

# **The Long Term Migration of Substances from In-situ Applied Epoxy Resin Coatings**

*Final Report to the Drinking Water Inspectorate*



**THE LONG TERM MIGRATION OF SUBSTANCES FROM IN-SITU APPLIED  
EPOXY RESIN COATINGS**

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# THE LONG TERM MIGRATION OF SUBSTANCES FROM IN-SITU APPLIED EPOXY RESIN COATINGS

## EXECUTIVE SUMMARY

Trials of epoxy resin relining for the rehabilitation of water mains in the UK started in the late 1970s and by the late 1990s epoxy lining had become the most popular non-structural rehabilitation method. Currently five manufacturers hold approvals for epoxy resins for the in-situ lining of water mains.

The Committee on Products and Processes for use in Public Water Supply (the CPP)<sup>1</sup> noted that there is a lack of leachate data from in-situ relined pipes after varying periods of time in service. Whilst the use of epoxy resins for mains rehabilitation is declining, the long service life of these products (of the order of 30 years or longer) means that applied linings have the potential to affect water quality for decades. To fill this gap in leachate data, DWI appointed WRc-NSF to examine the leaching of chemicals from existing epoxy resin in-situ relined water mains based on samples taken from consumers' taps.

Initially the existing information on leaching from epoxy resins was reviewed. The review covered pre-approval test results, audit test results and any other relevant information.

Water companies were contacted to attempt to identify suitable zones for sampling covering all combinations of: five epoxy resins; hard and soft water; low and high free chlorine concentration; and three ages of linings – 1-2, 3-6 and 7-10 years. It was not possible to identify sampling sites covering all possible combinations. A sampling plan was devised to cover as many combinations as possible – this included eight water undertakers' areas of supply. Two sets of samples were taken – the first during April to May 2006 and the second during August to September 2006, when water temperatures were warmer. Most of the locations sampled in the first phase were included in the second phase of sampling. A total of 120 samples, including field blanks, were taken.

Suitable streets for sampling were identified in consultation with water company staff. Samples were taken from domestic drinking water taps. The tap was fully opened and the water run to waste for at least three minutes to flush water that had been standing in the domestic pipework. Samples were taken for Total Organic Carbon (TOC) and general survey Gas Chromatography – Mass Spectrometry (GC-MS) analysis. After the samples had been taken the free chlorine concentration was determined using a test kit and the water temperature was measured using a digital thermometer. These readings, together with the address of the property and other pertinent information, were recorded. In each water supply zone, at least one field blank sample was taken. The blank samples were taken upstream of any relining.

The average water temperature during Phase 1 was 11 °C and during Phase 2 this had risen to 16.5 °C. Samples were assigned to the 'High' and 'Low' chlorine category in relation to the median chlorine concentration.

<sup>1</sup> The CPP was disbanded in March 2007.

There was no technically or statistically significant difference in TOC results between the samples and the field blanks for either phase of sampling. This suggests that any leaching from the pipe linings is at a low level.

The GC-MS results for Resins A, B, D and E did not show any evidence of leaching of components of the resins. The chemicals detected were those that are commonly found in drinking water samples; i.e. disinfection by-products and environmental contaminants such as phthalates. Overall, there does not appear to be a real difference between the results for samples and field blanks in the case of these resins. Repeat sampling during warmer water temperatures did not indicate any substantial change in leaching characteristics.

Evidence of leaching of 4-t-butylphenol (4-TBP) from Resin C was found – 4-TBP and various halogenated derivatives were detected in some (but not all) samples taken from taps fed from mains lined with Resin C. The highest concentration of 4-TBP found was 2.2 µg/l. Resin C is the only one of the five resins considered that contains 4-TBP as a component.

Comparison of the review of results from laboratory tests and the field survey indicates that laboratory test results may overstate the leaching of components from epoxy resins.

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# 1. INTRODUCTION

Trials of epoxy resin relining for the rehabilitation of water mains in the UK started in the late 1970s and by the late 1990s epoxy lining had become the most popular non-structural rehabilitation method. The first approval was granted in 1989 and since then several more products have been approved by the Government Authorities. Currently five manufacturers hold approvals for epoxy resins for the in-situ lining of water mains. Since 1989 the Operational Requirements and Code of Practice have covered the application of epoxy resins; these documents provide methods of working that form part of the approval for resin materials. Epoxy resins must be applied by an approved contractor. Lists of approved resins and contractors are published annually by DWI in the 'List of Approved Products and Processes'. Currently there are four organisations that are accredited to certify lining contractors.

At least 13 water companies are understood to have undertaken relining using epoxy resins during the past 10 years. Most of these companies have used more than one approved epoxy resin. All the utilities will have been required to keep records of varying quality depending on how long ago the relining was conducted. Exactly what will have been retained and for how long will vary from company to company. Currently they would be expected to keep copies of the following, for each lining length, for various periods but up to seven years after completion of the contract is not unusual:

- Lining date, location and gang
- Material type
- Pipe diameter, length and access holes
- Lining rig and application head numbers
- Batch numbers for resin and hardener
- Cleaning survey report
- Resin and hardener temperatures, spin up time, mix ratio, weight check data and dip cards
- Pre-cure thickness, quality and uniformity
- Post-cure thickness, colour and uniformity
- CCTV lining survey reports
- Cure time
- Chlorination records and flushing time
- Return to service time and details of any customer problems
- Pipe sample records (usually one sample per 500 m of lining)
- Non-conformance records
- In addition they may have retained the CCTV video

It is unlikely that this level of detail will be available for older linings but records should exist of when a main was lined, the lining material used, the contractor who applied it, pipe age, material and diameter. Weight check information and mix ratio details may also have been retained.

In 2002 the Committee on Products and Processes for use in Public Water Supply (the CPP)<sup>2</sup> initiated a scheme for the periodic audit of approved products and awarded a contract to administer the audit scheme and conduct the audits to WRc-NSF. The audits involve a factory inspection and, in the case of construction products such as epoxy resins, limited laboratory leaching tests according to the current CPP requirements. The GC-MS general survey test results for certain epoxy resins showed evidence of leaching of several compounds, some at relatively high concentrations. WRc-NSF prepared a summary of pre-approval test results, results of laboratory research conducted by WRc (Kanda *et al.* 1998), and the audit test results. The CPP reviewed these results and decided that, on the basis of the outcome of the audits, epoxy resin products are ‘high risk’ products.

The CPP also noted that there is a lack of leachate data from in-situ relined pipes after varying periods of time in service. The use of epoxy resins in England and Wales is now almost non-existent and any use will cease when the current Section 19 Water Quality Undertaking finishes in 2009. After that water utilities will only line mains as part of their Distribution Operations Maintenance Strategy (DOMS) and are unlikely to use epoxy resin materials as rapid-setting polyurethane products have largely superseded them. There is however some continued use of epoxy resins for water main lining in Scotland. This continued low usage of epoxy resins and the long service life of these products (of the order of 30 years or longer) means that applied linings have the potential to affect water quality for decades. To fill this gap in leachate data, DWI appointed WRc-NSF to examine the leaching of chemicals from existing epoxy resin in-situ relined water mains based on samples taken from consumers’ taps.

Initially the existing information on leaching from epoxy resins was reviewed. Most of this information is confidential and held on DWI’s CPP files and these files were reviewed at DWI’s offices. The review covered pre-approval test results, audit test results and any other relevant information. The resin manufacturers were contacted to determine whether they had any relevant data that they would be prepared to release in confidence but they did not have data other than that included in the CPP files. The review is not included in this report because it includes confidential formulation information.

Water companies were contacted to attempt to identify suitable zones for sampling covering all combinations of:

- five epoxy resins (A to E);
- hard and soft water;
- low and high free chlorine concentration; and
- three ages of linings – 1-2, 3-6 and 7-10 years.

It was not possible to identify sampling sites covering all possible combinations. A sampling plan was devised to cover as many combinations as possible – this is presented in **Section 2**. Two sets of samples were taken – the first during April to May 2006 and the second during August to September 2006, when water temperatures were warmer.

<sup>2</sup> The CPP was disbanded in March 2007.

The results of the field survey are given in **Section 3** and are discussed in **Section 4**. The principal conclusions are presented in **Section 5**.



## 2. SAMPLING

### 2.1 Sample locations

Water companies that have conducted mains rehabilitation during the past 10 years were contacted to obtain details of their rehabilitation schemes and the records held, together with maps of relevant water supply zones. Suitable sub-zones for sampling with relatively long lengths of relined main prior to the tap and relatively long residence time of water in the main were identified. We also sought to identify whether there had been any customer complaints of taste and odour, dirty water, poor pressure and flow and so on. On the basis of this information a structured sampling plan was developed to cover:

- Five approved epoxy resins – A to E
- Two types of water – hard and soft
- Two levels of chlorine – high and low
- Three ages of linings – 1-2 years, 3-6 years and 7-10 years

Ideally, this plan would have resulted in a total of 60 combinations of resin, hardness, chlorine concentration and age of lining. However, it was not possible to identify suitable sampling sites for each combination of resin, water type and age. In addition, it was difficult to predict in advance whether chlorine concentrations would be high or low – chlorine levels are likely to be relatively low where the water sampled has had a long residence time in the water main. Therefore, free chlorine concentrations were measured on site and the sample was subsequently assigned to the ‘low’ or ‘high’ chlorine category. It was not possible to identify sites covering:

Resin A	Hard water + 1-2 years; Soft water + 1-2 years; Soft water + 3-6 years
Resin B	Hard water + 1-2 years;
Resin C	Hard water + any age; Soft water + 1-2 years
Resin D	(all combinations covered)
Resin E	Hard water + 1-2 years

Based on discussions with water companies and epoxy resin manufacturers the sampling plan was developed – this included eight water undertakers’ areas of supply. These samples were taken during April to May 2006. A second phase of sampling was undertaken during August to September 2006 when water temperatures were warmer. Most of the locations sampled in the first phase were included in the second round of sampling – where it was not possible to gain access to the property sampled previously, an adjacent property was selected.

## 2.2 Sampling procedure

Suitable streets for sampling were identified in consultation with water company staff. In most cases sampling was undertaken by water company samplers under the instruction and supervision of WRc-NSF personnel. The WRc-NSF sampler selected a domestic property from which to sample. On arrival, the sampler introduced himself and requested permission to take water samples. If the property was unoccupied or permission was refused, the sampler approached other properties in the same area until a suitable site for sampling was found. Each sample was assigned a code.

Samples were taken from domestic drinking water taps. The tap was fully opened and the water run to waste for at least three minutes to flush water that had been standing in the domestic pipework. One sample was then taken into a clean 100 ml polyethylene bottle for TOC analysis and two others into 1-litre glass bottles containing 2 ml of 1 g/l ascorbic acid solution (to dechlorinate the samples) with PTFE-lined caps for GC-MS analysis. The bottles were filled to the top leaving no headspace. (Duplicate samples for GC-MS analysis were taken in case of sample bottles being broken or leakage occurring during transport to the laboratory.)

After the samples had been taken the free chlorine concentration was determined using a test kit and the water temperature was measured using a digital thermometer. These readings, together with the address of the property and other pertinent information, were recorded.

In each water supply zone, at least one field blank sample was taken. The blank samples were taken upstream of any relining; in some cases these were samples taken from the water treatment works feeding the zone. In some cases, a single field blank sample was sufficient for more than one test sample.

Copies of the sampling procedure and sample forms are given in Appendix A.

At the end of a sampling day, the samples were transported to WRc-NSF's Reading laboratory for analysis. Samples for GC-MS analysis were solvent extracted within 48 hours of the time of sampling. The samples were acidified to pH 2 with sulphuric acid (10%) and extracted with dichloromethane (DCM), 2 × 100 ml. The combined DCM extracts were dried (by storing overnight in a freezer and filtering to remove ice crystals) and concentrated in a Kuderna-Danish apparatus at 50°C to approximately 2 ml, and then concentrated further to 500 µl under a stream of nitrogen. The extracts were stored in a freezer prior to analysis by GC-MS.

