Department of Energy and Climate Change

MONITORING OF RADIOACTIVITY IN AIR AND RAINWATER IN THE UK

ANNUAL RESULTS REPORT 2010

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Abstract (100-200 words as desired):

Analysis of samples of atmospheric particulate material and rainwater collected from seven sites in the United Kingdom has continued during 2010. The results presented in this report show that there has been no significant increase in radioactivity measured in air and rain in 2010. These results are comparable to those reported for 2009. The trend of slowly declining levels of anthropogenic radioactivity in the environment has been generally maintained.

Executive Summary

This report presents the results obtained from the analysis of samples of atmospheric particulate material and rainwater collected from 7 sites around the United Kingdom during 2010.

Samples were analysed for beryllium-7, caesium-137 and (for some sites) a number of other analytes (gross beta activity, tritium, strontium-90, plutonium-239/240 and americium-241).

Where comparison of the 2010 results with previous years has been performed, this has been done by calculating the 10 year running mean and setting the significance level at the mean plus 2 standard deviations. Setting a significance level allows any uncertainties against the measured value to be accounted for and allows identification of elevated radioactivity levels in the presence of declining background.

Results contained in this report show that there has been no significant increase in anthropogenic radioactivity measured in air and rain during 2010. Specific comments on individual 2010 results can be found in the discussion section of this report. Measurements are comparable with those taken in 2009, continuing the trend of slowly declining levels of anthropogenic radioactivity in the environment.

Monitoring of Radioactivity in Air and Rainwater in the UK
Annual Results Report 2010

Contents

1. Introduction

A programme for monitoring of radioactivity in air and rainwater was established in the United Kingdom (UK) in the 1950's and is currently managed by the Environment Agency (EA) on behalf of DECC (Department of Energy and Climate Change).
The contract to carry out this work was awarded by competitive tender to the Health Protection Agency (HPA) in November 2008. The previous contracts were held by AMEC, Winfrith Environmental Level Laboratory (1999-2008) and AEA-T (and predecessor organisations) who undertook the contract from 1954 to1998. HPA commenced sampling and analysis in January 2009.

Samples of airborne particulates and rainwater are collected at 7 sites in the UK located at Aberporth (Ceredigion, Wales), Chilton (Oxfordshire, England), Conlig (Co. Down, N. Ireland), Dishforth (N. Yorkshire, England), Eskdalemuir (Dumfries, Scotland) and Lerwick (Shetland Islands, Scotland). The site locations and sampling programme can be found in Figure 1 and Table 1 respectively. The air and rainwater samples are securely packaged by site staff and returned to HPA Glasgow laboratories for analysis of beryllium-7 (Be-7) caesium-137 (Cs-137) and tritium (H-3) as well as a few other analytes at specific locations.

This report presents the analytical results of samples collected during calendar year 2010. A synopsis of the sampling schedules and analysis methods is given in section 2 and discussed in section 4 of this report. This section also provides a comparison of 2010 data with that from previous years.

In recent years there had been a general decline in the measured levels of anthropogenic radioactivity monitored by this programme. Previous measurements clearly show the influence of atmospheric testing of nuclear weapons and later the incident at the civil nuclear reactor Chernobyl Unit 4, which took place on 26th April 1986. This resulted in a significant release of radioactivity to the atmosphere. Above ground weapons testing officially ceased on 16th October 1980 when a nuclear explosion was carried out at the Lop Nor test site in China.

2 Sampling and Analysis

Airborne particulate material and rainwater samples are collected from 7 sites around the UK (Table 1, figure 1) and returned to HPA laboratories in Glasgow for preparation and analysis. Methods are outlined below.

All test methods are accredited by UKAS to the ISO 17025 standard.

2.1 Airborne Particulate Sampling

Atmospheric particulate sampling uses centrifugal fans and motors to pull air through melt-blown Polypropylene air filter material. The filter material has been tested and retains over 99.5% of particulates of 0.423µm aerodynamic diameter and above, under test conditions. Air samplers are housed in wooden cases; the air intake duct is positioned in a vertical position approximately 1metre above the ground to avoid fouling. Air filters are run continuously, excluding a few minutes down-time during the filter change procedure. Filters are changed weekly at 6 of the locations, with the Conlig filter being changed dependent on a defined pressure drop. The mass of air sampled at each site varies depending on the specific performance parameters of the filter motor unit. Normally for each site this is approximately 3000 to 4500 kg/day except at Chilton where approximately 15000 kg/day are sampled.

Air sampling is subject to occasional stoppages for a number of reasons ranging from local interruptions to electricity supply to mechanical failure. Reported results account for these interruptions.

Air filters are generally bulked and analysed quarterly, with the exception of the Chilton filter which is bulked and analysed on a monthly basis. The quarterly Chilton result can be inferred from the monthly results and compared with those from other locations.

2.2 Rainwater sampling

Rainwater samples are collected using polythene funnels which drain into polythene collection bottles ranging in size from 2.5 l (tritium collection), 5 l (quarterly gamma spec.) to 25 l (monthly Aberporth and Chilton gamma spec). A suitable carrier solution is added to the sample bottle directly before deployment in the field to reduce loss by adsorption on to the walls of the sample bottle. The measured samples include all material deposited by wet and dry deposition.

Rainwater samples are collected continuously at all sites and bulked quarterly at HPA labs. In addition, separate monthly samples are taken at Aberporth and Chilton sites, and an annual bulk sample is also taken at Aberporth. Sample collection bottles are deployed at Aberporth, Eskdalemuir and Orfordness for analysis of tritium.

2.3 Radiochemical Analysis

A summary of the sample preparation and analytical methods used is given below.

Individual air filters are bulked and ashed in a muffle furnace before leaching with concentrated mineral acids to extract the radioactivity into solution.

Rainwater samples are filtered prior to evaporation which concentrates the radionuclides. Particulates from the filtered rainwater undergo a leach using concentrated mineral acids to extract the radionuclides into solution which is combined with the evaporated water sample.

Gamma ray emitting radionuclides such as Cs-137 and Be-7 are measured in both air and rainwater samples by placing the prepared sample into a suitable geometry before assessing the activity by high resolution gamma spectrometry.

Strontium-90 (Sr-90) is determined in a sample by oxalate precipitation followed by purification using a crown-ether resin and then counting of the yttrium-90 daughter products after a suitable period of in-growth.

Gross alpha and gross beta measurements are carried out by evaporating a known volume of the sample on to a stainless steel planchet before assessing the activity with a gas-flow proportional counter.

Plutonium-239/240 and Americium-241 are all determined by separation from the sample using various selective ion exchange resins to remove interferants. The purified fractions of the sample are then electro-deposited on to a stainless steel disc and counted by alpha spectrometry.

2.4 Changes and Additions to the Programme

A pre-generated calendar of sample change dates is sent to each site for the start of each year. On occasions these dates change due to a variety of reasons. In addition air filter units can suffer from mechanical failures (drive belt breakage, wear and tear of bearings etc), electrical failures (power cuts etc) and planned interruptions (general site maintenance, filter unit maintenance etc). Where disruptions to the planned programme occur, the changes are reflected in the reported results for each site. Comments for each site are provided below for 2010.

