.62
25	3435.58	3829.32

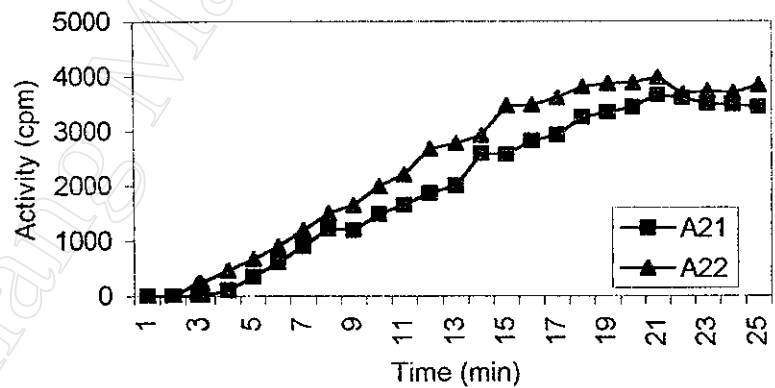


Table 3 Data for 500 ml standard solution

Sr. no.	A31	A32
1	0	0
2	112.59	88.77
3	343.95	323.21
4	582.81	568.85
5	800.44	994.91
6	1039.94	1005.48
7	1322.08	1341.62
8	1402.99	1456.44
9	1655.76	1718.69
10	1968.1	2004.98
11	2014.53	2143.26
12	2303.67	2520.29
13	2549.87	2637.32
14	2734.02	2841.23
15	2977.25	3231.77
16	3217.2	3467.67
17	3307.25	3576.24
18	3565.47	3828.99
19	3468.71	3645.04
20	3606.92	3694.18

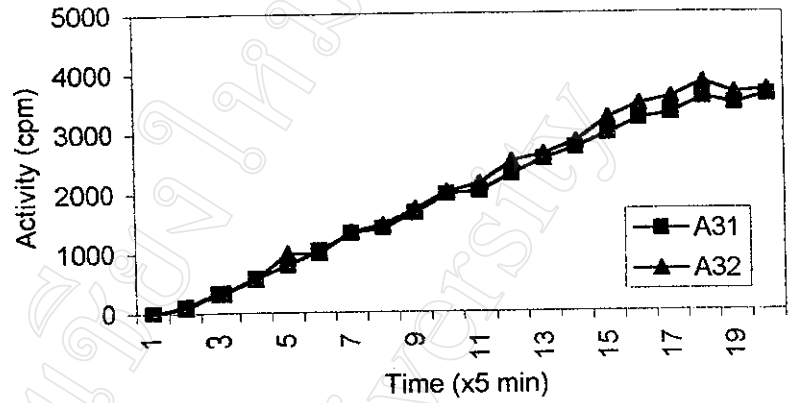


Table 4 Data for 1000 ml standard solution

Sr. no.	A41	A42
1	0	0
2	235.13	74.95
3	309.35	262.27
4	583.84	580.22
5	799.65	819.67
6	875.72	1118.9
7	1106.49	1537.06
8	1387.21	1818.41
9	1865.42	2126.15
10	2038.71	2158.85
11	2416.75	2394.33
12	2752.76	2683.13
13	3003.81	2938.29
14	3189.3	3113.54
15	3444.39	3511.41
16	3782.44	3699.51
17	3752.66	3649.43