General survey GC-MS analysis was conducted according to BS6920 Part 4 using a Hewlett-Packard 5890 gas chromatograph (GC) directly coupled to a VG 70S mass spectrometer.

Data interpretation was undertaken by inspecting the mass spectra of all the peaks detected on the total ion current (TIC) chromatogram. If mass spectra were not recognised, libraries of mass spectra (either the NIS, NISTREP and Wiley libraries held on the GC-MS data system or a hard copy version of the Eight Peak Index) were utilised in an attempt to identify the compound giving rise to a particular mass spectrum. If this

approach was unsuccessful, an attempt was made to interpret the mass spectrum from first principles. Where no identity can be suggested, compounds are listed as unknowns, together with a listing of the four most intense ions in the mass spectrum (in decreasing order of intensity).

Estimates of the concentrations of the compounds identified were made using the responses obtained for deuterated internal standards, which were added to the sample prior to analysis –  $d_{13}$  4-t-butylphenol was included as an internal standard in addition to the internal standards normally used. Quantification was based on a comparison of the TIC chromatogram peak area of a compound of interest with the peak area of an internal standard. The internal standard used was that with the closest retention time to the peak for the compound of interest.

TOC was determined by a UV/persulphate oxidation technique with non-dispersive infra-red detection. The instrument was calibrated externally with a standard solution of potassium hydrogen phthalate (10 mg/l as organic carbon). In addition, control standards, a solution of potassium hydrogen phthalate (5 mg/l as organic carbon), and blank water were analysed with the samples.





### 3. RESULTS

The average water temperature during Phase 1 was 11 °C and during Phase 2 this had risen to 16.5 °C.

The results for on-site tests and TOC are given in Table 1 and Table 2 for Phases 1 and 2 respectively. Samples were assigned to the ‘High’ and ‘Low’ chlorine category respectively depending on whether the chlorine concentration was  $\geq$  or  $<$  the median chlorine concentration (Phase 1: 0.16 mg/l, Phase 2: 0.19 mg/l; excluding field blanks).

The CG-MS results are given in Table 3 to Table 12. The results for the field blanks are presented alongside the test sample results; the test sample results are not corrected for the field blanks.

Many of the chemicals detected were disinfection by-products (e.g. bromoform) and environmental contaminants such as phthalates. Table 13 summarises the chemicals detected, excluding disinfection by-products and environmental contaminants. Concentrations  $\geq 0.5$   $\mu\text{g/l}$  are highlighted in **bold** – a concentration of 0.5  $\mu\text{g/l}$  was selected arbitrarily simply to highlight higher concentrations.

4-t-Butyl phenol (4-TBP) was detected in some samples taken from houses fed from mains lined with Resin C – the results are summarised in Table 14. 4-TBP was not found in the field blanks<sup>3</sup>.

<sup>3</sup> 4-TBP was also detected at low concentrations ( $\leq 0.1$   $\mu\text{g/l}$ ) in two other samples – its source in those samples is unknown.

**Table 1 Results for on-site tests and TOC – Phase 1**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
A	3-6	Hard	Low	Clear	0.10	9.6	0.31
Blank					0.13	10.8	0.40
A	7-10	Hard	Low	Clear	0.06	12.8	0.62
Blank					0.40	11.3	0.62
A	7-10	Hard	High	Clear	0.16	10.7	1.36
Blank					0.50	10.9	1.68
A	7-10	Soft	Low	Clear	0.10	12.5	0.45
Blank					0.90	13.4	0.92
A	7-10	Soft	High	Clear	0.53	12.1	0.98
Blank					0.90	13.4	0.92
B	?	Soft	Low	Clear	0.10	11.5	1.76
Blank					0.26	10.3	1.83
B	1-2	Soft	High	Clear	0.23	10.6	0.78
Blank					0.51	10.7	1.11
B	3-6	Hard	Low	Clear	0.13	12.0	0.65
Blank					0.31	9.7	1.11
B	3-6	Soft	Low	Clear	0.07	9.8	1.66
Blank					0.06	9.3	1.99
B	3-6	Soft	Low	Clear	0.01	13.2	1.35
Blank					1.66	10.6	2.29

**Table 1**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
B	3-6	Soft	High	Clear	0.79	12.3	0.72
Blank					0.69	13.3	0.63
B	7-10	Hard	Low	Clear	0.12	11.8	1.66
Blank					0.10	11.3	1.47
B	7-10	Hard	High	Clear	0.73	10.9	0.83
Blank					0.71	10.9	0.98
C	3-6	Soft	Low	Clear	0.13	11.9	1.17
Blank					0.51	10.7	1.11
C	3-6	Soft	High	Clear	0.50	12.4	1.11
Blank					0.30	10.2	0.89
C	7-10	Soft	Low	Clear	0.01	9.4	0.99
Blank					0.30	10.2	0.89
C	7-10	Soft	Low	Clear	0.14	10.3	1.03
Blank					0.30	10.2	0.89
C	7-10	Soft	Low	Clear	0.01	10.3	0.93
Blank					0.30	10.2	0.89
C	7-10	Soft	High	Clear	0.40	10.9	1.02
Blank					0.30	10.2	0.89
D	1-2	Hard	High	Clear	0.25	9.7	1.04
Blank					0.20	10.4	0.81

**Table 1**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
D	1-2	Soft	High	Clear	0.18	15.8	0.94
Blank					0.36	14.7	0.85
D	1-2	Soft	High	Clear	0.16	10.2	1.08
Blank					0.25	10.1	1.50
D	3-6	Hard	Low	Clear	0.09	12.5	0.41
Blank					0.19	12.5	0.39
D	3-6	Hard	High	Clear	0.36	10.8	0.35
Blank					0.20	10.4	0.81
D	3-6	Hard	High	Clear	0.51	10.2	1.11
Blank					0.02	11.1	1.73
D	3-6	Hard	High	Clear	0.27	13.2	1.55
Blank					0.15		1.55
D	3-6	Soft	Low	Clear	0.08	11.1	0.91
Blank					0.13	11.6	1.76
D	7-10	Hard	Low	Clear	0.15	12.6	1.44
Blank					0.10	11.3	1.47
D	7-10	Soft	High	Clear	0.18	13.0	0.90
Blank					0.30	13.1	0.80
E	1-2	Soft	Low	Clear	0.04	11.6	0.86
Blank					0.65	8.6	0.82

**Table 1**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
E	3-6	Hard	Low	Clear	0.00	11.5	1.05
Blank					0.06	10.4	1.33
E	3-6	Hard	High	Clear	0.17	9.9	2.00
Blank					0.80	9.0	1.71
E	3-6	Soft	Low	Clear	0.04	11.5	1.07
Blank					0.69	13.3	0.63
E	7-10	Hard	High	Clear	0.25	8.9	1.91
Blank					0.80	9.0	1.70
E	7-10	Hard	High	Clear	0.80	9.9	1.24
Blank					0.89	9.9	1.16
E	7-10	Soft	High	Clear	0.28	9.6	1.96
Blank					0.26	10.3	1.83
E	7-10	Soft	High	Clear	0.40	11.3	1.76
Blank					0.26	10.3	1.77

**Table 2 Results for on-site tests and TOC – Phase 2**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
A	3-6	Hard	High	Clear	0.51	16.8	0.19
Blank					0.52	12.4	0.24
A	7-10	Hard	High	Clear	0.22	18.7	0.94
Blank					0.78	18.0	1.06
A	7-10	Hard	Low	Clear	0.08	17.2	0.75
Blank					0.44	13.8	0.56
A	7-10	Soft	High	Clear	0.31	18.6	1.00
Blank					1.16	19.0	1.06
A	7-10	Soft	Low	Clear	0.13	16.0	1.11
Blank					1.16	19.0	1.06
B	1-2	Soft	High	Clear	0.20	12.8	1.10
Blank					0.40	12.5	1.07
B	3-6	Hard	High	Clear	0.38	18.6	0.51
Blank					0.38	19.4	0.74
B	3-6	Soft	High	Clear	0.19	17.5	1.44
Blank					0.16	15.5	1.50
B	3-6	Soft	High	Clear	0.63	18.9	0.70
Blank					0.76	18.7	0.69
B	3-6	Soft	Low	Clear	0.09	0.0	1.51
Blank					1.49	11.8	2.35

**Table 2**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
B	7-10	Hard	High	Clear	0.57	19.4	0.87
Blank					0.98	12.7	0.75
B	7-10	Hard	Low	Clear	0.16	17.5	1.22
Blank					0.18	17.9	1.30
B	7-10	Soft	High	Clear	0.20	18.1	1.89
Blank					0.23	17.8	2.00
C	3-6	Soft	High	Clear	0.25	13.4	0.87
Blank					0.40	12.5	1.07
C	3-6	Soft	Low	Slightly cloudy	0.04	12.4	1.43
Blank					0.43	10.2	0.92
C	7-10	Soft	High	Clear	0.24	13.2	1.30
Blank					0.43	10.2	0.92
C	7-10	Soft	High	Clear	0.40	11.9	0.86
Blank					0.43	10.2	0.92
C	7-10	Soft	Low	Clear	0.06	12.2	1.06
Blank					0.43	10.2	0.92
C	7-10	Soft	Low	Clear	0.04	12.2	1.17
Blank					0.43	10.2	0.92
D	1-2	Soft	Low	Clear	0.03	21.6	0.92
Blank					0.07	20.9	1.02
D	3-6	Hard	High	Clear	0.27	16.6	1.25
Blank					0.14	17.7	1.26

**Table 2**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
D	3-6	Hard	High	Clear	0.19	17.0	1.37
Blank					0.23	16.2	1.20
D	3-6	Hard	Low	Clear	0.17	16.1	0.22
Blank					0.12	13.9	0.25
D	3-6	Soft	Low	Clear	0.16	17.4	1.60
Blank					0.16	17.3	1.78
D	7-10	Hard	Low	Clear	0.17	18.1	1.15
Blank					0.18	17.9	1.30
D	7-10	Soft	Low	Clear	0.03	17.4	0.98
Blank					0.09	17.5	1.00
E	1-2	Soft	Low	Clear	0.13	19.3	0.86
Blank					0.82	16.6	0.83
E	3-6	Hard	High	Clear	0.19	18.4	1.05
Blank					0.13	17.7	0.95
E	3-6	Hard	High	Clear	0.28	18.1	1.47
Blank					0.84	19.2	1.54
E	3-6	Soft	Low	Clear	0.04	19.3	0.73
Blank					0.76	18.7	0.69
E	7-10	Hard	High	Clear	0.48	16.4	1.77
Blank					0.64	12.8	2.41
E	7-10	Hard	Low	Clear	0.06	17.5	1.26
Blank					0.84	19.2	1.54



**Table 2**      **Continued**

Resin	Age years	Type	Chlorine	Appearance	Cl <sub>2</sub> mg/l	Temp °C	TOC mg/l
E	7-10	Soft	High	Clear	0.23	16.5	2.15
Blank					0.23	17.8	2.00
E	7-10	Soft	Low	Clear	0.16	17.8	1.90
Blank					0.07	17.5	1.92

**Table 3 GC-MS results – Resin A – Phase 1**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		7-10		7-10		7-10		7-10	
Water type	Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low	
Chloroacetone			4.4	1.1	3.5	1.1				
Chloroacetone + 2-Chloro-2-methylbutane							1.3	3.1	0.9	
2-Chloro-2-methyl butane + Cyclohexane	0.5	0.6								
Cyclohexane				0.1		0.1				
Dichloroacetonitrile			0.8	0.9	0.4	0.9	1.0	0.6		
Bromodichloromethane			8.7	5.7	8.2	5.7	8.7	8.9	0.9	0.6
1,1-Dichloroacetone			0.7	1.5	1.4	1.5		1.0	0.5	5.7
Bromoacetone									1.0	
Unknown m/z 55,84,27,28									0.9	3.4
2(5H)-Furanone				0.3		0.3				
Chlorodibromomethane	0.2	0.1	4.7	3.1	4.3	3.1	5.2	2.9	1.4	0.9
Bromochloroacetonitrile			0.5	0.3	0.3	0.3	0.6	0.1	0.9	0.1
Tetrachloroethylene							0.1			
1,1,1-Trichloroacetone			0.1	4.3		4.3				0.7
Trichloroacetone isomer							0.3	0.1		
Hexamethylcyclotrisiloxane									0.1	
Xylene isomer	0.2	0.2								
Bromoform	0.2	0.1	0.5	0.4	0.7	0.4	0.9	0.3	2.2	1.1