Aberporth

- Site staff noted the volcanic ash event during the air sampling period from 12th to 19th April. There was a slight indication of increased particulate loading of the filter during this period although no effects were seen in the results.
- Quarter 2 air sample collection was disrupted on 3 separate occasions due to a mixture of power supply disruptions and a defective drive belt.
- The air sampling unit failed a portable appliance safety test (PAT) on 19th July and was taken out of commission until 4th October, when a repair to the electrical supply could be carried out.

Chilton

- Quarter 4 rainwater bottles were left sampling for an extended period. This has been accounted for in reported results.

Conlig

- Quarter 2 air sample collection was disrupted on a number of occasions due to site power failure.
- A portion of the rainwater collected from 21st to 29th April was removed and sent to Defra for analysis of volcanic ash. This has been accounted for in reported results.
- The air sampling unit failed on 20th June due to misalignment of the drive belt pulleys. This was corrected and the unit brought back into use on 21st July.
- A new air sampler was installed on 14th October due to increasing unreliability of the existing sampler.

Dishforth

- A defective drive belt on the air sampler caused disruptions to sample collection on 1st and 8th March.
- A short power outage on 12th March disrupted air sample collection.
- A short power outage on 16th April disrupted air sample collection.

- An air filter covering 6th to 13th September did not arrive at CRCE Scotland and was excluded from the sample bulk and analysis.
- The air sampler was taken out of service on 5th December due to a mechanical fault and did not run for the remainder of the sampling quarter.

Eskdalemuir

- A number of short disruptions to air sampling were experienced during quarter 2. Power failures are a known issue due to the remote location of this site.
- The air sampling unit was found to have stopped twice during quarter 3 sampling, probably as a result of a site power failure.
- A new air sampler was installed on 26th November due to a major mechanical failure of the existing unit.

Lerwick

- Quarter 2 air sample collection was disrupted on 2 separate occasions due to power supply disruptions and a defective drive belt. The volcanic ash cloud arrived over Shetland on 14th April. There was no visual indication of increased particulate loading of the filter and no effects were seen in the results.

Orfordness

- Complete failure of the air sampler on 1st February and problems finding an electrician to attend site to replace the unit disrupted sample collection until a new sampler was fitted on 19th April.
- Q1 and Q2 tritium and gamma rainwater bottles were left sampling for an extended period. This has been accounted for in reported results.
- Quarter 4 air sampling was disrupted due to a short power failure on site.

3 Calculation and Presentation of Results

Sampling of air and rainwater is carried out by site operators (currently MET Office, Babcock Communications and Northern Ireland Environment Agency staff) and includes a number of factors with associated uncertainties e.g. atmospheric temperature and pressure. These uncertainties have not been considered in this report.

The analytical uncertainties quoted in this report contain an estimate of all sources of uncertainty except those caused by sub-sampling in the analytical process. The uncertainties are calculated at the 95% confidence level.

Limits of detection are calculated following the procedure described by T J Summerling and S C Darby (NRPB R-113) [1] as agreed with the Environment Agency Programme Manager. In addition HPA undertook a comparison of the calculation of decision thresholds and detection levels for radioactive counting experiments between the methods described in ISO 11929-7 [2] and NRPB R-113. For cases where the decision threshold is based on counting statistics of a measured background, it has been demonstrated that the two methods are identical. A document summarising HPA's analysis of the 2 methods has been passed to the Environment Agency Programme Manager [3].

Reported results have been decay corrected to the mid-point of the sampling period and any missed sampling time is accounted for.

For consistency results are presented in a similar format to that produced by the previous contractor.

Statistical data presented in this report have been derived from a database of results produced from 1987 to date. Trending of results is carried out on data collected over a 10 year period (current year plus previous 9 year's results) to produce a 10 year running mean. This is compared to the current year's data and a significance level set at the 10 year running mean plus 2 standard deviations.

All Limits of Detection quoted depend on the collection of an adequate sample size. Air collection disruptions and low rainfall will both reduce the sample size available and thus increase the analytical detection limit.

4 Results and Discussion

4.1 Cs-137 concentrations in air and rainwater

The Cs-137 found in both air particulate and rainwater samples derives from anthropogenic sources including discharges from nuclear installations, fallout from the Chernobyl incident and nuclear weapons testing.

Table 2 shows the Cs-137 results from monthly rainwater and bulked air filter samples at Chilton and monthly rainwater samples at Aberporth. All rainwater samples at both Chilton and Aberporth were below the analytical limit of detection, as were the Chilton air particulate concentrations.

The monthly airborne particulate results are shown graphically in Figure 2. Figure 3 illustrates the monthly measurements from 1987 until the end of 2010, along with the 10 year running mean. This graph indicates the continued plateau in the airborne concentrations of Cs-137 mentioned in previous annual reports, with results being around or below the limit of detection.

Further statistical analysis of the past 10 years data (2001-2010) are presented in Table 2. All air and rain results from Chilton and all rainwater results from Aberporth are below the significance level.

The results from analysis of airborne particulates for Cs-137 at all the collection sites are shown in Table 3 and illustrated in Figure 4. All results are below the analytical limit of detection and individual significance levels, except Q4 Eskdalemuir result which is fractionally above the significance level, but being below the analytical limit of detection it is not possible to say whether there is a real difference.

Tables 4 and 5 display the rainwater concentration and deposition of Cs-137 in quarterly samples. All results are below the analytical limit of detection. All concentration values are below the significance level based on the 10 year mean for each station.

4.2 Be-7 concentrations in air and rainwater

Beyllium-7 is a naturally occurring gamma-emitting radionuclide which is produced during cosmic ray interactions with nitrogen and oxygen in the upper atmosphere. It has a relatively short half-life of 53.2 days and is measured and reported to ensure a consistency in monitoring across the programme; it can also provide a context against which the anthropogenic radioactivity can be compared.

The Be-7 results from Chilton monthly air filter and rainwater samples and the monthly rainwater from Aberporth are shown in Table 6.

Chilton Be-7 results in air range between 0.000301 ± 0.000032 (December) to 0.00218 ± 0.00023 (April) Bq kg^{-1}. These are all below the significance level although some of the results are slightly elevated above the 10-year mean. This pattern of results is consistent with previous data, illustrated in Figure 5.

Chilton Be-7 in 2010 rain ranges between 0.16 ± 0.15 and 1.42 ± 0.37 Bq l^{-1} for September and November respectively. No Chilton Be-7 results are above the significance level. Figure 6 illustrates Be-7 concentrations in Chilton air since 1990 and shows 2010 results are consistent with previous years.

The December result for Aberporth monthly beryllium-7 in rain slightly exceeds the

significance level. This may be consistent with low rainfall or other atmospheric conditions, where elevated Be-7 results are possible.

Quarterly Be-7 measurements in air at all sites are shown in Table 7. Excluding the Q2 and Q3 Chilton results, all other results are below the significance levels. The slightly elevated Q2 and Q3 Chilton results may indicate some atmospheric process causing more efficient mixing of tropospheric air (where Be-7 is produced) with stratospheric air (where the samplers are situated).