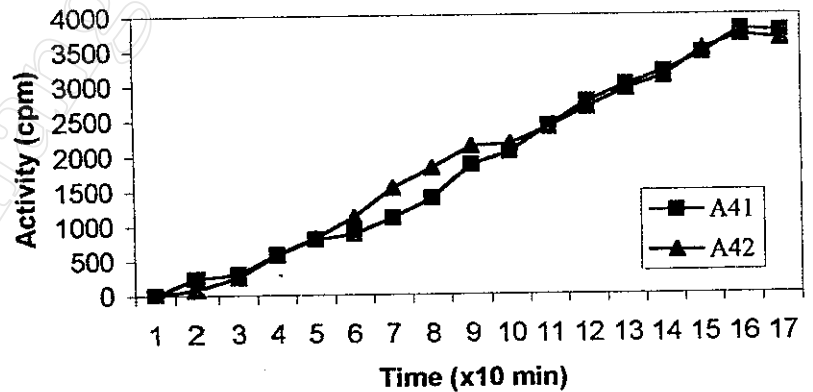
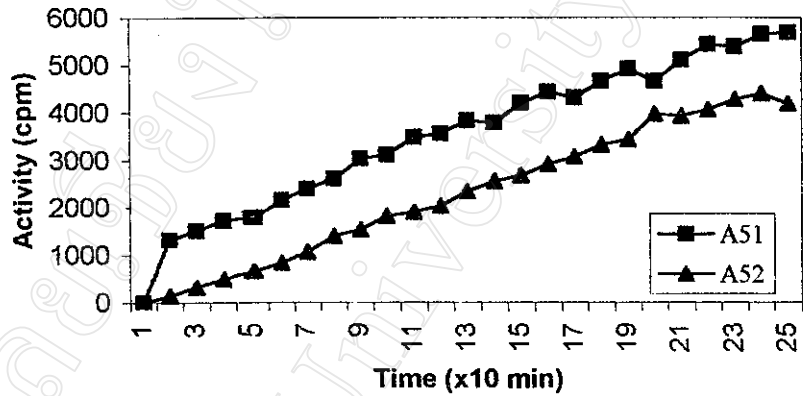


Table 5 Data for 1500 ml standard solution

Sr. no.	A51	A52
1	0	0
2	1323.74	141.35
3	1515.08	324.26
4	1732.48	491.41
5	1799.8	665.95
6	2161.69	843.86
7	2398.05	1068.8
8	2611.75	1407.78
9	3028.43	1541.31
10	3105.35	1818.11
11	3476.34	1908.47
12	3560.75	2036.06
13	3824.21	2336.93
14	3782.67	2551.63
15	4193.67	2684.48
16	4430.32	2920.67
17	4311.77	3078.75
18	4655.22	3321.92
19	4920.47	3429.53
20	4661.16	3972.01
21	5115.71	3923.21
22	5434.33	4064.74
23	5385.76	4274.23
24	5645.49	4402.19
25	5680.35	4192.08



(C) Standard radioactivity measurement of Cs-137 by using continuous flow system (0.01 M NaCl)

Table 1 Data for 10 ml standard solution

Sr. no.	A11	A12	A13
1	0	0	0
2	735.4	0	68.35
3	3096.31	754.18	62.15
4	3472.81	3143.3	495.21
5	3597.1	3644.07	2934.13
6	3515.42	3599.78	3996.4
7	3669.11	3413.46	3807.91
8	3652.62	3517.61	3748.77
9	3797.23	3584.08	3979.82
10	3533.5	3559.33	3743.2
11	3542.5	3479.73	3938.61
12	3756.69	3361.12	3991.11

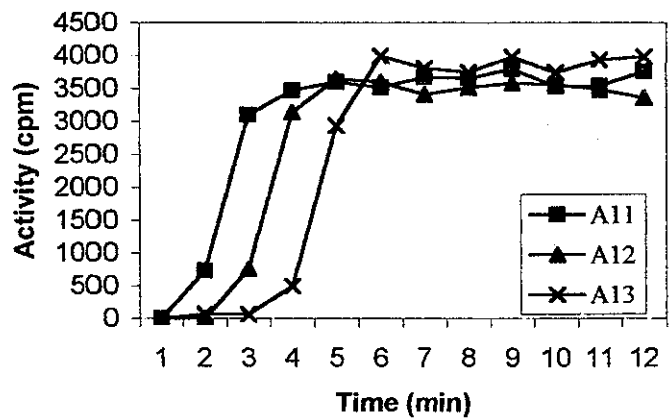


Table 2 Data for 100 ml standard solution

Sr. no.	A21	A22
1	0	0
2	30.85	0
3	126.06	0
4	322.09	15.86
5	480.85	97.45
6	735.95	335.96
7	915.29	571.48
8	1212.87	839.89
9	1358.14	1187.76
10	1556.71	1212.8
11	1815.9	1648.16
12	1924.44	1694.35
13	2251.55	1927.61
14	2439.02	2109.38
15	2474.54	2364.52
16	2978.15	2891.34
17	2817.42	3007.41
18	3176.52	3245.77
19	3323.36	3480.65
20	3112	3670.13
21	3097.73	3966.92
22	3272.9	3540.42
23	3330.27	3834.12
24	3312.7	3644.86
25	3161.05	3717.91