**Table 3 Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		7-10		7-10		7-10		7-10	
Water type	Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low	
Xylene isomer		0.4								
Dibromoacetonitrile	0.1	0.1	0.3	0.2	0.2	0.2	0.4	0.1	0.4	0.7
Xylene isomer	0.1									
Unknown m/z 109,71,111,43				0.1	0.1	0.1			0.3	0.1
Trichloroacetone isomer							0.3	0.1		
Benzaldehyde				0.1	0.1	0.1				
Unknown m/z 87,43,59,41			0.3	0.1	0.2	0.1	0.2		0.3	0.1
Benzyl alcohol	0.2	0.2								
2-Ethylhexanol	0.1	0.2					0.1			
Trimethylbenzene isomer			0.1		0.1					
Acetophenone		0.1								
Unknown m/z 58,43,59,45				0.2		0.2				
n-Nonanal			0.1		0.1					
N,N-Dibutylformamide			0.06		0.05					
Octamethylcyclotetrasiloxane									0.6	
Decamethylcyclopentasiloxane									0.5	
Dodecamethylcyclohexasiloxane									0.1	
Unknown m/z 68,96,185,53					0.03					

**Table 3 Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		7-10		7-10		7-10		7-10	
Water type	Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low	
2,4,6-Trichlorophenol			0.17							
2,2,4-Trimethylpentane-1,3-diol monoisobutyrate isomer	0.1	0.5								
2,2,4-Trimethylpentane-1,3-diol monoisobutyrate isomer	0.1	0.6								
Unknown m/z 43,151,109,41		0.3								
Dimethyl maleic anhydride			0.1		0.1					
Ethylmethylemaleic anhydride			0.1	0.05	0.2	0.05				
Unknown m/z 55,43,41,69									0.04	
Diethyl phthalate			0.1						0.1	
Unknown m/z 173,55,99,84										0.1
Unknown m/z 55,173,41,43									1.1	
Tris-(chloropropyl)phosphate isomer								0.1	0.02	0.1
Tris-(chloropropyl)phosphate isomer										0.05
n-Butylbenzenesulphonamide	0.08									
Unknown m/z 43,73,115,87			0.17							
Di-isobutyl phthalate	0.2	0.1	0.3	0.1	0.2	0.1	0.3	0.3	0.2	0.3
Di-n-butyl phthalate		0.04	0.1	0.1	0.3	0.1		0.1		0.1
Butyl benzyl phthalate				5.3	10.7	5.3				

**Table 4 GC-MS results – Resin A – Phase 2**

	Sample 3-6	Blank	Sample 7-10	Blank	Sample 7-10	Blank	Sample 7-10	Blank	Sample 7-10	Blank
Age										
Water type	Hard		Soft		Soft		Hard		Hard	
Chlorine	High		Low		High		Low		High	
Chloroacetone			1.2	2.1	2.5	2.1		4.4		1.6
Dichloroacetonitrile			0.3	1.2		1.2				0.4
Bromodichloromethane		1.7		8.3	12.9	8.3	1.1	0.8		6.6
Unknown m/z 41,43,56,72		1.2								
1,1-Dichloroacetone	9.7	5.9		1.6	2.7	1.6		3.8		1.9
Chlorodibromomethane		0.6	5.1	3.2	6.6	3.2	1.5	0.9		2.8
Bromochloroacetonitrile			0.1	0.1	0.1	0.1	0.2			0.3
Dichloroiodomethane				0.2	0.1	0.2				
Bromochloroacetone isomer	0.9	0.8						0.3		
1,1,1-Trichloroacetone	2.1	4.3		0.1		0.1				0.1
Bromoform			0.4	0.3	0.7	0.3	2.4	1.4		0.8
Dibromoacetonitrile			0.2	0.1	0.1	0.1	0.4	0.3	3.4	0.2
Unknown m/z 68,53,68,39			0.1							
Bromodichloroacetone isomer		0.4								
Unknown m/z 87,43,59,41				0.2	0.1	0.2				
N,N-Dibutylformamide									2	
Octamethylcyclotetrasiloxane				0.3		0.3				
Dimethylcyclopentasiloxane				0.9		0.9				
Dodecamethylcyclohexasiloxane				0.3	0.1	0.3				

**Table 4      Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		7-10		7-10		7-10		7-10	
Water type	Hard		Soft		Soft		Hard		Hard	
Chlorine	High		Low		High		Low		High	
Unknown m/z 67,53,69,39					0.1					
Unknown m/z 41,43,57,55									56.5	
Unknown m/z 173,55,99,84				0.3	1.1	0.3				
Unknown m/z 41,69,43,85			0.1	.		.				
Tris-(chloropropyl)phosphate isomer	0.9	0.4	0.4	0.3	2.1	0.3	0.3	0.6	1.1	0.8
Tris-(chloropropyl)phosphate isomer	0.2	0.1	0.3	0.2	0.1	0.2	0.1	0.2	0.4	0.2
Tris-(chloropropyl)phosphate isomer								0.04	0.1	0.04
Di-isobutyl phthalate	0.3	0.1	1.0	0.6	0.4	0.6	0.1	0.3	0.4	0.2
Di-n-butyl phthalate			0.1							
Unknown m/z 43,44,64,41							7.4			

**Table 5 GC-MS results – Resin B – Phase 1**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Chloroacetone	2.5	4.6	1.4		1.4	2	4.1	6.3			2.1	3				
2-Chloro-2-methylbutane											0.3	0.4				
Chloroacetone + 2-Chloro-2-methylbutane										1.5				2	1.3	
2-Chloro-2-methyl butane + Cyclohexane									0.8							
2-Methoxy-2- methylbutane							2.8									
Ethyl propionate									0.1							
3-Pentene-2-ol						0.3										
Dichloroacetonitrile	1	0.9	2.5	2	0.6	1.9	0.5	0.2	0.1	1	1.8	2	0.3		0.3	0.3
Bromodichloromethane	1.9	2.4	8.4	8.3	2.7	2.4	3.9	2.9	1	4.1	4	3.2	6.5		1.4	1.1
Unknown m/z 59,41,43,42				0.7												
Unknown m/z 41,43,56,72			0.7	0.8												
Trichloroethylene									0.1							
1,1-Dichloroacetone	0.4	1.8	2.9	0.7	0.6	3.1	0.9	2.3			0.5	0.9	0.7		3	0.5

**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Unknown m/z																
55,84,27,28						0.4										
Methyl(1,1-dichloroethyl) ketone											0.2					
2(5H)-Furanone			1.5													
Chloropicrin			0.2			0.11					0.1					
Chlorodibromomethane	0.2	0.3	1.4	1.3	0.3	0.2	1.9	1.5	2.4	3.9	0.8	0.7	7.2	0.3	2.7	2.4
Bromochloroacetonitrile	0.1	0.1	0.1	0.2		0.8	0.4	0.3	0.2	0.6			0.2		0.3	0.2
Dichloriodomethane						0.11										
Unknown m/z																
43,87,58,59										0.4						
1,2-Dichloroacetone																0.2
Tetrachloroethylene									0.2		0.1	0.2				
1,1,1-Trichloroacetone	0.4	0.3	2	3.6		14	0.4			0.2	1.5	1.1	0.3			
C <sub>9</sub> H <sub>18</sub> isomer						0.4										
Xylene isomer											0.3	0.2				
Bromoform							0.2	0.3	1.6	1.1					1.2	1.1



**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Xylene isomer + Bromohydroxypentane isomer		0.1														
Dibromoacetonitrile							0.2		0.5	0.7			0.3		0.4	0.4
Unknown m/z 109,71,111,43	0.1															
Unknown m/z 43,70,55,41					0.4											
Unknown m/z 109,71,111,83					0.1											
Bromodichloroacetone isomer						0.2										
Unknown m/z 57,29,89,83						0.1										
Unknown m/z 109,111,71,83						0.1										
Benzaldehyde						0.1										
Trichloroacetone isomer										0.2					0.1	0.2

**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Unknown m/z																
87,43,59,41		0.1								0.2			0.2	0.4	0.4	0.9
Benzyl alcohol										0.1						
2-Ethylhexanol		1.4							0.1	0.1				0.2		
C <sub>3</sub> -alkylbenzene isomer					0.1											
n-Nonanal													0.1	0.2		
Triethyl phosphate									0.1				1.7	1.4	0.05	
n-Decanal													0.1			
2-Phenoxy ethanol			1.6													
2,4,6-Trichlorophenol + Hexachlorocyclo- pentadiene						0.1										
Unknown m/z													0.03			
95,43,93,136														0.1	0.1	
Triacetin																
2,2,4-Trimethylpentane- 1,3-diol monoisobutyrate isomer													0.06		0.1	0.1

**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
2,2,4-Trimethylpentane- 1,3-diol monoisobutyrate isomer													0.1			
Unknown m/z 43,179,59,161			0.4													
Unknown m/z 43,163,145,115			1.9													
Unknown m/z 43,179,158,59 + 43,163,145,160			1													
Unknown m/z 43,163,145,115			8.9													
Dodecanal																0.1
Unknown m/z 43,151,109,41																0.2
2,2,4-Trimethylpentane- 1,3-diol di-isobutyrate				0.13									0.19	0.3		
Phthalide		0.9														

**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Unknown m/z																
43,71,57,41					0.1											
Unknown m/z																
43,71,57,41					0.1											
Ethylmethyleic anhydride					0.1					0.1						
Unknown m/z																
43,41,57,68					0.1											
Unknown m/z																
57,43,41,71					0.1											
Tetradecanol					0.27											
4-Ethoxy ethylbenzoate										0.2						
Tris- (chloropropyl)phosphate isomer														0.1	0.05	
Tris- (chloropropyl)phosphate isomer														0.02	0.01	

**Table 5 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		Low		High		Low		Low		Low		High	
Unknown m/z 69,113,41,39																0.1
Unknown m/z 69,113,41,86								0.1								
Diethyl phthalate		0.05									0.1					
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione	0.1	0.2														
Di-isobutyl phthalate	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.4	0.4	0.2	0.1	0.1	0.1
Di-n-butyl phthalate	0.02		0.04					0.1		0.1	0.3	0.1			0.04	

**Table 6 GC-MS results – Resin B – Phase 2**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6	0	3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft	0	Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		High		High		High		High		Low		High	
Chloroacetone	1.5	3.3		3.7	0.6	1.0	1.6	3.3		0.9	2.2	2.1	2.6	0.2		
Dichloroacetonitrile	1.0	1.0		0.3	0.9	1.1	0.4	3.8	0.5	0.4	1.3	1.3			0.8	
Bromodichloromethane	3.2	3.8		1.5	8.5	8.5	4.1		11.5	1.9	5.7	5.2	3.0		2.7	
Unknown m/z 41,43,56,72															1.0	
Unknown m/z 41,43,83,72					0.8											
Unknown m/z 41,43,27,56						0.8										
Chloromethylbutane isomer									1.7						1.2	
1,1-Dichloroacetone		0.5		3.6				2.0	6.4	4.5	0.4	0.5			3.9	
Unknown m/z 83,85,48,47 (dichloro)											0.5					
Unknown m/z 43,41,27,71				0.3												
Dichloroacetone isomer							0.9									
Chloropicrin										0.6	0.2					