The corresponding quarterly Be-7 results in rainwater are shown in Table 8. A similar pattern to the airborne particulate pattern is observed, with the Q1 Eskdalemuir and Q4 Orfordness results just reaching their respective significance levels. The situation is less clear with the rainfall data as the levels can be influenced by seasonal variations in rainfall. Table 9 shows the calculated Be-7 deposition results for all sites. It should be noted that periods of low rainfall are known to be associated with elevated levels of Be-7 in rain.

4.3 Other gamma emitting radionuclides

During the analysis of all samples for gamma emitting radionuclides, any artificial nuclides above the detection limit are quantified. No samples have produced results above the detection limit during 2010. Table 10 shows the annual results for Be-7 and Cs-137 in Chilton rainwater. No other artificial gamma emitting radionuclides were detected.

4.4 Sr-90 concentration in Chilton rainwater

The annual sample for analysis of strontium-90 activity at Chilton was made by bulking the monthly rainwater samples collected during 2010. Results are shown in Table 11.

Strontium-90 was measured in this sample, at half the contract limit of detection. The result is also less than both the 10-year mean and the significance levels, continuing the downward trend year on year. Strontium in the atmosphere is mainly from anthropogenic sources.

4.5 Gross alpha and gross beta in Chilton rainwater

The annual sample for analysis of gross alpha and beta particle activity at Chilton was made by bulking the monthly rainwater samples collected during 2010. Samples were counted using a low background, gas flow proportional counter. These results are presented in Table 12. Figure 7 illustrates the annual gross beta results from 1996-2010 along with the 10 year running mean.

Both gross alpha and gross beta radioactivity were quantified in the sample at very low levels. The gross alpha result is slightly higher than the 10 year mean and less than the significance levels for each measurement.

It should be noted that the World Health Organisation guideline value for drinking water is < 0.5 Bq l^{-1} and < 1.0 Bq l^{-1} for gross alpha and gross beta respectively. 2010 results are significantly below this level.

4.6 Pu-239/240 and Am-241 in Aberporth air and rainwater

The 2010 results for plutonium-239/240 and americium-241 in air particulate and rainwater samples are shown in Table 13.

Analysis of Am-241 in air returned a result below the analytical limit of detection. Pu-239/240 was quantified in both the air and rainwater sample and Am-241 quantified in the rainwater sample at very low levels, consistent with previous measurements. It should be noted that all results are below the 10 year mean and significance levels for each radionuclide measured.

4.7 Tritium in rainwater

Quarterly concentrations of tritium in rainwater are shown in Table 14. All results, except for Q4 Orfordness, were below the analytical limit of detection and during 2010 no results were detected above the significance level.

Tritium in the environment can be from natural or anthropogenic sources. Small quantities are produced by cosmic ray reactions with gases in the upper atmosphere, which are then deposited by rain.

5 Conclusion

Samples of rainwater and airborne particulates have been collected during 2010 for seven sites around the UK. There were some disruptions to the sampling programme due to mechanical and electrical failures of air samplers and some variable collection periods for rainwater samples. Overall these were of a minor nature allowing a large dataset to be collected for 2010.

Samples were analysed for beryllium-7, caesium-137 and (for some sites) a number of other analytes (gross alpha and beta activity, tritium, strontium-90, plutonium-239/240 and americium-241).

Beryllium-7 results were broadly similar to recent historic values with only one result just exceeding the significance level.

For Cs-137 all air and all rainwater results were below the analytical limit of detection. Results were comparable to the 10-year means and no results required further investigation or explanation when compared to the significance level.

Comparison of the 2010 results with those from previous years has been done where possible by calculating the 10 year running mean and setting a significance level at the mean plus 2 standard deviations. This helps to account for results which are close to the analytical detection limits, where uncertainties are large compared to the result. The significance level allows identification of any comparatively high levels of radioactivity in the presence of declining background levels.

The results show that there has been no significant increase in the measured levels of anthropogenic radioactivity in air particulate and rainwater samples taken during 2010.
The results are comparable to the previous 10 year's data and show a continuing decline of anthropogenic radioactivity in the environment.

6 References

1. Statistical Aspects of the Interpretation of Counting Experiments Designed to Detect Low Levels of Radioactivity, T J Summerling and S C Darby, NRPB R-113

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3. Davidson M, A comparison of two methods for calculating limits of detection for measurements of radioactivity- HPA internal document (November 2008).

4. AA Dale/DEFRA, Monitoring of Radioactivity in Air and Rainwater in the UK, Annual Results Report 2008, DEFRA/RWP/09.001 (July 2009)

5. L Mitchell/DECC, Monitoring of Radioactivity in Air and Rainwater in the UK, Annual Results Report 2009, HPA/MR/4/6602

Table 1 Sampling Programme

Airborne Particulates

Station	Latitude	Longitude	Height above ground	Sampling Frequency
Lerwick, Shetland	N60^{o}:08':20"	W1^{o}:11':01"	approx. 1m	weekly
Eskdalemuir, Dumfries	N55^{o}:18':43"	W3^{o}:12':22"	approx. 1m	weekly
Conlig, Co Down	N54^{o}:37':50"	W5^{o}:40':56"	approx. 1m	weekly*
Dishforth, N Yorks	N54^{o}:08':05"	W1^{o}:24':52"	approx. 1m	weekly
Orfordness, Suffolk	N52^{o}:06':18"	W1^{o}:35':03"	approx. 1m	weekly
Aberporth, Ceredigion	N52^{o}:08':23"	W4^{o}:34':11"	approx. 1m	weekly
Chilton, Oxon	N51^{o}:34':23"	W1^{o}:18':34"	approx. 1m	weekly

* The air filter at Conlig is monitored twice-weekly and changed if airflow falls by 30% of its original value.

Rainwater

Station	Latitude	Longitude	approx. mean annual rainfall (mm)	Sampling Frequency
Lerwick, Shetland	N60^{o}:08':20"	W1^{o}:11':01"	1260	quarterly
Eskdalemuir, Dumfries	N55^{o}:18':43"	W3^{o}:12':22"	1840	quarterly
Conlig, Co Down	N54^{o}:37':50"	W5^{o}:40':56"	935	quarterly
Dishforth, N Yorks	N54^{o}:08':05"	W1^{o}:24':52"	655	quarterly
Orfordness, Suffolk	N52^{o}:06':18"	W1^{o}:35':03"	600	quarterly
Aberporth, Ceredigion	N52^{o}:08':23"	W4^{o}:34':11"	930	quarterly & monthly
Chilton, Oxon	N51^{o}:34':23"	W1^{o}:18':34"	745	quarterly & monthly

Table 2 Monthly Cs-137 concentrations at Chilton and Aberporth

Sampling Period 2010	Chilton			Aberporth	
	Cs-137 in air (Bq kg^{-1})	Rainfall (mm)	Cs-137 in rain (Bq l^{-1})	Rainfall (mm)	Cs-137 in rain (Bq l^{-1})
Jan	< 0.00000030	59.9	< 0.010	44.2	< 0.0026
Feb	< 0.00000021	69.5	< 0.011	45.7	< 0.016
Mar	< 0.00000026	47.5	< 0.013	64.8	< 0.011
Apr	< 0.00000025	22.6	< 0.019	37.6	< 0.017
May	< 0.00000025	26.7	< 0.016	51.4	< 0.012
Jun	< 0.00000022	17.7	< 0.020	23.4	< 0.011
Jul	< 0.00000030	20.8	< 0.0064	122.2	< 0.0072
Aug	< 0.00000030	105.2	< 0.0087	34.2	< 0.018
Sep	< 0.00000030	48.0	< 0.013	101.5	< 0.020
Oct	< 0.00000030	41.6	< 0.011	54.0	< 0.020
Nov	< 0.00000030	64.9	< 0.020	118.4	< 0.020
Dec	< 0.00000030	11.6	< 0.015	12.2	< 0.016
Annual mean	< 0.00000027	-	< 0.014	-	< 0.014
10 year mean	0.00000041	-	0.013	-	0.012
Significance Level	0.00000071	-	0.036	-	0.038