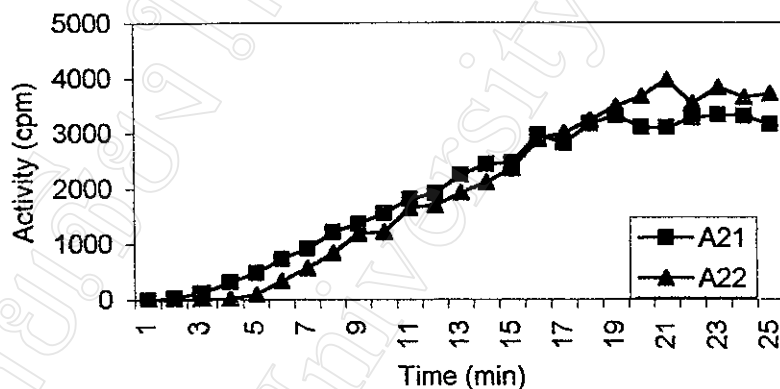


Table 3 Data for 500 ml standard solution

Sr. no.	A31	A32
1	0	0
2	27.29	40.18
3	239.23	301.68
4	521.12	565.36
5	693.51	791.77
6	931.21	1062.9
7	1179.92	1312.19
8	1454.87	1527.97
9	1669.6	1903.37
10	1991.19	2078.99
11	2174.81	2376.76
12	2412.74	2541.92
13	2672.4	2869.81
14	2926.27	3074.49
15	3072.4	3379.14
16	3424.92	3549.19
17	3596.2	3926.78
18	3582.52	3860.24
19	3603.18	3847.03

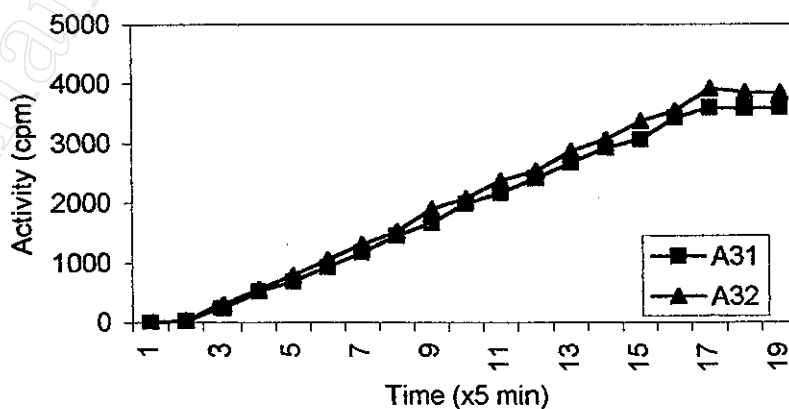


Table 4 Data for 1000 ml standard solution

Sr. no.	A41	A42
1	0	0
2	106.45	48.22
3	325.28	266.37
4	567.58	486.08
5	807.46	723.78
6	993.28	947.11
7	1228.93	1218.12
8	1421.75	1373.64
9	1730.54	1684.87
10	1898.37	1910.22
11	2131.3	2144.18
12	2328.86	2370.93
13	2548.31	2578.35
14	2856.1	2855.77
15	3013.28	3100.77
16	3222.45	3255.14
17	3426.99	3442.34
18	3545.85	3466.68