**Table 6 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6	0	3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft	0	Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		High		High		High		High		Low		High	
Chlorodibromomethane	0.3	0.4			1.1	1.2	1.3	0.9	3.2	1.5	0.7	0.7	2.6		2	
Bromochloroacetonitrile							0.1	0.1	0.1	0.2					0.3	
Bromochloroacetone isomer									0.5						0.3	
Unknown m/z 41,39,71,69				0.2												
1,1,1-Trichloroacetone	0.4	0.3		0.8	0.4	0.4	0.2		4.4	0.1	1	1.1	0.2		3.6	
Bromoform							0.1	0.1	0.4	0.4			1.1		0.9	
Bromohydroxypentane isomer								0.2	0.4	0.1					0.1	
Xylene isomer + Bromohydroxypentane isomer							0.2									
Dibromoacetonitrile					0.8	0.1			0.1	0.1					0.3	
Bromodichloroacetone isomer									0.4						0.2	
Unknown m/z 87,43,59,41															0.1	

**Table 6 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6	0	3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft	0	Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		High		High		High		High		Low		High	
Octamethylcyclotetra- siloxane													0.1			
Decamethylcyclotetra- siloxane													0.1			
Dodecamethylcyclohexa- siloxane													0.1			
Unknown m/z 41,43,55,57															0.6	
Unknown m/z 222,224,143,240																6
Unknown m/z 66,46,174,192																9.3
Unknown m/z 97,57,41,43														0.1		
Tris- (chloropropyl)phosphate isomer	0.04			0.3	0.1		0.63	0.8	0.8	0.9	0.3	0.6	0.8	0.5	0.8	1



**Table 6 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6	0	3-6		3-6		7-10		7-10		7-10	
Water type	Soft		Soft		Soft	0	Soft		Hard		Soft		Hard		Hard	
Chlorine	High		Low		High		High		High		High		Low		High	
Tris-(chloropropyl)phosphate isomer				0.1	0.1		0.2	0.2	0.3	0.2	0.1	0.2	0.3	0.2	0.2	0.3
Tris-(chloropropyl)phosphate isomer									0.1							
Di-isobutyl phthalate	0.1	0.2		0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.3
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione	0.1															

**Table 7 GC-MS results – Resin C – Phase 1**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Soft		Soft	
Chlorine	Low		High		Low		Low		Low		High	
Chloroacetone	5.2	4.6	0.9	2.9	2	2.9	2.1	2.9	1.4	2.9	4.7	2.9
Dichloroacetonitrile	1.4	0.9	0.9	0.6		0.6	1.3	0.6	0.9	0.6	1.1	0.6
Bromodichloromethane	3	2.4	2.3	1.4		1.4	1.7	1.4	2.1	1.4	1.1	1.4
Dichloroacetonitrile + Bromodichloromethane					2.6							
1,1-Dichloroacetone	0.9	1.8	0.3	0.5		0.5	0.3	0.5	0.3	0.5	7.4	0.5
Chlorodibromomethane	0.4	0.3	0.2	0.2	0.1	0.2	0.1	0.2	0.2	0.2		0.2
Bromochloroacetonitrile	0.1	0.1			0.1		0.1		0.1			
Chlorohydroxypentane isomer			0.1									
1,1,1-Trichloroacetone	0.3	0.3	0.4	0.3	0.4	0.3	0.6	0.3	0.4	0.3	0.3	0.3
Unknown m/z 109,71,111,43	0.1			0.05	0.1	0.05	0.1	0.05	0.09	0.05		0.05
Benzaldehyde			0.1									
C <sub>9</sub> H <sub>18</sub> isomer			0.4									
Xylene isomer			0.1									
Xylene isomer + Bromohydroxypentane isomer		0.1										

**Table 7 Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Soft		Soft	
Chlorine	Low		High		Low		Low		Low		High	
Unknown m/z 87,43,59,41		0.1										
Unknown m/z 55,84,112,29											0.2	
2-Ethylhexanol		1.4										
C <sub>3</sub> -alkylbenzene isomer				0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Terephthalaldehyde					0.7		0.5				0.2	
4-t-Butylphenol			0.22		1.5		0.2				0.95	
2-Chloro-4-t-butylphenol					0.3						0.2	
2,4,6-Trichlorophenol					0.1		0.1				0.1	
Unknown m/z 68,96,185,53			0.06									
2-Bromo-4-t-butylphenol					0.2						0.1	
Dodecanol					0.2							
Unknown m/z 57,41,29,43					0.3		0.2				0.2	
Unknown m/z 41,43,55,57			0.1		0.3		0.1				0.1	
2,6-Dichloro-4-t-butylphenol					0.3						0.3	
6-Bromo-2-chloro-4-t-butylphenol					0.1		0.02					
2-Bromo-6-chloro-4-t-butylphenol											0.1	

**Table 7      Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Soft		Soft	
Chlorine	Low		High		Low		Low		Low		High	
2,6-Dibromo-4-t-butylphenol					0.1						0.03	
Phthalide		0.9										
Diethyl phthalate		0.05		0.05		0.05		0.05		0.05	0.1	0.05
Di-isobutyl phthalate	0.1	0.1	0.1	0.2	0.1	0.2	0.1	0.2	0.1	0.2	0.2	0.2
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione		0.2										
Di-n-butyl phthalate				0.1		0.1		0.1		0.1	0.1	0.1
Butyl benzyl phthalate				0.5		0.5	1.0	0.5	1.3	0.5	0.4	0.5

**Table 8 GC-MS results – Resin C – Phase 2**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Soft		Soft	
Chlorine	High		Low		Low		High		High		Low	
Chloroacetone	1	3.3	0.3	3.1	0.3	3.1	1.6	3.1	0.4	3.1	0.4	3.1
Dichloroacetonitrile	0.9	1		0.6	0.8	0.6	1.2	0.6	0.4	0.6	0.9	0.6
Bromodichloromethane	4.2	3.8	3.2	2.6	2.5	2.6	3	2.6	3.1	2.6	1.9	2.6
1,1-Dichloroacetone	0.3	0.5		0.5		0.5		0.5		0.5		0.5
Chlorodibromomethane	0.6	0.4	0.1	0.2	0.2	0.2	0.1	0.2	0.3	0.2		0.2
1,1,1-Trichloroacetone	0.1	0.3		0.2	0.2	0.2	0.4	0.2	0.1	0.2	0.2	0.2
o-Phthalaldehyde							1.9					
Terephthalaldehyde + 2-Phenoxyethanol					0.7							
4-t-Butylphenol			0.06		2.2		0.04				0.5	
Chloro-4-t-butylphenol isomer					0.3							
2-Chloro-4-t-butylphenol											0.2	
2,4,6-Trichlorophenol							0.2					
2-Bromo-4-t-butylphenol					0.3						0.2	
Unknown m/z 57,41,29,43							0.2					
2,6-Dichloro-4-t-butylphenol					0.2						0.2	
Unknown m/z 249,247,168,264					0.1							

**Table 8**      **Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Soft		Soft		Soft		Soft	
Chlorine	High		Low		Low		High		High		Low	
Unknown m/z 85,41,69,43			0.1									
Unknown m/z 173,55,99,84									0.2			
Tris-(chloropropyl)phosphate isomer	0.06		0.33	0.1		0.1	0.2	0.1	0.3	0.1		0.1
Tris-(chloropropyl)phosphate isomer			0.1	0.1		0.1	0.05	0.1		0.1		0.1
Di-isobutyl phthalate	0.2	0.2	0.5	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.1	0.2

**Table 9 GC-MS results – Resin D – Phase 1**

	Spl. 1-2	Blank 1-2	Spl. 1-2	Blank 1-2	Spl. 1-2	Blank 1-2	Spl. 3-6	Blank 3-6	Spl. 7-10	Dup. Blank	Spl. 3-6	Blank 3-6	Spl. 3-6	Blank 3-6	Spl. 3-6	Blank 3-6	Spl. 7-10	Blank 7-10		
Age	1-2		1-2		1-2		3-6		7-10		3-6		3-6		3-6		7-10			
Water type	Soft		Hard		Soft		Hard		Hard		Soft		Hard		Hard		Hard		Soft	
Chlorine	High		High		High		High		Low		Low		High		Low		High		High	
Chloroacetone				2.5	5.3	0.7	1.2	0.2					1.8	1.8			2.9	1.5	1.4	
Chloroacetone + 2-Chloro-2- methylbutane	1.1	1.5	1.0								2.1	4.1			1.1	0.5	4.8			
2-Chloro-2- methylbutane				0.4	0.2	0.4	0.5	0.4												
Cyclohexane								0.1											0.2	
Bromoacetone							0.08							0.9	0.3					
Dichloroaceto- nitrile	0.8	1	2.4	1.2	0.9	1.4		1.4	0.7	0.9	1.9	4.1	0.8	2.3			1.2	1.1	1.1	
Bromodichloro- methane	4.1	4.1	2.2	1.8	3.5	5.2		3.4	7.7	6.9	5.7	4.4	2.1	6.3			4.5	4	2.8	3.1
Trichloronitro- methane						0.1					0.1	0.1								
Chloromethyl- butene isomer			1.2					1.1												
1,1- Dichloroacetone			3.2	3.2	3.3			7.7		0.5		1	0.5	0.6			1.9	0.8	0.7	1.3
Unknown m/z 55,84,27,28															1.3	0.2				

**Table 9 Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank							
Age	1-2	1-2	1-2	3-6	7-10				3-6	3-6	3-6	3-6	7-10								
Water type	Soft	Hard	Soft	Hard	Hard				Soft	Hard	Hard	Hard	Soft								
Chlorine	High	High	High	High	Low				Low	High	Low	High	High								
Dichloroacetone isomer	0.3																				
Chlorodibromo methane	3.8	3.9	0.5	1.3	1.9	1.1	0.2	2.8	8	5.8	0.3	1.1	0.4	0.5	0.7	0.2	0.2	2	2.3	0.5	0.6
Bromochloro-acetonitrile	0.6	0.6	0.1	0.1	0.2	0.1		0.3	0.2	0.5		0.2	0.2	0.1	0.1			0.5	0.4	0.2	
Dichloriodo-methane						0.1															
Unknown m/z 43,87,58,59									0.2												
Bromochloro-acetone				0.3	0.3		0.1	1.8													
Chlorohydroxy-pentane isomer 1,1,1-			2.9					1.6					0.6								
Trichloroacetone	0.3	0.2	3.4	0.8	0.7	1.2		6.4	0.4	0.6		1.5	2.8	0.7	1.2			0.6	0.5	0.5	0.4
Bromohydroxy-pentane isomer			0.7	0.9	0.6												0.2				
Trichloro-1-propene																	0.2				



**Table 9**      **Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	
Age	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10		
Water type	Soft	Hard	Soft	Hard	Hard		Soft	Hard	Hard	Hard	Soft		
Chlorine	High	High	High	High	Low		Low	High	Low	High	High		
Bromoform	1	1.1	1	0.8	0.4	1.1			1	0.8	0.4	0.7	
Xylene isomer + Bromohydroxy- pentane isomer								0.2					
Dibromoaceto- nitrile	0.6	0.7	0.1	0.1	0.1	0.3	0.7	0.3		0.1	0.2	0.3	
Dibromo- acetonitrile + Unknown m/z 55,27,84,26										0.5			
Xylene isomer Unknown m/z 109,71,111,43			0.2	0.1			0.1		0.1		0.2	0.1	0.1
Dibromoacetone Bromodichloro- acetone isomer					0.3			0.1		0.2	0.2	0.1	
Trichloroacetone isomer	0.2	0.2											
Unknown m/z 109,111,71,43				0.1					1.1	0.1			

**Table 9**      **Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank
Age	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10	
Water type	Soft	Hard	Soft	Hard	Hard		Soft	Hard	Hard	Hard	Soft	
Chlorine	High	High	High	High	Low		Low	High	Low	High	High	
Unknown m/z												
87,43,59,41	0.2	0.4	0.2	0.2	1.2	0.4	0.3	0.4		0.2	0.1	
n-Nonanal					0.1	0.2		0.2				
Benzyl alcohol	0.1	0.1										
2-Ethylhexanol	0.1	0.1						0.2				
Octamethylcyclo tetrasiloxane									0.3			
Undecanal										0.1		
n-Tridecane										0.07		
Dodecanol										0.9		
Unknown m/z												
45,73,42,89										0.07		
Unknown m/z												
41,43,55,57										0.12		
Dodecanal										0.89		
Trimethyl- benzene isomer							0.1					
Triethyl phosphate		0.1	0.1	0.1	0.1	2.2		1.4				