Note: 'less than' values are taken to be the reported result for the calculation of annual and 10 year mean values. Significance values are based on the mean plus 2 standard deviations.
No uncertainty is reported where there is a mix of positive and 'less than' results.
For Chilton Cs-137 in rain the April 2007 result has been excluded from running mean due to an unavoidably high limit of detection

Table 3 Quarterly concentration of Cs-137 in air at all sites

Sample station	Cs-137 in air (Bq kg^{-1})				10 year mean (Bq kg^{-1})	Significance level (Bq kg^{-1})
	Q1	**Q2**	**Q3**	**Q4**		
AB	< 0.00000062	< 0.00000056	< 0.00000070	< 0.0000010	0.00000063	0.0000011
CH	< 0.00000077	< 0.00000072	< 0.00000090	< 0.00000090	0.00000060	0.0000011
CO	< 0.00000083	< 0.00000029	< 0.00000091	< 0.0000010	0.00000070	0.0000012
DI	< 0.00000092	< 0.00000070	< 0.00000091	< 0.0000010	0.00000067	0.0000011
ES	< 0.00000048	< 0.00000047	< 0.00000087	< 0.0000010	0.00000057	0.00000098
LE	< 0.00000045	< 0.00000090	< 0.0000010	< 0.0000010	0.00000068	0.0000013
OR	< 0.00000092	< 0.00000086	< 0.00000096	< 0.0000010	0.00000067	0.0000011

Table 4 Quarterly concentration of Cs-137 in rainwater at all sites

Sample station	Cs-137 in rainwater (Bq l^{-1})				10 year mean (Bq l^{-1})	Significance level (Bq l^{-1})
	Q1	**Q2**	**Q3**	**Q4**		
AB	< 0.018	< 0.012	< 0.011	< 0.013	0.040	0.11
CH	< 0.020	< 0.020	< 0.014	< 0.012	0.039	0.098
CO	< 0.019	< 0.016	< 0.020	< 0.020	0.029	0.068
DI	< 0.016	< 0.013	< 0.019	< 0.020	0.040	0.098
ES	< 0.020	< 0.017	< 0.020	< 0.016	0.015	0.032
LE	< 0.020	< 0.015	< 0.019	< 0.020	0.026	0.056
OR	< 0.020	< 0.021	< 0.017	< 0.030	0.054	0.12

Table 5 Quarterly Cs-137 deposition by rainwater at all sites

Sample Station	**Q1**		**Q2**		**Q3**		**Q4**	
	Rainfall (mm)	Cs-137 (Bq m^{-2})	Rainfall (mm)	Cs-137 (Bq m^{-2})	Rainfall (mm)	Cs-137 (Bq m^{-2})	Rainfall (mm)	Cs-137 (Bq m^{-2})
AB	156.9	< 2.8	112.4	< 1.3	257.7	< 2.8	184.8	< 2.4
CH	176.9	< 3.5	67.0	< 1.3	174	< 2.4	221.5	< 2.7
CO	316.5	< 6.0	72.1	< 1.2	368.4	< 7.4	360.4	< 7.2
DI	178.3	< 2.9	45	< 0.59	154.8	< 2.9	159.2	< 3.2
ES	293.8	< 5.9	146.2	< 2.5	512.9	< 10.3	382	< 6.1
LE	336.3	< 6.7	131.2	< 2.0	335.4	< 6.4	280.4	< 5.6
OR	170.5	< 3.4	105.4	< 2.2	219	< 3.7	37	< 1.1

Table 6 Monthly Be-7 concentrations at Chilton and Aberporth

Sampling Period 2010	Chilton			Aberporth	
	Be-7 in air (Bq kg^{-1})	Rainfall (mm)	Be-7 rain (Bq l^{-1})	Rainfall (mm)	Be-7 in rain (Bq l^{-1})
Jan	0.00115 ± 0.00012	59.9	0.92 ± 0.43	44.2	0.98 ± 0.15
Feb	0.00105 ± 0.00011	69.5	0.41 ± 0.24	45.7	1.60 ± 0.42
Mar	0.00177 ± 0.00018	47.5	1.34 ± 0.35	64.8	1.17 ± 0.28
Apr	0.00218 ± 0.00023	22.6	1.07 ± 0.41	37.6	2.64 ± 0.55
May	0.00204 ± 0.00021	26.7	0.51 ± 0.30	51.4	1.76 ± 0.39
Jun	0.00202 ± 0.00021	17.7	0.82 ± 0.19	23.4	1.42 ± 0.24
Jul	0.00178 ± 0.00019	20.8	0.85 ± 0.12	122.2	1.43 ± 0.25
Aug	0.00147 ± 0.00016	105.2	0.38 ± 0.24	34.2	1.71 ± 0.44
Sep	0.00170 ± 0.00018	48	0.16 ± 0.15	101.5	1.35 ± 0.22
Oct	0.000708 ± 0.000075	41.6	0.66 ± 0.24	54.0	1.18 ± 0.21
Nov	0.000646 ± 0.000067	64.9	1.42 ± 0.37	118.4	0.91 ± 0.21
Dec	0.000301 ± 0.000032	11.6	0.73 ± 0.26	12.2	3.90 ± 0.58
Annual mean	0.00140 ± 0.000046	-	0.77 ± 0.084	-	1.67 ± 0.10
10 year mean	0.00159	-	0.93	-	1.4
Significance Level	0.00250	-	1.88	-	2.8

Table 7 Quarterly concentrations of Be-7 in airborne particulates

Sample station	Be-7 in air (Bq kg^{-1})				Annual mean (Bq kg^{-1})	Significance level (Bq kg^{-1})
	Q1	**Q2**	**Q3**	**Q4**		
AB	0.00170 ± 0.00018	0.00192 ± 0.00021	0.00117 ± 0.00013	0.00143 ± 0.00017	0.001555 ± 0.000087	0.0028
CH	0.00397 ± 0.00024	0.00624 ± 0.00038	0.00495 ± 0.00031	0.00166 ± 0.00017	0.004204 ± 0.000143	0.0049
CO	0.00152 ± 0.00017	0.000607 ± 0.000063	0.00116 ± 0.00013	0.000600 ± 0.000070	0.000972 ± 0.000059	0.0028
DI	0.00119 ± 0.00013	0.00145 ± 0.00016	0.00108 ± 0.00013	0.000376 ± 0.000006	0.001024 ± 0.000063	0.0021
ES	0.00148 ± 0.00016	0.00122 ± 0.00015	0.000675 ± 0.000090	0.00101 ± 0.00012	0.001096 ± 0.000022	0.0023
LE	0.00153 ± 0.00016	0.00116 ± 0.00013	0.00118 ± 0.00014	0.00096 ± 0.00012	0.001208 ± 0.000069	0.0023
OR	0.00140 ± 0.00015	0.00169 ± 0.00019	0.00175 ± 0.00020	0.00097 ± 0.00011	0.001453 ± 0.000083	0.0031