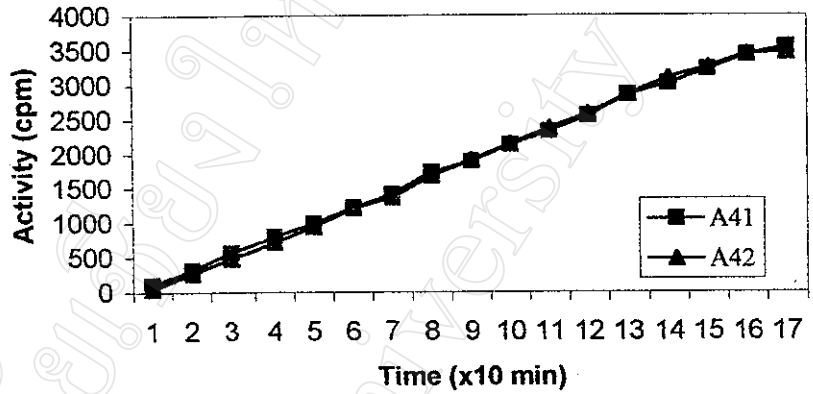
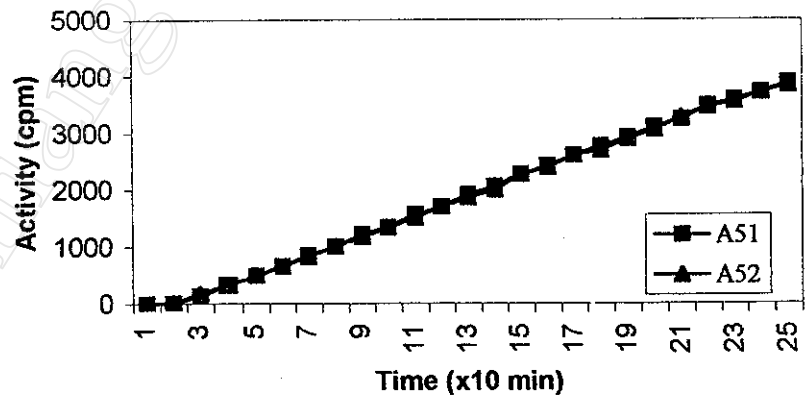


Table 5 Data for 1500 ml standard solution

Sr. no.	A51	A52
1	0	0
2	13.71	16.66
3	143.7	180.57
4	330.74	329.41
5	492.72	499.34
6	657.19	661.05
7	845.4	829
8	993.3	1005.37
9	1222.39	1177.32
10	1342.87	1336.22
11	1573.27	1517.41
12	1699.11	1699.28
13	1912.79	1868.05
14	2060.74	1999.45
15	2271.15	2270.65
16	2423.69	2397.71
17	2606.97	2609.2
18	2772.53	2697.58
19	2924.33	2899.75
20	3107.11	3065.45
21	3240.36	3276.8
22	3490.08	3464.93
23	3589.68	3551.5
24	3717.43	3722.4
25	3881.01	3845.14



(D) Standard radioactivity measurement of Cs-137 by using continuous flow system (0.02 M NaCl)

Table 1 Data for 10 ml standard solution

No.	A11	A12	A13
1	0	0	0
2	0	74.89	0
3	1800.72	612.91	158.82
4	4003.68	2983.68	2043.04
5	4058.71	4507.66	4266.15
6	4008.99	4655.95	4252.63
7	3617.62	4415.39	4433.07
8	4136.67	4364.56	4314.51
9	4022.53	4624.56	4390.61
10	3883.79	4429.23	4551.41
11	3911.76	4524.17	4330.68
12	3960.91	4527.49	4315.98

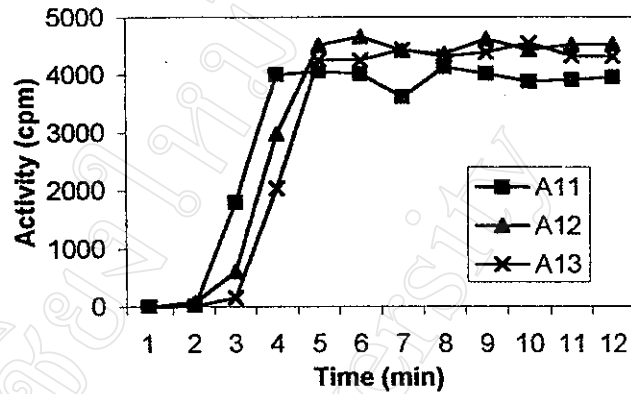


Table 2 Data for 100 ml standard solution

Sr. no.	A21	A22
1	75.94	52.4
2	262.08	232.16
3	488.81	501.07
4	807.71	855.45
5	1140.54	1204.45
6	1349.71	1362.34
7	1671.57	1827.22
8	2013.93	2120.66
9	2302.32	2363.6
10	2490.18	2572.88
11	2637.45	2885.92
12	3122.69	3131.38
13	3320.12	3562.15
14	3629.34	3928.48
15	3906.26	4081.77
16	4164.26	4569.22
17	4269.66	4848.41
18	4649.09	4749.74
19	4518.66	4655.83
20	4754.12	4889.54
21	4906.91	4728.23
22	4983.98	5059.63
23	4830.4	4915.94
24	5047.93	4632.59
25	5116.95	4690.79
26	4967.98	4718.4
27	4834.42	4910.91