**Table 9**      **Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank
Age	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10
Water type	Soft	Hard	Soft	Hard	Hard		Soft	Hard	Hard	Hard	Soft
Chlorine	High	High	High	High	Low		Low	High	Low	High	High
Triacetin						0.1	0.1				
2,2,4-Trimethyl- pentane-1,3-diol monoisobutyrate isomer			0.1	0.04	5.9						
2,2,4-Trimethyl- pentane-1,3-diol monoisobutyrate isomer			0.1	0.1	7						
Unknown m/z 43,179,161,59											0.5
2-(4-Acetyl- phenyl)propan- 2-ol											1.5
Unknown m/z 43,179,161,158											0.2
Unknown m/z 43,163,145,121											0.7
2-Ethyl-3- methyl maleic anhydride	0.1	0.1					0.1				

**Table 9**      **Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank
	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10
Age	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10
Water type	Soft	Hard	Soft	Hard	Hard		Soft	Hard	Hard	Hard	Soft
Chlorine	High	High	High	High	Low		Low	High	Low	High	High
Unknown m/z 41,57,55,43									0.13		
Unknown m/z 41,43,55,57									0.15		
Tetradecanol									0.4		
4-Ethoxy ethylbenzoate	0.2	0.2			0.2						
Diethyl phthalate	0.1	0.1									
Unknown m/z 163,43,145,148					1.2						
Unknown m/z 173,55,99,84										0.1	0.1
Tris- (chloropropyl)- phosphate isomer						0.04	0.1	0.05		0.1	0.1
Tris- (chloropropyl)- phosphate isomer						0.03	0.05	0.01		0.1	0.03

**Table 9**      **Continued**

	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Dup. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank	Spl. Blank							
Age	1-2	1-2	1-2	3-6	7-10		3-6	3-6	3-6	3-6	7-10										
Water type	Soft	Hard	Soft	Hard	Hard		Soft	Hard	Hard	Hard	Soft										
Chlorine	High	High	High	High	Low		Low	High	Low	High	High										
Unknown m/z 69,113,41,39													0.1								
Unknown m/z 69,113,41,86													0.1								
n-Butylbenzene- sulphonamide	0.04																				
2,2,4-Trimethyl- pentane-1,3-diol di-isobutyrate			0.6			0.6	0.12	0.04	0.3												
Dibutyl phthalate		0.1	0.1	0.03		0.05	0.03		0.04												
Di-isobutyl phthalate	0.2	0.2	0.3	0.4	0.5	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.3	0.1	0.1	0.2	0.2	0.1	0.1
Di-n-butyl phthalate	0.1	0.1	0.1	0.1	0.1	0.03	0.1	0.05	0.03	0.03	0.04	0.05	0.04	0.1	0.1			0.04	0.3		
Butyl benzyl phthalate													0.1	2.6							

**Table 10 GC-MS results – Resin D – Phase 2**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Hard		Soft		Hard	
Chlorine	Low		Low		High		High		High		Low		High	
Chloroacetone	0.8	0.9	6.7	2	7.4	0.3			4.4	4.1	3.5	4.3	4.7	0.2
Cyclohexane						0.3	0.2							
Bromoacetone							0.4							
Dichloroacetonitrile	0.4	0.6	0.8	2	1.5				1	1	1.1	1.5		
Bromodichloromethane	4.7	4.8	5.9	4.6	4.6	5.6			5.5	5.2	4.5	4.4	3	
Unknown m/z 41,43,27,56						0.5								
1,1-Dichloroacetone			1.9	7.6	6.9				3.6	3.1	1.7	4.1		
Unknown m/z 41,43,56,27					0.6									
Chlorodibromomethane	2.9	3.2	2.5	0.2	0.6	0.8	0.2		2.9	2.9	0.4	0.3	2.7	
Bromochloroacetonitrile	0.4	0.2	0.2						0.4	0.3	0.3			
1,1,1-Trichloroacetone	0.2	0.2	0.6	1.5	0.9				0.4	0.4	0.1	0.2	0.2	
Bromohydroxypentane isomer	0.3	0.3												
Bromoform	1	1	0.2				1	0.6	0.7	0.8			1.2	
Dibromoacetonitrile	0.4	0.5					0.1		0.2	0.3				
Bromodichloroacetone isomer									0.1	0.2				
Unknown m/z 87,43,59,41													0.2	0.1

**Table 10 Continued**

	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank	Sample	Blank
Age	1-2		3-6		3-6		3-6		3-6		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Hard		Soft		Hard	
Chlorine	Low		Low		High		High		High		Low		High	
4-t-Butylphenol														0.1
2,6-Di-t-butyl-p-benzoquinone		0.4												
Unknown m/z 97,57,41,43														0.1
Tris-(chloropropyl)phosphate isomer	0.3	0.3	0.2	0.2	0.4	0.1	0.7	0.3	0.5	0.8	0.9	0.6	0.8	0.5
Tris-(chloropropyl)phosphate isomer	0.1	0.1	0.1	0.1	0.3	0.1	0.2	0.1	0.2	0.2	0.3	0.2	0.3	0.2
Tris-(chloropropyl)phosphate isomer					0.03		0.1	0.1	0.04	0.1		0.1		
Di-isobutyl phthalate	0.1	0.2	0.3	0.3		0.5	0.3	0.1	0.3	0.4	0.3	0.2	0.3	0.2
Di-n-butyl phthalate										0.3				

**Table 11 GC-MS results – Resin E – Phase 1**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		Low		High		High		High		High		High	
Trimethyl borate															0.5	
Chloroacetone	1	5.9	7.9	6.3		0.8	0.4				3					
2-Chloro-2-methylbutane											0.4					
Chloroacetone + 2-Chloro-2-methylbutane								0.9			3.5	3.3			1.2	1.3
2-Methoxy-2-butanol		0.7														
Bromoacetone					0.8									0.7		
Ethyl propyl ketone															0.2	
2-Chloro-2-methylbutane							0.3									
Dichloroacetonitrile	1.3	0.4	1.1	0.2	0.4	0.8	0.4	0.2	1.6	2	2.2	2.9	1.5	0.5	1.1	0.2
Bromodichloromethane	2.9	2.2	6.2	2.9	4.1	2.1	3.2	1.2	3.1	3.2	4.4	6.6	11	5.2	5.1	1
Trichloronitromethane											0.2	0.1				
1,1-Dichloroacetone		2.5	4.3	2.3	0.9	3.4	0.3	0.2	0.5	0.9	3	0.8	1.5	2.5	0.4	0.7
2(5H)-Furanone						2.7										
Chlorodibromomethane	0.6		3.1	1.5	4.8	3.5	5.1	3.1	0.7	0.7	0.6	1.2	8.4	6	6.1	2.8
Bromochloroacetonitrile	0.2		0.4	0.3	0.4	0.2	0.6	0.3			0.1	0.2	0.7	0.2	0.9	0.2
4-Methyl-3-penten-2-one													0.5			



**Table 11 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		Low		High		High		High		High		High	
Unknown m/z 43,87,58,129															1.1	
Chlorohydroxypentane isomer										0.2	0.3					
Tetrachloroethylene									0.2	0.2						0.1
1,1,1-Trichloroacetone	0.8		0.9		0.3	0.3	0.4		1.2	1.1	1.8	2	1	0.5	0.7	
Bromohydroxypentane isomer						0.7										
Bromoform			0.4	0.3		1.8	1.2	1.1				0.1			1.5	1
Dibromoacetonitrile					0.5	0.3	0.5	0.4					0.3		0.7	0.3
Xylene isomer										0.2						
Benzaldehyde	0.6															
Bromodichloroacetone isomer													0.2			
Trichloroacetone isomer							0.4	0.2							0.5	0.2
Unknown m/z 87,43,59,41					0.3		1.4	0.7						0.1	0.7	0.2

**Table 11 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		Low		High		High		High		High		High	
n-Nonanal															0.1	
Unknown m/z 95,43,93,136											0.03					
2,2,4-Trimethylpentane- 1,3-diol											0.1					
monoisobutyrate isomer 2,2,4-Trimethylpentane- 1,3-diol											0.1					
monoisobutyrate isomer Unknown m/z 43,151,109,41							1.1									1.5
Triethyl phosphate									0.1							
Triacetin															0.1	
Unknown m/z 69,113,41,86		0.1		0.1												
Unknown m/z 43,41,55,145					0.1											
2,2,4-Trimethylpentane- 1,3-diol di-isobutyrate					0.2								0.1	0.2		

**Table 11 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		Low		High		High		High		High		High	
Unknown m/z							0.1									
43,41,55,83																
Tris-(chloropropyl)phosphate isomer							0.04	0.1								0.1
Di-isobutyl phthalate	0.2	0.2	0.3	0.2	0.1	0.2	0.1		0.5	0.4	0.3	0.4	0.1	0.1	0.1	0.1
Di-n-butyl phthalate	0.05	0.05	0.1	0.1	0.02				0.2	0.1	0.06	0.07				0.1

**Table 12 GC-MS results – Resin E – Phase 2**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		3-6		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low		High		Low		High	
Chloroacetone	1.2	0.6	0.5	3.3			5.5	5.9	3.6	4.4	10.8	2.1			3.6	0.4
2-Chloro-2-methylbutane	0.4															
Cyclohexane					0.3											
Bromoacetone						0.5								0.5		
Unknown m/z 83,55,41,39						0.3								0.3		
Dichloroacetonitrile	0.9	0.3		3.8	0.9			0.4	1.7	1.3	4.2	1.3			1.4	1.1
Bromodichloromethane	5.3	1.1	5.9		2.7	5	3.2	2.9	5.2	6.1	2.2	5.2		5	12.3	7.5
Dichloroacetonitrile + Chloromethylbutene isomer						0.8									0.8	
Unknown m/z 41,43,56,72		0.4														
Chloromethylbutane isomer		0.2			2.7	3.2									3.2	
1,1-Dichloroacetone		4.4	2.5	2	9.6	4.7	0.4	0.5	8.4	0.8	2.8	0.5		4.7	0.6	4.5
2(5H)-Furanone					0.8											
Chloropicrin									2.2	0.3		0.2				
Chlorodibromomethane	0.9	0.2	2.2	0.9	3.2	3.7	3.7	2.7	0.5	0.9	1.1	0.7	3	3.7	4.2	1.6
Bromochloroacetonitrile	0.2			0.1	0.4	0.3	0.1	0.1						0.3	0.2	
Unknown m/z 55,41,39,83						0.4								0.4		

**Table 12 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	
Age	1-2		3-6		7-10		3-6		7-10		7-10		7-10		7-10		
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard		
Chlorine	Low		Low		High		High		Low		High		Low		High		
Bromochloroacetone isomer					0.9		1.2							1.2		0.2	
Chlorohydroxypentane isomer							0.3							0.3			
Unknown m/z 55,83,27,39							0.3							0.3			
1,1,1-Trichloroacetone	0.1	0.1	0.2		4		5.4			1.1	1.2	3.1	1.1		5.4	1	5.6
Bromoform			0.3	0.1	1.4			1.8	1.5							0.2	
Bromoform + d <sub>10</sub> p-Xylene (internal std.)														4.8			
C <sub>3</sub> H <sub>11</sub> OBr isomer				0.2	1.1	1.3	0.5	0.4							1.3	0.2	
Dibromoacetonitrile					0.6	0.3	0.3	0.2						6.3	0.3		
Unknown m/z 109,71,111,41	0.2																
Unknown m/z 87,43,59,27																	0.2
1,1-Dibromoacetone							0.2								0.2		
Bromodichloroacetone isomer					0.5	1.6								1.6			
Unknown m/z 59,43,41,39					0.5	0.5								0.5			
Unknown m/z 73,43,55,27					0.2	0.3								0.3			
Unknown m/z 73,43,55,27					0.3	0.4								0.4			
Unknown m/z 117,178,69,68						0.2								0.2			