Table 8 Quarterly concentrations of Be-7 in rainwater

Sample station	Be-7 in rain (Bq l^{-1})				Annual mean (Bq l^{-1})	Significance level (Bq l^{-1})
	Q1	**Q2**	**Q3**	**Q4**		
AB	1.44 ± 0.39	1.69 ± 0.29	1.18 ± 0.28	1.78 ± 0.34	1.52 ± 0.16	2.6
CH	0.85 ± 0.42	0.64 ± 0.40	1.15 ± 0.34	1.28 ± 0.38	0.98 ± 0.19	3.1
CO	0.64 ± 0.40	1.60 ± 0.41	1.70 ± 0.52	1.23 ± 0.37	1.29 ± 0.21	2.4
DI	1.96 ± 0.48	3.63 ± 0.49	1.99 ± 0.47	1.03 ± 0.37	2.15 ± 0.23	4.0
ES	1.90 ± 0.48	1.74 ± 0.44	1.30 ± 0.39	1.17 ± 0.42	1.53 ± 0.22	1.9
LE	1.38 ± 0.53	0.91 ± 0.26	1.55 ± 0.48	1.89 ± 0.48	1.43 ± 0.22	2.6
OR	2.43 ± 0.63	1.90 ± 0.69	2.72 ± 0.50	3.70 ± 0.78	2.69 ± 0.33	3.7

Table 9 Quarterly Be-7 deposition by rainwater at all sites

Sample Station	**Q1**		**Q2**		**Q3**		**Q4**	
	Rainfall (mm)	Be-7 (Bq m^{-2})	Rainfall (mm)	Be-7 (Bq m^{-2})	Rainfall (mm)	Be-7 (Bq m^{-2})	Rainfall (mm)	Be-7 (Bq m^{-2})
AB	156.9	226 ± 61	112.4	190 ± 33	257.7	304 ± 72	184.8	329 ± 63
CH	176.9	150 ± 74	67.0	43 ± 27	174	200 ± 59	221.5	284 ± 84
CO	316.5	203 ± 127	72.1	115 ± 30	368.4	626 ±192	360.4	443 ± 133
DI	178.3	349 ± 86	45.0	163 ± 22	154.8	308 ± 73	159.2	164 ± 59
ES	293.8	558 ± 141	146.2	254 ± 64	512.9	667 ±200	382	447 ± 160
LE	336.3	464 ± 178	131.2	119 ± 34	335.4	520 ±161	280.4	530 ± 135
OR	170.5	414 ± 107	105.4	200 ± 73	219	596 ±110	37.0	137 ± 29

Table 10 Annual concentrations of gamma emitting radionuclides in Chilton rainwater

Sample station	Radionuclide activity (Bq l^{-1})	
	Be-7	**Cs-137**
Chilton	1.79 ± 0.59	< 0.00063
10-year mean	2.185 ± 0.094	< 0.0018
Significance level (+2σ)	3.1	< 0.0033

Table 11 Annual concentration and deposition of Sr-90 in Chilton rainwater

Sample station	Sr-90 in rain (Bq l^{-1})	10 year mean (Bq l^{-1})	Significance level (Bq l^{-1})	Rainfall (mm)	Sr-90 deposition (Bq m^{-2})
Chilton	0.00100 ± 0.00041	0.0018	0.0065	639.4	6.0

Table 12 Annual concentration of gross alpha and gross beta in Chilton rainwater

Sample station	Gross alpha (Bq l^{-1})	Gross beta (Bq l^{-1})
Chilton	0.043 ± 0.018	0.037 ± 0.029
10 year mean	0.042	0.10
Significance level (+2σ)	0.075	0.20

Table 13 Annual concentrations of Pu-239+240 and Am-241 in Aberporth air particulates and rainwater

Sample station	Air		Rain		
	Pu 239+240 (Bq kg^{-1})	Am-241 (Bq kg^{-1})	Rainfall (mm)	Pu 239+240 (Bq l^{-1})	Am-241 (Bq l^{-1})
Aberporth	0.00000000046 ± 0.00000000017	< 0.00000000030	718.9	0.0000057 ± 0.0000021	0.0000052 ± 0.0000023
10 year mean	0.00000000065	< 0.0000000023	–	0.000022	0.000040
Significance level (+2σ)	0.0000000014	0.0000000091		0.000067	0.000124

Table 14 Quarterly tritium concentrations in rainwater

Sample station	Q1 H-3 (Bq l^{-1})	Q2 H-3 (Bq l^{-1})	Q3 H-3 (Bq l^{-1})	Q4 H-3 (Bq l^{-1})	10 year mean (Bq l^{-1})	Significance level (+2σ) (Bq l^{-1})
Aberporth	< 1.2	< 1.6	< 0.97	< 1.2	1.2	2.5
Eskdalemuir	< 1.2	< 1.6	< 0.94	< 1.2	1.7	4.5
Orfordness	< 1.2	< 1.7	< 0.98	1.3 ± 1.1	1.3	2.8