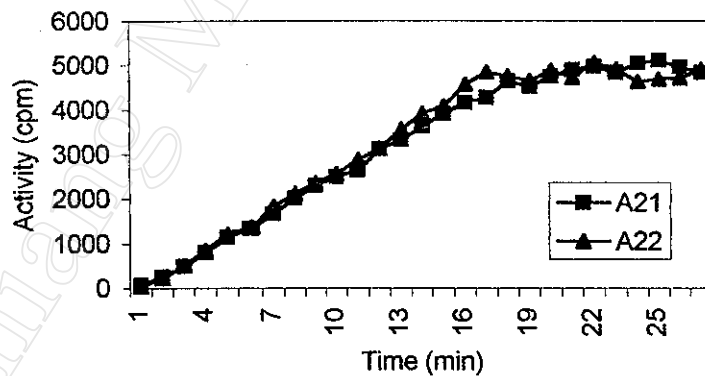


Table 3 Data for 500 ml standard solution

Sr. no.	A31	A32
1	0	0
2	305.6	26.39
3	567.54	285.66
4	946.74	541.73
5	1044.19	953.14
6	1463.12	1069.19
7	1676.33	1280.46
8	1982.72	1619.08
9	2362.64	1885.57
10	2779.11	2154.65
11	2893.81	2457.48
12	3353	2531.92
13	3558.23	3084.36
14	3731.68	3240.36
15	3982.77	3515.73
16	4472.84	4031.78
17	4480.18	4064.21
18	4538.23	4185.47
19	4545.13	4104.08
20	4425.53	4184.27

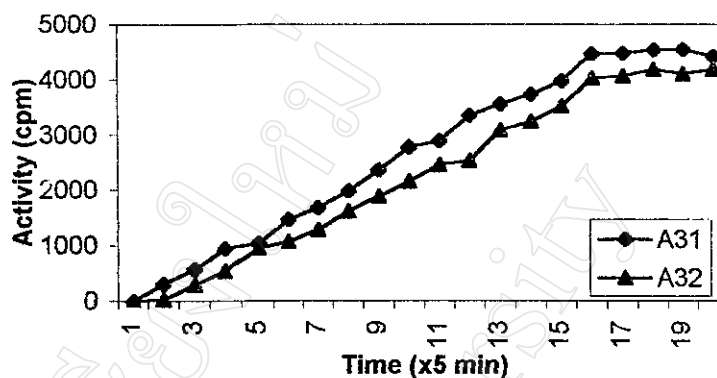


Table 4 Data for 1000 ml standard solution

Sr. no.	A41	A42
1	0	0
2	152.85	205.88
3	531.56	259.12
4	682.83	657.73
5	1008.29	907.44
6	1268.4	1189.74
7	1509.97	1488.67
8	1904.2	1859.87
9	2111.65	2031.58
10	2275.43	2350.85
11	2555.73	2539.39
12	3077.66	2582.29
13	3221.92	3158.75
14	3146.49	3481.83
15	3849.88	3704.56
16	3584.27	3985.59
17	3785.66	3924.98
18	3811.47	3914.23