**Table 12 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		7-10		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low		High		Low		High	
Unknown m/z 176,178,69,41							0.2								0.2	
Unknown m/z 117,123,61,29					0.2											
4-t-Butylphenol			0.07													
Unknown m/z 41,43,57,55					0.2											
Unknown m/z 41,43,55,57							0.3								0.3	
Unknown m/z 222,224,143,240													0.6			
Unknown m/z 235,46,207,66							0.2								0.2	
Unknown m/z 43,151,109,41					1.2		1.5						0.5		1.5	
2,6-Di-t-butyl-p- benzoquinone							0.3				2.2		0.03		0.3	
Unknown m/z 220,238,172,57													0.1			
2,2,4-Trimethylpentane-1,3- diol di-isobutyrate isomer													0.1			
Unknown m/z 173,55,99,84	1.1		1.1													
Unknown m/z 66,85,43,41													0.1			

**Table 12 Continued**

	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank	Spl.	Blank
Age	1-2		3-6		7-10		3-6		7-10		7-10		7-10		7-10	
Water type	Soft		Soft		Hard		Hard		Soft		Soft		Hard		Hard	
Chlorine	Low		Low		High		High		Low		High		Low		High	
Tris-(chloropropyl)phosphate isomer	2.1		2.1	0.8	1	0.9	0.3	1.33	0.3	0.4	0.6	0.6	0.9	0.9	0.6	0.2
Tris-(chloropropyl)phosphate isomer	0.1		0.2	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.3	0.2	0.2	0.2	0.2	0.1
Tris-(chloropropyl)phosphate isomer					0.1	0.05							0.04	0.05		
Unknown m/z 45,158,188,218													0.03			
Di-isobutyl phthalate	0.2	0.2	0.2	0.3	0.3	0.2	0.2	0.4	0.2	0.2	0.3	0.3	0.3	0.2	0.2	0.2

**Table 13 Summary of GC-MS results (excluding disinfection by-products and environmental contaminants)**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
2-(4-Acetylphenyl)propan-2-ol	D	3-6	Hard	High	1	<b>1.5</b>	
2(5H)-Furanone	A	7-10	Soft	High	1		0.3
2(5H)-Furanone	A	7-10	Soft	Low	1		0.3
2(5H)-Furanone	B	3-6	Soft	Low	1	<b>1.5</b>	
2(5H)-Furanone	E	3-6	Hard	High	2	<b>0.8</b>	
2(5H)-Furanone	E	3-6	Hard	Low	1		<b>2.7</b>
2,6-Dibromo-4-t-butylphenol	C	7-10	Soft	High	1	0.03	
2,6-Dibromo-4-t-butylphenol	C	7-10	Soft	Low	1	0.1	
2,6-Dichloro-4-t-butylphenol	C	7-10	Soft	High	1	0.3	
2,6-Dichloro-4-t-butylphenol	C	7-10	Soft	Low	1	0.3	
2,6-Dichloro-4-t-butylphenol	C	7-10	Soft	Low	2	0.2	
2,6-Dichloro-4-t-butylphenol	C	7-10	Soft	Low	2	0.2	
2,6-Di-t-butyl-p-benzoquinone	D	1-2	Soft	Low	2		0.4
2,6-Di-t-butyl-p-benzoquinone	E	3-6	Hard	High	2		0.3
2,6-Di-t-butyl-p-benzoquinone	E	7-10	Hard	Low	2	0.03	0.3
2,6-Di-t-butyl-p-benzoquinone	E	7-10	Soft	High	2	<b>2.2</b>	
2-Bromo-4-t-butylphenol	C	7-10	Soft	High	1	0.1	
2-Bromo-4-t-butylphenol	C	7-10	Soft	Low	1	0.2	
2-Bromo-4-t-butylphenol	C	7-10	Soft	Low	2	0.3	
2-Bromo-4-t-butylphenol	C	7-10	Soft	Low	2	0.2	
2-Bromo-6-chloro-4-t-butylphenol	C	7-10	Soft	High	1	0.1	



**Table 13**      **Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
2-Chloro-2-methyl butane + Cyclohexane	A	3-6	Hard	Low	1	<b>0.5</b>	<b>0.6</b>
2-Chloro-2-methyl butane + Cyclohexane	B	3-6	Hard	Low	1	<b>0.8</b>	
2-Chloro-2-methylbutane	B	7-10	Soft	Low	1	0.3	0.4
2-Chloro-2-methylbutane	D	1-2	Hard	High	1		0.4
2-Chloro-2-methylbutane	D	1-2	Soft	High	1	0.2	0.4
2-Chloro-2-methylbutane	D	3-6	Hard	High	1	<b>0.5</b>	0.4
2-Chloro-2-methylbutane	E	1-2	Soft	Low	2	0.4	
2-Chloro-2-methylbutane	E	7-10	Soft	High	1		0.4
2-Chloro-4-t-butylphenol	C	7-10	Soft	High	1	0.2	
2-Chloro-4-t-butylphenol	C	7-10	Soft	Low	1	0.3	
2-Chloro-4-t-butylphenol	C	7-10	Soft	Low	2	0.2	
2-Ethyl-3-methyl maleic anhydride	D	1-2	Soft	High	1	0.1	0.1
2-Ethylhexanol	A	3-6	Hard	Low	1	0.1	0.2
2-Ethylhexanol	A	7-10	Hard	High	1	0.1	
2-Ethylhexanol	B	1-2	Soft	High	1		<b>1.4</b>
2-Ethylhexanol	B	3-6	Hard	Low	1	0.1	0.1
2-Ethylhexanol	B	7-10	Hard	Low	1		0.2
2-Ethylhexanol	C	3-6	Soft	Low	1		<b>1.4</b>
2-Ethylhexanol	D	1-2	Soft	High	1	0.1	0.1
2-Ethylhexanol	D	7-10	Hard	Low	1		0.2

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
2-Methoxy-2-butanol	E	1-2	Soft	Low	1		<b>0.7</b>
2-Methoxy-2-methylbutane	B	3-6	Soft	High	1	<b>2.8</b>	
2-Phenoxy ethanol	B	3-6	Soft	Low	1	<b>1.6</b>	
3-Pentene-2-ol	B	3-6	Soft	Low	1		0.3
4-Ethoxy ethylbenzoate	B	3-6	Hard	Low	1		0.2
4-Ethoxy ethylbenzoate	D	1-2	Soft	High	1	0.2	0.2
4-Ethoxy ethylbenzoate	D	3-6	Hard	High	1	0.2	
4-Methyl-3-penten-2-one	E	7-10	Hard	High	1	<b>0.5</b>	
4-t-Butylphenol	C	3-6	Soft	High	1	0.22	
4-t-Butylphenol	C	3-6	Soft	Low	2	0.06	
4-t-Butylphenol	C	7-10	Soft	High	1	<b>0.95</b>	
4-t-Butylphenol	C	7-10	Soft	High	2	0.04	
4-t-Butylphenol	C	7-10	Soft	Low	1	<b>1.5</b>	
4-t-Butylphenol	C	7-10	Soft	Low	1	0.2	
4-t-Butylphenol	C	7-10	Soft	Low	2	<b>2.2</b>	
4-t-Butylphenol	C	7-10	Soft	Low	2	<b>0.5</b>	
4-t-Butylphenol	D	7-10	Hard	Low	2	0.1	
4-t-Butylphenol	E	3-6	Soft	Low	2	0.07	
6-Bromo-2-chloro-4-t-butylphenol	C	7-10	Soft	Low	1	0.1	
6-Bromo-2-chloro-4-t-butylphenol	C	7-10	Soft	Low	1	0.02	

**Table 13**      **Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione	B	1-2	Soft	High	1	0.1	0.2
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione	B	1-2	Soft	High	2	0.1	
7,9-Di-t-butyl-1-oxaspiro[4,5]deca-6,9-diene-2,8-dione	C	3-6	Soft	Low	1		0.2
Acetophenone	A	3-6	Hard	Low	1		0.1
Benzaldehyde	A	7-10	Soft	High	1	0.1	0.1
Benzaldehyde	A	7-10	Soft	Low	1		0.1
Benzaldehyde	C	3-6	Soft	High	1	0.1	
Benzaldehyde	E	1-2	Soft	Low	1	<b>0.6</b>	
Benzyl alcohol	A	3-6	Hard	Low	1	0.2	0.2
Benzyl alcohol	B	3-6	Hard	Low	1		0.1
Benzyl alcohol	D	1-2	Soft	High	1	0.1	0.1
C <sub>3</sub> -alkylbenzene isomer	B	3-6	Soft	Low	1	0.1	
C <sub>3</sub> -alkylbenzene isomer	C	3-6	Soft	High	1		0.1
C <sub>3</sub> -alkylbenzene isomer	C	7-10	Soft	High	1	0.1	0.1
C <sub>3</sub> -alkylbenzene isomer	C	7-10	Soft	Low	1	0.1	0.1
C <sub>3</sub> -alkylbenzene isomer	C	7-10	Soft	Low	1	0.1	0.1
C <sub>3</sub> -alkylbenzene isomer	C	7-10	Soft	Low	1	0.1	0.1
C <sub>9</sub> H <sub>18</sub> isomer	B	3-6	Soft	Low	1		0.4
C <sub>9</sub> H <sub>18</sub> isomer	C	3-6	Soft	High	1	0.4	
Chloro-4-t-butylphenol isomer	C	7-10	Soft	Low	2	0.3	

**Table 13**      **Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Cyclohexane	A	7-10	Soft	High	1		0.1
Cyclohexane	A	7-10	Soft	Low	1		0.1
Cyclohexane	D	1-2	Hard	High	1		0.1
Cyclohexane	D	3-6	Hard	High	1		0.1
Cyclohexane	D	3-6	Hard	High	2		0.3
Cyclohexane	D	3-6	Hard	Low	2	0.2	
Cyclohexane	D	7-10	Soft	High	1		0.2
Cyclohexane	E	3-6	Hard	High	2	0.3	
Decamethylcyclopentasiloxane	A	7-10	Hard	Low	1	<b>0.53</b>	
Decamethylcyclotetrasiloxane	B	3-6	Hard	High	2		0.1
Dimethyl maleic anhydride	A	7-10	Soft	High	1	0.1	
Dimethyl maleic anhydride	A	7-10	Soft	Low	1	0.1	
Dimethylcyclopentasiloxane	A	7-10	Soft	High	2		<b>0.9</b>
Dimethylcyclopentasiloxane	A	7-10	Soft	Low	2		<b>0.9</b>
Dodecamethylcyclohexasiloxane	A	7-10	Hard	Low	1	0.13	
Dodecamethylcyclohexasiloxane	A	7-10	Soft	High	2	0.1	0.3
Dodecamethylcyclohexasiloxane	A	7-10	Soft	Low	2		0.3
Dodecamethylcyclohexasiloxane	B	3-6	Hard	High	2		0.1
Dodecanal	B	7-10	Hard	High	1	0.1	
Dodecanal	D	3-6	Hard	Low	1	<b>0.89</b>	
Dodecanol	C	7-10	Soft	Low	1	0.2	