Figure 1 Sampling Station Locations

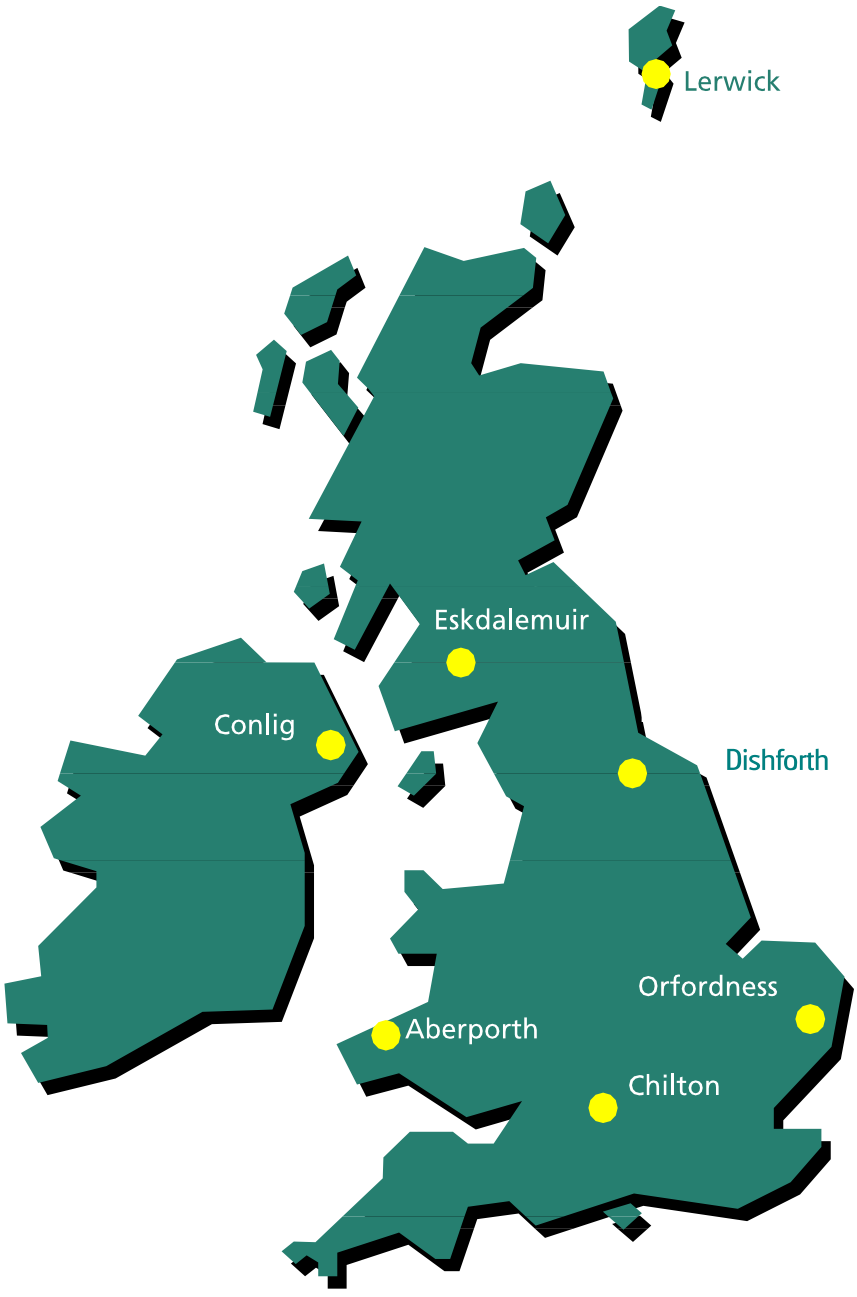

Figure 2 Monthly Cs-137 concentrations in air at Chilton

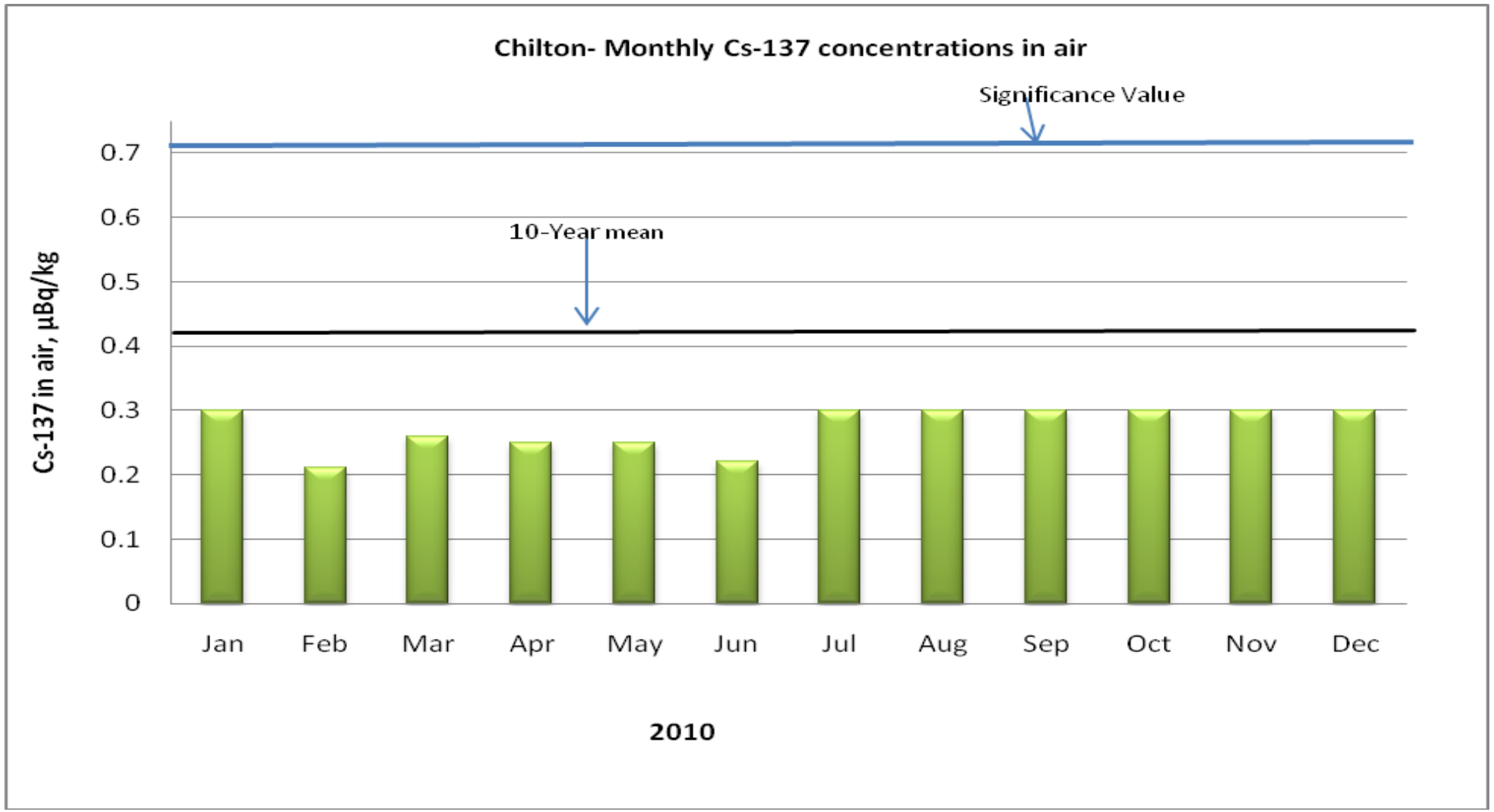

Figure 3 Cs-137 concentrations in air at Chilton. Monthly measurements from 1987 until end 2010