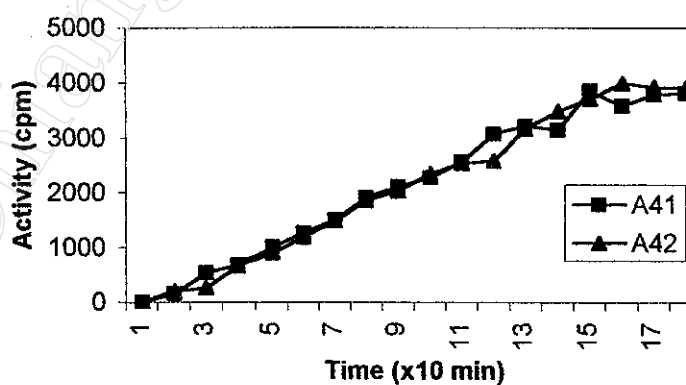
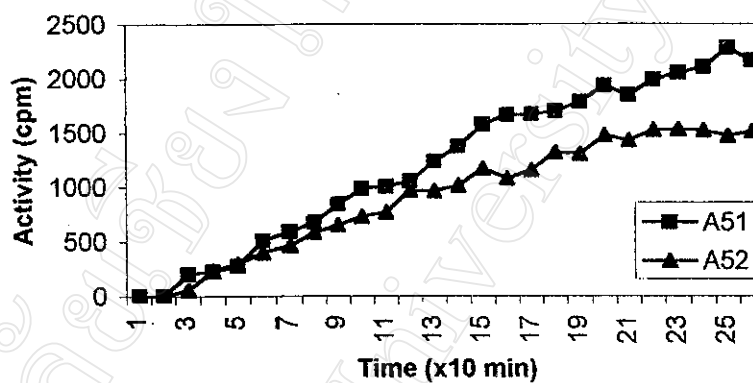


Table 5 Data for 1500 ml standard solution

Sr. no.	A51	A52
1	0	0
2	0	0
3	206.24	60.9
4	225.77	234.08
5	279.25	300.6
6	509.03	401.57
7	595.11	466.58
8	677.23	582.32
9	846.48	653.11
10	987.82	731.07
11	1008.71	771.68
12	1057.47	973.35
13	1240.11	965.89
14	1373.49	1014.55
15	1575.59	1172.34
16	1666.34	1082.87
17	1669.64	1157.57
18	1697.01	1319.37
19	1784.35	1306.31
20	1933.52	1479.29
21	1848.75	1431.06
22	1990.91	1527.97
23	2051.44	1534.12
24	2106.31	1521.26
25	2281.74	1473.92
26	2165.31	1512.34



(E) Standard radioactivity measurement of Cs-137 by using continuous flow system (0.1 M NaCl)

Table 1 Data for 10 ml standard solution

Sr. no.	A11	A12
1	0	86.47
2	1387.49	1621.45
3	3803.49	3915.45
4	4032.08	4494.14
5	3893.68	4530.23
6	3886.11	4470.72
7	4035.59	4500
8	3968.71	4574.54
9	3771.75	4336.79
10	3996.65	4617.11
11	3812.11	4508.2

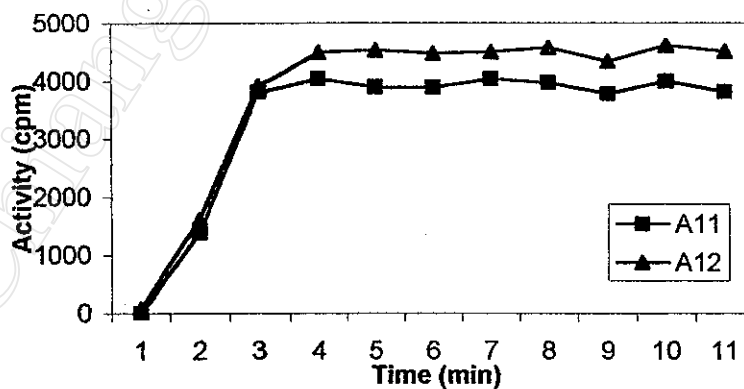


Table 2 Data for 100 ml standard solution

Sr. no.	A21	A22
1	0	0
2	90.79	98.49
3	360.31	400.69
4	640.86	563.41
5	932.66	932.62
6	1032.79	1208.64
7	1552.3	1475.2
8	1774.75	1649.44
9	1956.87	2048.85
10	2209.4	2078.81
11	2537.62	2435.85
12	2837.41	2673.85
13	3254.03	2895.76
14	3406.4	3282.48
15	3618.13	3476.48
16	3840.19	3667.14
17	4374.52	4075.08
18	4460.76	4208.2
19	4513.11	4282.31
20	4462.35	4280.3
21	4398.36	4207.06