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Dodecanol	D	3-6	Hard	Low	1	<b>0.9</b>	
Ethyl propionate	B	3-6	Hard	Low	1	0.1	
Ethyl propyl ketone	E	7-10	Hard	High	1	0.2	
Ethylmethylemaleic anhydride	A	7-10	Soft	High	1	0.2	0.05
Ethylmethylemaleic anhydride	A	7-10	Soft	Low	1	0.1	0.05
Ethylmethylemaleic anhydride	B	3-6	Hard	Low	1		0.1
Ethylmethylemaleic anhydride	B	3-6	Soft	Low	1	0.1	
Hexamethylcyclotrisiloxane	A	7-10	Hard	Low	1	0.1	
Methyl(1,1-dichloroethyl) ketone	B	7-10	Soft	Low	1	0.2	
N,N-Dibutylformamide	A	7-10	Hard	High	2	<b>2</b>	
N,N-Dibutylformamide	A	7-10	Soft	High	1	0.05	
N,N-Dibutylformamide	A	7-10	Soft	Low	1	0.06	
n-Butylbenzenesulphonamide	A	3-6	Hard	Low	1	0.08	
n-Butylbenzenesulphonamide	D	1-2	Soft	High	1	0.04	
n-Decanal	B	7-10	Hard	Low	1	0.1	
n-Nonanal	A	7-10	Soft	High	1	0.1	
n-Nonanal	A	7-10	Soft	Low	1	0.1	
n-Nonanal	B	7-10	Hard	Low	1	0.1	0.2
n-Nonanal	D	3-6	Hard	High	1	0.1	
n-Nonanal	D	7-10	Hard	Low	1	0.2	0.2
n-Nonanal	E	7-10	Hard	High	1	0.1	

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample $\mu\text{g/l}$	Blank $\mu\text{g/l}$
n-Tridecane	D	3-6	Hard	Low	1	0.07	
Octamethylcyclotetrasiloxane	A	7-10	Hard	Low	1	<b>0.6</b>	
Octamethylcyclotetrasiloxane	A	7-10	Soft	High	2		0.3
Octamethylcyclotetrasiloxane	A	7-10	Soft	Low	2		0.3
Octamethylcyclotetrasiloxane	B	3-6	Hard	High	2		0.1
Octamethylcyclotetrasiloxane	D	3-6	Hard	High	1	0.3	
o-Phthalaldehyde	C	7-10	Soft	High	2	<b>1.9</b>	
Phthalide	B	1-2	Soft	High	1		<b>0.9</b>
Phthalide	C	3-6	Soft	Low	1		<b>0.9</b>
Terephthalaldehyde	C	7-10	Soft	High	1	0.2	
Terephthalaldehyde	C	7-10	Soft	Low	1	<b>0.7</b>	
Terephthalaldehyde	C	7-10	Soft	Low	1	<b>0.5</b>	
Terephthalaldehyde + 2-Phenoxyethanol	C	7-10	Soft	Low	2	<b>0.7</b>	
Tetrachloroethylene	A	7-10	Hard	High	1	0.1	
Tetrachloroethylene	B	3-6	Hard	Low	1	0.2	
Tetrachloroethylene	B	7-10	Soft	Low	1	0.1	0.2
Tetrachloroethylene	E	7-10	Hard	High	1		0.1
Tetrachloroethylene	E	7-10	Soft	High	1	0.2	0.2
Tetradecanol	B	3-6	Soft	Low	1	0.27	
Tetradecanol	D	3-6	Hard	Low	1	0.4	

**Table 13**      **Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Triacetin	B	7-10	Hard	Low	1	0.1	0.1
Triacetin	D	3-6	Soft	Low	1		0.1
Triacetin	D	7-10	Hard	Low	1		0.1
Triacetin	E	7-10	Hard	High	1	0.1	
Trichloroethylene	B	3-6	Hard	Low	1	0.1	
Trimethyl borate	E	7-10	Hard	High	1	<b>0.5</b>	
Trimethylbenzene isomer	A	7-10	Soft	High	1	0.1	
Trimethylbenzene isomer	A	7-10	Soft	Low	1	0.1	
Undecanal	D	3-6	Hard	Low	1	0.1	
Unknown m/z 109,111,71,43	D	3-6	Hard	Low	1	<b>1.1</b>	
Unknown m/z 109,111,71,83	B	3-6	Soft	Low	1		0.1
Unknown m/z 109,71,111,41	E	1-2	Soft	Low	2	0.2	
Unknown m/z 109,71,111,43	A	7-10	Hard	Low	1	0.3	0.1
Unknown m/z 109,71,111,43	A	7-10	Soft	High	1	0.1	0.1
Unknown m/z 109,71,111,43	A	7-10	Soft	Low	1		0.1
Unknown m/z 109,71,111,43	B	1-2	Soft	High	1	0.1	
Unknown m/z 109,71,111,43	C	3-6	Soft	High	1		0.05
Unknown m/z 109,71,111,43	C	3-6	Soft	Low	1	0.1	
Unknown m/z 109,71,111,43	C	7-10	Soft	High	1		0.05
Unknown m/z 109,71,111,43	C	7-10	Soft	Low	1	0.1	0.05
Unknown m/z 109,71,111,43	C	7-10	Soft	Low	1	0.1	0.05

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 109,71,111,43	C	7-10	Soft	Low	1	0.09	0.05
Unknown m/z 109,71,111,43	D	1-2	Soft	High	1	0.1	
Unknown m/z 109,71,111,43	D	3-6	Hard	High	1	0.2	
Unknown m/z 109,71,111,43	D	3-6	Hard	Low	1	0.1	
Unknown m/z 109,71,111,43	D	3-6	Soft	Low	1		0.1
Unknown m/z 109,71,111,43	D	7-10	Soft	High	1	0.1	0.1
Unknown m/z 109,71,111,83	B	3-6	Soft	Low	1	0.1	
Unknown m/z 117,123,61,29	E	3-6	Hard	High	2	0.2	
Unknown m/z 117,178,69,68	E	3-6	Hard	High	2		0.2
Unknown m/z 117,178,69,68	E	7-10	Hard	Low	2		0.2
Unknown m/z 163,43,145,148	D	3-6	Hard	High	1	<b>1.2</b>	
Unknown m/z 173,55,99,84	A	7-10	Hard	Low	1		0.1
Unknown m/z 173,55,99,84	A	7-10	Soft	High	2	<b>1.1</b>	0.3
Unknown m/z 173,55,99,84	A	7-10	Soft	Low	2		0.3
Unknown m/z 173,55,99,84	C	7-10	Soft	High	2	0.2	
Unknown m/z 173,55,99,84	D	3-6	Hard	High	1	0.1	0.1
Unknown m/z 173,55,99,84	E	1-2	Soft	Low	2	<b>1.1</b>	
Unknown m/z 173,55,99,84	E	3-6	Soft	Low	2	<b>1.1</b>	
Unknown m/z 176,178,69,41	E	3-6	Hard	High	2		0.2
Unknown m/z 176,178,69,41	E	7-10	Hard	Low	2		0.2
Unknown m/z 220,238,172,57	E	7-10	Hard	Low	2	0.1	



**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 222,224,143,240	B	7-10	Hard	High	2		<b>6</b>
Unknown m/z 222,224,143,240	E	7-10	Hard	Low	2	<b>0.6</b>	
Unknown m/z 235,46,207,66	E	3-6	Hard	High	2		0.2
Unknown m/z 235,46,207,66	E	7-10	Hard	Low	2		0.2
Unknown m/z 249,247,168,264	C	7-10	Soft	Low	2	0.1	
Unknown m/z 41,39,71,69	B	3-6	Soft	Low	2		0.2
Unknown m/z 41,43,27,56	B	3-6	Soft	High	2		<b>0.8</b>
Unknown m/z 41,43,27,56	D	3-6	Hard	High	2		<b>0.5</b>
Unknown m/z 41,43,55,57	B	7-10	Hard	High	2	<b>0.6</b>	
Unknown m/z 41,43,55,57	C	3-6	Soft	High	1	0.1	
Unknown m/z 41,43,55,57	C	7-10	Soft	High	1	0.1	
Unknown m/z 41,43,55,57	C	7-10	Soft	Low	1	0.3	
Unknown m/z 41,43,55,57	C	7-10	Soft	Low	1	0.1	
Unknown m/z 41,43,55,57	D	3-6	Hard	Low	1	0.12	
Unknown m/z 41,43,55,57	E	3-6	Hard	High	2		0.3
Unknown m/z 41,43,55,57	E	7-10	Hard	Low	2		0.3
Unknown m/z 41,43,56,27	D	3-6	Hard	High	2	<b>0.6</b>	
Unknown m/z 41,43,56,72	A	3-6	Hard	High	2		<b>1.2</b>
Unknown m/z 41,43,56,72	B	3-6	Soft	Low	1	<b>0.7</b>	<b>0.8</b>
Unknown m/z 41,43,56,72	B	7-10	Hard	High	2	<b>1</b>	
Unknown m/z 41,43,56,72	E	1-2	Soft	Low	2		0.4

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 41,43,57,55	A	7-10	Hard	High	2	<b>56.5</b>	
Unknown m/z 41,43,57,55	E	3-6	Hard	High	2	0.2	
Unknown m/z 41,43,83,72	B	3-6	Soft	High	2	<b>0.8</b>	
Unknown m/z 41,57,55,43	D	3-6	Hard	Low	1	0.13	
Unknown m/z 41,69,43,85	A	7-10	Soft	Low	2	0.1	
Unknown m/z 43,151,109,41	B	7-10	Hard	High	1	0.2	
Unknown m/z 43,151,109,41	E	3-6	Hard	High	1	<b>1.1</b>	
Unknown m/z 43,151,109,41	E	3-6	Hard	High	2	<b>1.2</b>	<b>1.5</b>
Unknown m/z 43,151,109,41	E	7-10	Hard	High	1		<b>1.5</b>
Unknown m/z 43,151,109,41	E	7-10	Hard	Low	2	<b>0.5</b>	<b>1.5</b>
Unknown m/z 43,163,145,115	B	3-6	Soft	Low	1	<b>1.9</b>	
Unknown m/z 43,163,145,121	D	3-6	Hard	High	1	<b>0.7</b>	
Unknown m/z 43,179,158,59 + 43,163,145,160	B	3-6	Soft	Low	1	<b>1</b>	
Unknown m/z 43,179,161,158	D	3-6	Hard	High	1	0.2	
Unknown m/z 43,179,161,59	B	3-6	Soft	Low	1	0.4	
Unknown m/z 43,179,161,59	D	3-6	Hard	High	1	<b>0.5</b>	
Unknown m/z 43,41,27,71	B	3-6	Soft	Low	2		0.3
Unknown m/z 43,41,55,145	E	3-6	Hard	Low	1	0.1	
Unknown m/z 43,41,55,83	E	3-6	Hard	Low	1		0.1
Unknown m/z 43,41,57,68	B	3-6	Soft	Low	1	0.1	
Unknown m/z 43,44,64,41	A	7-10	Hard	Low	2	<b>7.4</b>	

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 43,70,55,41	B	3-6	Soft	Low	1	0.4	
Unknown m/z 43,71,57,41	B	3-6	Soft	Low	1	0.1	
Unknown m/z 43,71,57,41	B	3-6	Soft	Low	1	0.1	
Unknown m/z 43,73,115,87	A	7-10	Soft	Low	1	0.17	
Unknown m/z 43,87,58,129	E	7-10	Hard	High	1	<b>1.1</b>	
Unknown m/z 43,87,58,59	B	3-6	Soft	High	1	0.4	
Unknown m/z 45,158,188,218	E	7-10	Hard	Low	2	0.03	
Unknown m/z 45,73,42,89	D	3-6	Hard	Low	1	0.07	
Unknown m/z 55,173,41,43	A	7-10	Hard	Low	1	<b>1.1</b>	
Unknown m/z 55,41,39,83	E	3-6	Hard	High	2		0.4
Unknown m/z 55,41,39,83	E	7-10	Hard	Low	2		0.4
Unknown m/z 55,43,41,69	A	7-10	Hard	Low	1	0.04	
Unknown m/z 55,83,27,39	E	3-6	Hard	High	2		0.3
Unknown m/z 55,83,27,39	E	7-10	Hard	Low	2		0.3
Unknown m/z 55,84,27,28	A	7-10	Hard	Low	1	<b>0.9</b>	<b>3.4</b>
Unknown m/z 55,84,27,28	B	3-6	Soft	Low	1		0.4
Unknown m/z 55,84,27,28	C	7-10	Soft	High	1	0.2	
Unknown m/z 55,84,27,28	D	3-6	Hard	Low	1	<b>1.3</b>	0.2
Unknown m/z 57,29,89,83	B	3-6	Soft	Low	1		0.1
Unknown m/z 57,41,29,43	C	7-10	Soft	High	1	0.2	
Unknown m/z 57,41,29,43	C	7-10	Soft	High	2	0.2	