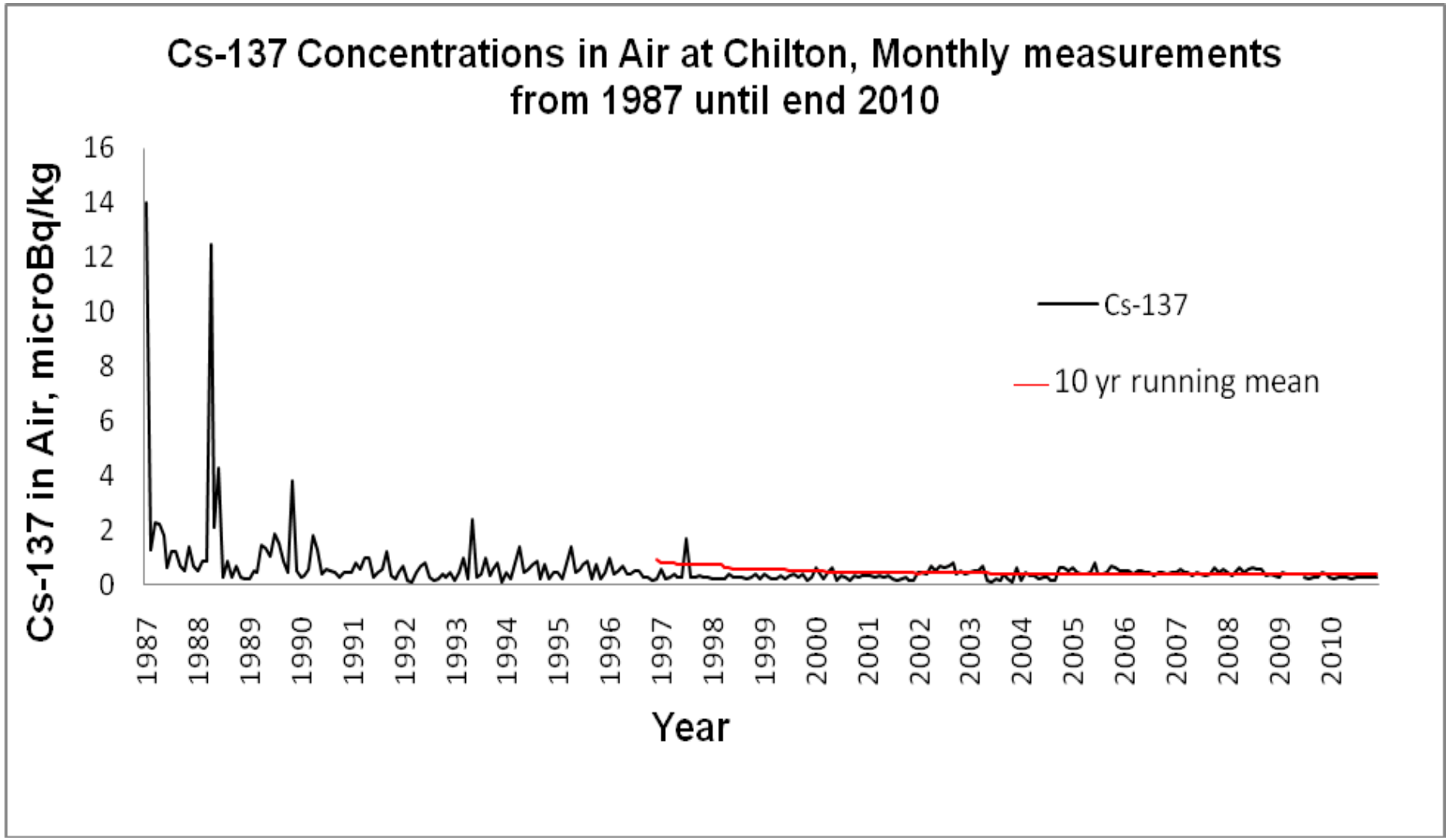

Figure 4 Quarterly Cs-137 concentrations in air at all stations for 2010

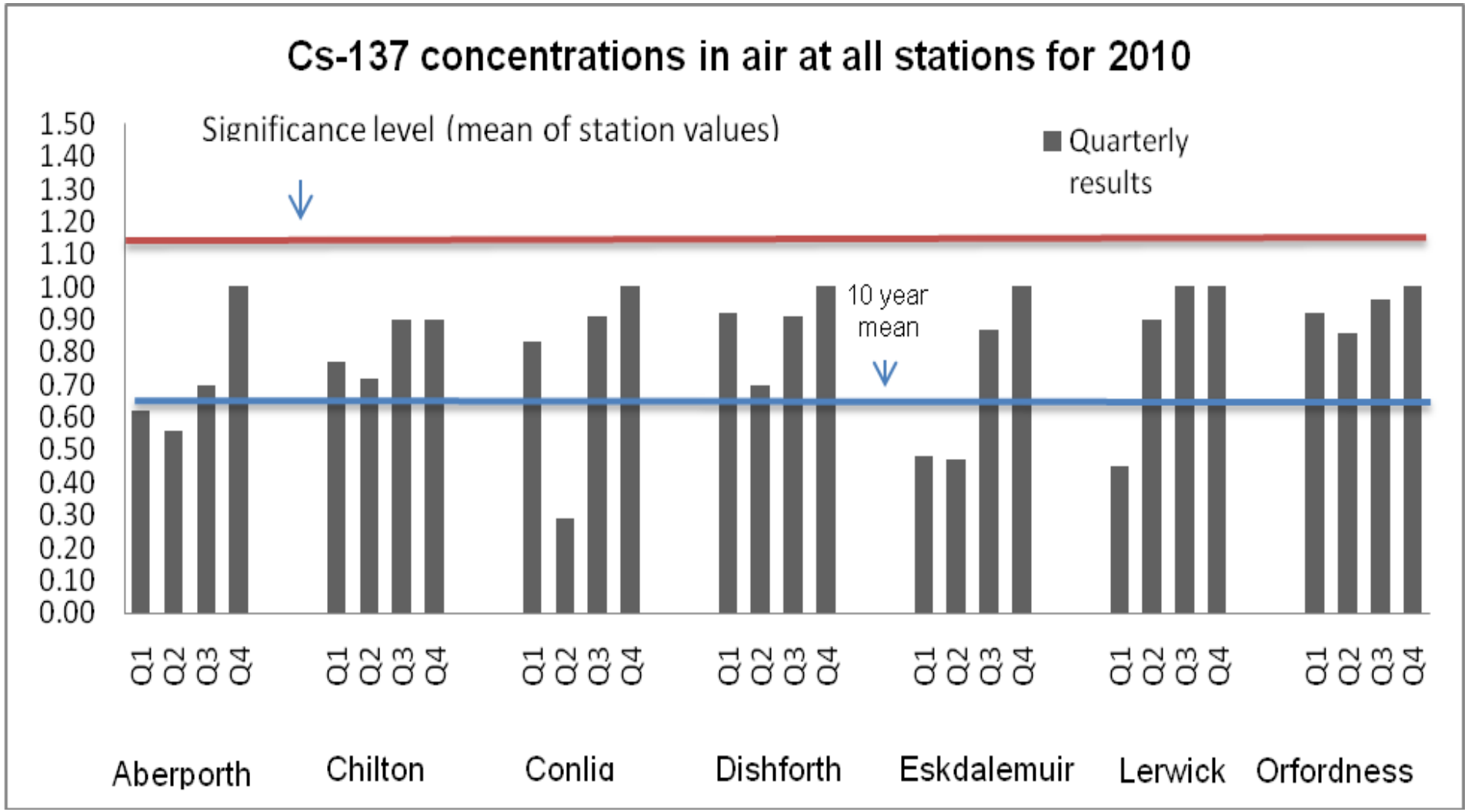

Figure 5 Be-7 Concentrations in Air at Chilton