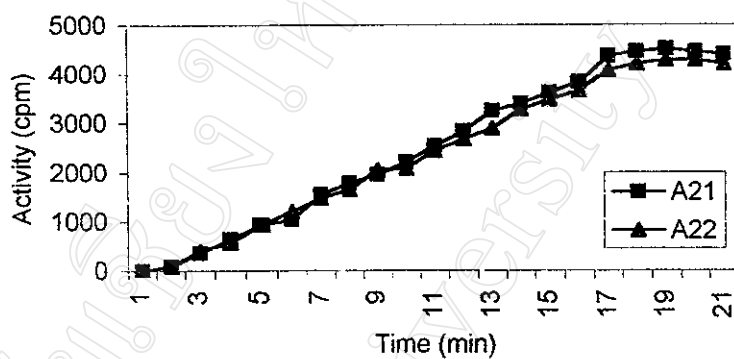


Table 3 Data for 500 ml standard solution

Sr. no.	A31	A32
1	0	0
2	220.93	128.73
3	460.21	409.84
4	855.31	690.32
5	1192.02	1082.01
6	1443.66	1280.65
7	1866.23	1566.96
8	2004.12	1829.02
9	2379.11	1987.66
10	2514.24	2364.67
11	2733.06	2184.95
12	3019.07	2614.03
13	3218.64	2742.82
14	3421.38	3006.63
15	3579.17	2879.57
16	3619.06	3022.22
17	3672.41	3072.49

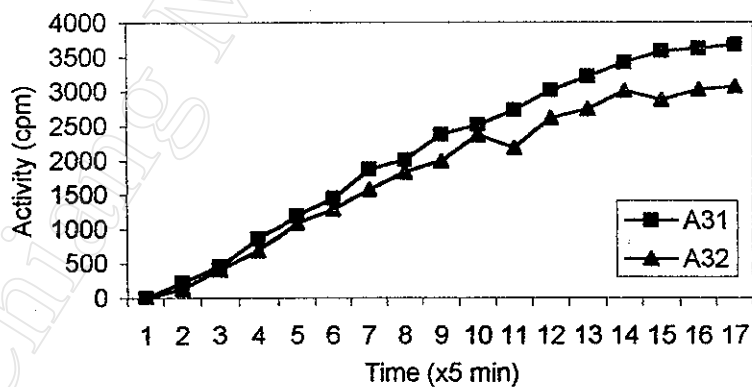


Table 4 Data for 1000 ml standard solution

Sr. no.	A41	A42
1	157.93	162.73
2	579.85	490.44
3	891.03	686.62
4	1050.55	984.62
5	1375.51	1348.41
6	1577.09	1257.07
7	1649.99	1568.86
8	1757.43	1667.88
9	1831.06	1862.55
10	1775.15	1988.89
11	1859.46	1853.38
12	1964.53	1985.89
13	1999.48	2134.4
14	2051.81	2128.65
15	2051.5	2089.02
16	2057.41	2043.74
17	2009.89	1938.96
18	1965.76	2084.86

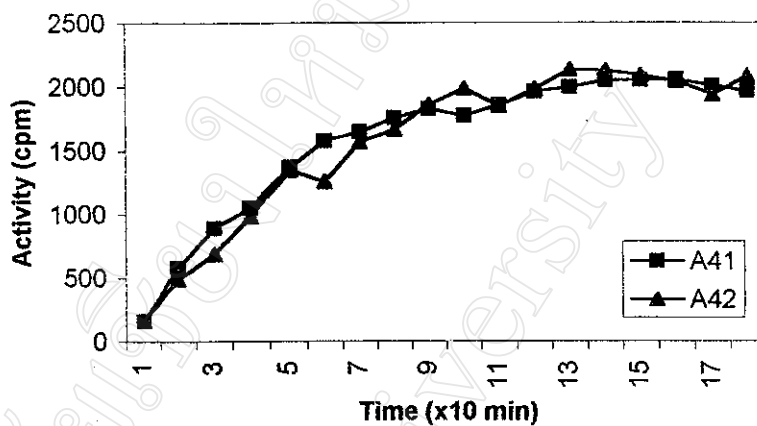
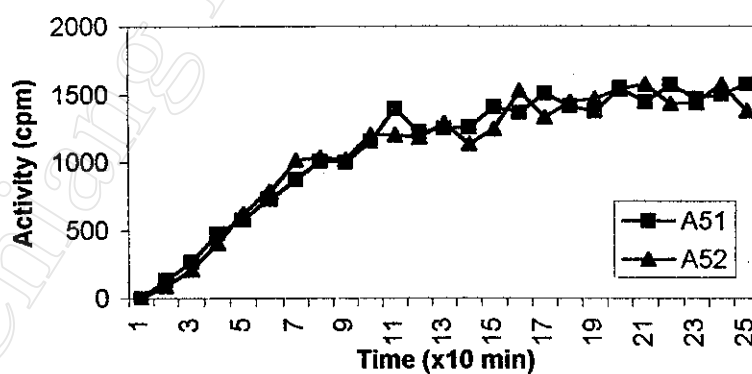