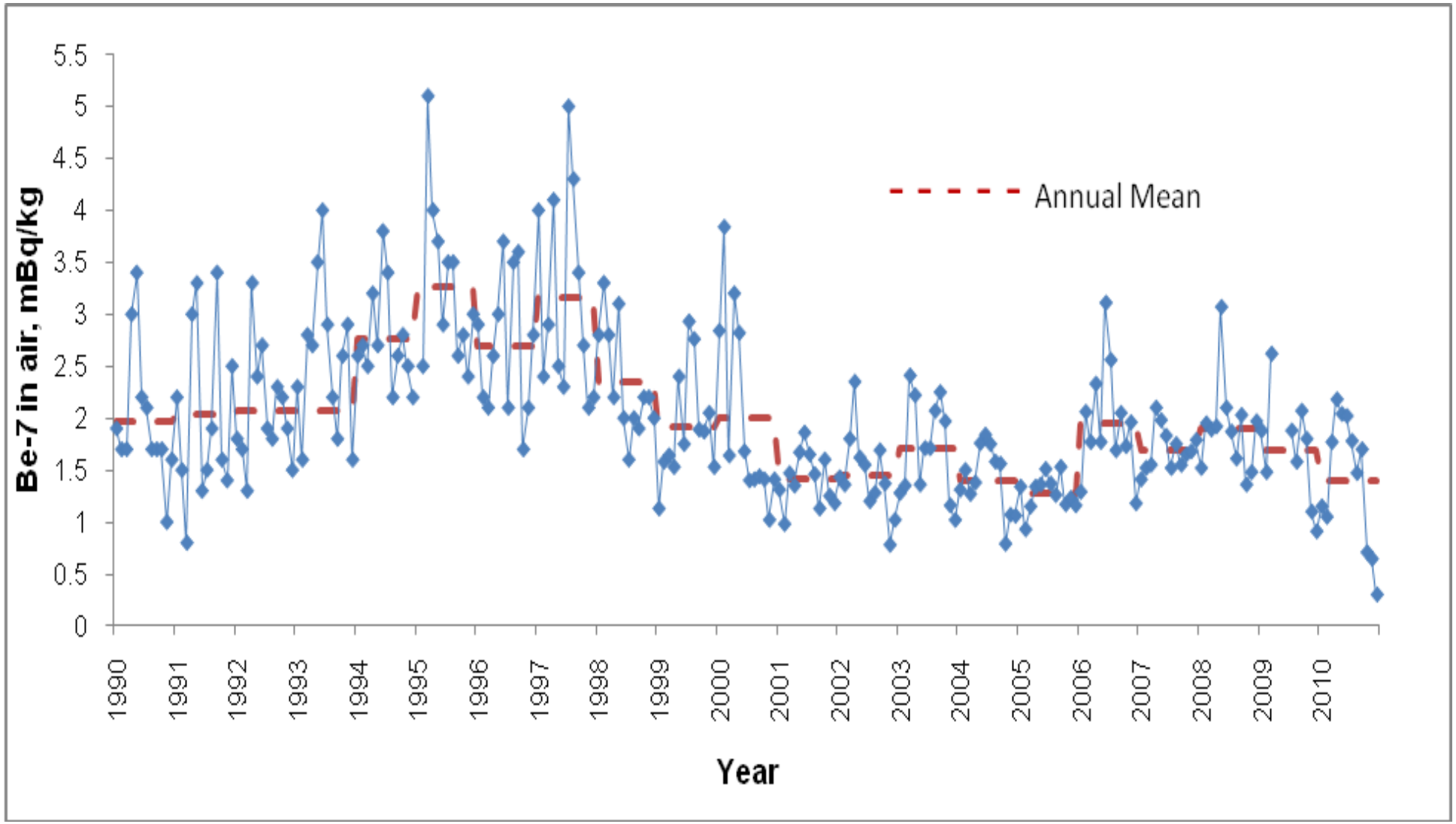

Figure 6 Be-7 Concentrations in Rain at Chilton

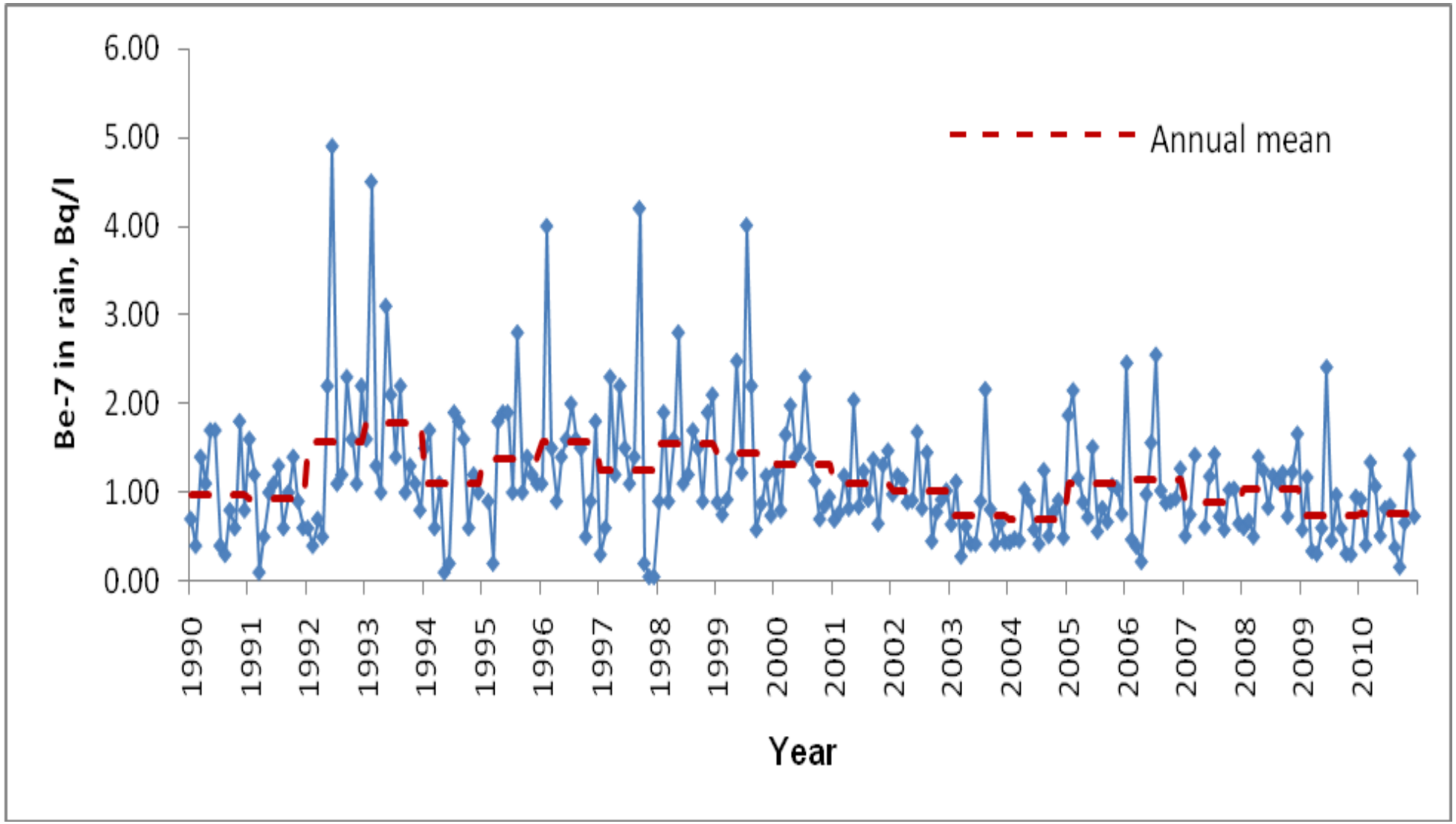

Figure 7 Annual concentration of gross beta activity in rainwater at Chilton