Table 5 Data for 1500 ml standard solution

Sr. no.	A51	A52
1	0	0
2	132.8	89.45
3	267.66	210.04
4	473.74	404.5
5	576.82	623.73
6	729.59	783.58
7	873.74	1016.98
8	1008.92	1034.16
9	1000.37	1020.01
10	1154.29	1202.58
11	1394.48	1205.13
12	1224.73	1182.88
13	1250.42	1288.51
14	1257.72	1137.07
15	1408.45	1246.47
16	1367.3	1530.24
17	1508.29	1331.67
18	1416.54	1446.45
19	1377.37	1470.76
20	1549.31	1539.96
21	1441.78	1576.68
22	1570.63	1433.17
23	1471.72	1439.2
24	1501.18	1576.45
25	1575.99	1379.03



Appendix 4 Calculation for Sorption Efficiency

$$\text{Sorption efficiency (\%)} = \frac{\text{Net rate of activity (average) for sample}}{\text{Net rate of activity (average) for standard}} \times 100$$

$$\text{Activity (average)} = \text{Activity (total)} / \text{number of counts}$$

$$\text{Net rate of activity (average)} = \text{Activity (average)} - \text{activity (background)}$$

e.g., Table –Recorded data for Cs-137 in 10 ml tap water (continuous)

Sr. no.	A11 (cpm)	A12 (cpm)	A13 (cpm)
1	0	0	0
2	0	0	0
3	529.75	0	805.75
4	2398.73	1933.65	2990.82
5*	2578.25	4117.37	3454.07
6	2823.23	4133.67	3465.39
7	2541.06	4174.76	3417.70
8	2717.11	4416.85	3335.27
9	2736.32	4103.47	3389.65
10	2781.26	3331.10	3400.35
11	2748.28	3013.03	3495.73
12*	2924.64	3050.18	3525.34
(n = 8) Average =	2731.27	3792.55	3435.44
Activity (background) = 0 cpm			

Net rate of activity (average) for standard = 6143.21 cpm

For sample A11,

$$\text{Sorption efficiency (\%)} = (2731.27 / 6143.21) \times 100 = 44.46$$

For sample A12,

$$\text{Sorption efficiency (\%)} = (3792.55 / 6141.82) \times 100 = 61.76$$

For sample A13,

$$\text{Sorption efficiency (\%)} = (3435.44 / 6141.82) \times 100 = 55.93$$

Appendix 5 Determination for efficiency of detector % (η)

Standard Cs-137 (446.7 kBq, 5.12.1994) was used to determine efficiency of detector

Original Activity (A_0) = 446.7 kBq

Measured Activity (A_m) = 344141.86 cpm

Correction factor for geometry (k) = 7.37

Intensity at 662 keV energy region (I) = 85%

Half-life = 30.0 Yr

Time elapsed (T) = (3.3.98) – (5.12.94) \cong 3.25 Yr

Activity at present time (A_i) = ?

$$\lambda = 0.693 / t_{1/2}$$

$$A_i = A_0 \cdot e^{-\lambda T} \rightarrow A_i = 414391.93 \text{ dps}$$

$$\eta = (A_m / A_i \times 60) \cdot 100 \cdot (1/I) \cdot k \rightarrow \eta = 12 \%$$

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Scholar Awarded

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