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 57,41,29,43	C	7-10	Soft	Low	1	0.3	
Unknown m/z 57,41,29,43	C	7-10	Soft	Low	1	0.2	
Unknown m/z 57,43,41,71	B	3-6	Soft	Low	1	0.1	
Unknown m/z 58,43,59,45	A	7-10	Soft	High	1		0.2
Unknown m/z 58,43,59,45	A	7-10	Soft	Low	1		0.2
Unknown m/z 59,41,43,42	B	3-6	Soft	Low	1		<b>0.7</b>
Unknown m/z 59,43,41,39	E	3-6	Hard	High	2	<b>0.5</b>	<b>0.5</b>
Unknown m/z 59,43,41,39	E	7-10	Hard	Low	2		<b>0.5</b>
Unknown m/z 66,46,174,192	B	7-10	Hard	High	2		<b>9.3</b>
Unknown m/z 66,85,43,41	E	7-10	Hard	Low	2	0.1	
Unknown m/z 67,53,69,39	A	7-10	Soft	High	2	0.1	
Unknown m/z 68,53,68,39	A	7-10	Soft	Low	2	0.1	
Unknown m/z 68,96,185,53	A	7-10	Soft	High	1	0.03	
Unknown m/z 69,113,41,39	B	7-10	Hard	Low	1		0.1
Unknown m/z 69,113,41,39	D	7-10	Hard	Low	1		0.1
Unknown m/z 69,113,41,86	B	3-6	Soft	High	1		0.1
Unknown m/z 69,113,41,86	D	3-6	Soft	Low	1		0.1
Unknown m/z 69,113,41,86	E	1-2	Soft	Low	1		0.1
Unknown m/z 69,113,41,86	E	3-6	Soft	Low	1		0.1
Unknown m/z 73,43,55,27	E	3-6	Hard	High	2	0.2	0.3
Unknown m/z 73,43,55,27	E	7-10	Hard	Low	2		0.3

**Table 13 Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample $\mu\text{g/l}$	Blank $\mu\text{g/l}$
Unknown m/z 83,55,41,39	E	3-6	Hard	High	2		0.3
Unknown m/z 83,55,41,39	E	7-10	Hard	Low	2		0.3
Unknown m/z 83,85,48,47 (dichloro)	B	7-10	Soft	High	2	<b>0.5</b>	
Unknown m/z 85,41,69,43	C	3-6	Soft	Low	2	0.1	
Unknown m/z 87,43,59,27	E	7-10	Hard	High	2	0.2	
Unknown m/z 87,43,59,41	A	7-10	Hard	High	1	0.2	
Unknown m/z 87,43,59,41	A	7-10	Hard	Low	1	0.3	0.1
Unknown m/z 87,43,59,41	A	7-10	Soft	High	1	0.2	0.1
Unknown m/z 87,43,59,41	A	7-10	Soft	High	2	0.1	0.2
Unknown m/z 87,43,59,41	A	7-10	Soft	Low	1	0.3	0.1
Unknown m/z 87,43,59,41	A	7-10	Soft	Low	2		0.2
Unknown m/z 87,43,59,41	B	1-2	Soft	High	1		0.1
Unknown m/z 87,43,59,41	B	3-6	Hard	Low	1		0.2
Unknown m/z 87,43,59,41	B	7-10	Hard	High	1	0.4	<b>0.9</b>
Unknown m/z 87,43,59,41	B	7-10	Hard	Low	1	0.2	0.4
Unknown m/z 87,43,59,41	B	7-10	Hard	Low	2		0.1
Unknown m/z 87,43,59,41	C	3-6	Soft	Low	1		0.1
Unknown m/z 87,43,59,41	D	1-2	Hard	High	1		0.4
Unknown m/z 87,43,59,41	D	1-2	Soft	High	1		0.2
Unknown m/z 87,43,59,41	D	1-2	Soft	High	1	0.2	0.2
Unknown m/z 87,43,59,41	D	3-6	Hard	High	1	<b>1.2</b>	0.4

**Table 13**      **Continued**

Chemical	Resin	Age	Water type	Chlorine	Phase	Sample µg/l	Blank µg/l
Unknown m/z 87,43,59,41	D	3-6	Hard	Low	1	0.2	0.1
Unknown m/z 87,43,59,41	D	7-10	Hard	Low	1		0.4
Unknown m/z 87,43,59,41	D	7-10	Hard	Low	2	0.2	0.1
Unknown m/z 87,43,59,41	E	3-6	Hard	High	1	<b>1.4</b>	<b>0.7</b>
Unknown m/z 87,43,59,41	E	3-6	Hard	Low	1	0.3	
Unknown m/z 87,43,59,41	E	7-10	Hard	High	1	<b>0.7</b>	0.2
Unknown m/z 87,43,59,41	E	7-10	Hard	High	1		0.1
Unknown m/z 95,43,93,136	B	7-10	Hard	Low	1	0.1	0.1
Unknown m/z 95,43,93,136	B	7-10	Soft	Low	1		0.03
Unknown m/z 95,43,93,136	D	7-10	Hard	Low	1		0.1
Unknown m/z 95,43,93,136	E	7-10	Soft	High	1		0.03
Unknown m/z 97,57,41,43	B	7-10	Hard	Low	2		0.1
Unknown m/z 97,57,41,43	D	7-10	Hard	Low	2		0.1
Xylene isomer	A	3-6	Hard	Low	1	0.2	0.2
Xylene isomer + Bromohydroxypentane isomer (artefact)	B	1-2	Soft	High	1		0.1
Xylene isomer + Bromohydroxypentane isomer (artefact)	B	3-6	Soft	High	2	0.2	
Xylene isomer + Bromohydroxypentane isomer (artefact)	C	3-6	Soft	Low	1		0.1
Xylene isomer + Bromohydroxypentane isomer (artefact)	D	3-6	Soft	Low	1		0.2

**Table 14** 4-t-Butyl phenol concentrations ( $\mu\text{g/l}$ ) by GC-MS – Resin C

Age years	Water type	Phase 1	Phase 2
3-6	Soft	<0.01	<0.01
3-6	Soft	0.22	0.06
7-10	Soft	1.5	2.2
7-10	Soft	0.20	0.04
7-10	Soft	<0.01	<0.01
7-10	Soft	0.95	0.5





## 4. DISCUSSION

The water temperature during Phase 1 of sampling was fairly cool (average 11 °C) but was higher (average 16.5 °C) during Phase 2. There was no technically or statistically significant difference in TOC results between the samples and the field blanks for either phase of sampling (see Appendix B). This suggests that any leaching from the pipe linings is at a low level.

The GC-MS results for Resins A, B, D and E did not show any evidence of leaching of components of the resins. The chemicals detected were those that are commonly found in drinking water samples; i.e. disinfection by-products and environmental contaminants such as phthalates. Overall, there does not appear to be a real difference between the results for samples and field blanks in the case of these resins. Repeat sampling during warmer water temperatures did not indicate any substantial change in leaching characteristics.

Evidence of leaching of 4-TBP from Resin C was found – 4-TBP and various halogenated derivatives were detected in some (but not all) samples taken from taps fed from mains lined with Resin C. This is the only one of the five resins considered that contains 4-TBP as a component. It is understood that Resin C has now been withdrawn from the market.

One of the duplicate samples (designated ‘Dup.’) was analysed. The results for the ‘Spl.’ and the ‘Dup.’ are in reasonable agreement (Table 9).

During the initial analysis of samples from Phase 1, contamination of some laboratory blanks and samples by phthalates was found. The source of this was identified and procedures were modified to eliminate contamination.

Resin manufacturers were contacted at the start of the project to identify any additional leaching data. All of them were cooperative but it was found that no additional data existed. They also assisted in providing available information on where their products had been used.

All of the water companies contacted were cooperative and most provided staff to undertake the sampling. It was found that in many cases, lining records have been archived and are difficult to locate.



## 5. CONCLUSIONS

1. The use of epoxy resins within the water industry is declining, with most companies now preferring polyurethane-based products.
2. It was not possible to identify sampling sites covering all possible combinations of resin, age of lining and water hardness. Nevertheless, the field survey covered a reasonable cross-section of these characteristics.
3. There was no technically or statistically significant difference in TOC results between the samples and the field blanks, suggesting that any leaching from the pipe linings is at a low level.
4. The GC-MS results for Resins A, B, D and E did not show any evidence of leaching of components of the resins. The chemicals detected were those that are commonly found in drinking water samples; i.e. disinfection by-products and environmental contaminants such as phthalates.
5. 4-TBP and various halogenated derivatives were found in some (but not all) samples taken from taps fed from mains lined with Resin C. This is the only one of the five resins considered that contains 4-TBP as a component. Low concentrations of 4-TBP were found in two other samples but its source in those samples is unknown.
6. Repeat sampling during warmer water temperatures did not indicate any substantial change in leaching characteristics.
7. Comparison of the results of laboratory tests (not included in this report) and the field survey indicates that laboratory test results may overstate the leaching of components from epoxy resins.



## **REFERENCES**

Kanda, R., Norris, M. and Wilson, I.M. (1998) Improved material testing: validation of laboratory leaching tests for epoxy resin products for site applied pipe lining. Confidential Final Report to the Drinking Water Inspectorate, WRc Report DETR/DWI 4555.



## APPENDIX A    SAMPLING PROCEDURES

### A.1    SAMPLE LOCATION FORM

<b>Form Number</b>	
<b>Address sampled from</b>	
<b>Water Supply Zone</b>	
<b>Water Source</b>	
<b>Water Type</b>	<b>Hard</b> <input type="checkbox"/> <b>Soft</b> <input type="checkbox"/>
<b>Pipe Diameter (mm)</b>	
<b>Pipe age (years)</b>	
<b>Pipe Material (e.g. cast iron)</b>	
<b>Length lined &amp; access hole numbers</b>	
<b>Epoxy Resin Type</b>	
<b>Batch numbers</b>	<b>Resin:</b> ..... <b>Hardener:</b> .....

<b>Approximate length of epoxy lines pipe upstream of sample point</b>	
<b>Lining Application Date</b>	
<b>Lining Contractor</b>	
<b>Lining Rig Number</b>	
<b>Cleaning CCTV Survey Report</b>	
<b>Resin and Hardener Temperature (°C)</b>	
<b>Weight Check Data</b>	
<b>Mix Ratio</b>	
<b>Spin-up Time</b>	
<b>Lining thickness Pre and/or Post Cure</b>	
<b>Cure Time</b>	
<b>CCTV Lining Survey Report</b>	
<b>Chlorination Method</b>	
<b>Return to Service Time</b>	
<b>Customer Problems on Return to Service (describe)</b>	
<b>Non-Conformance Records</b>	



<b>Customer Complaints Since Lining Application (describe)</b>		
<b>Comments</b>		
<b>Name:</b> .....	<b>Signature:</b> .....	<b>Date:</b> .....

## A.2 SAMPLE RECORD FORM

<b>Date</b>	
<b>Time</b>	
<b>Address</b>	
<b>Contact Person</b>	
<b>Telephone*</b>	
<b>Water Company</b>	
<b>Supply sub-zone code</b>	
<b>Sample Location Form Number</b>	
<b>Sample bottle number</b>	
<b>Water temperature °C</b>	
<b>Free chlorine concentration mg/l</b>	
<b>Water appearance (e.g. clear, cloudy)</b>	
<b>Is this a Blank?</b>	<b>Yes</b> <input type="checkbox"/> <b>No</b> <input type="checkbox"/>

\* Telephone number required in the event that we need to arrange to take a further sample.

**Observations**

**Name**

**Signature**

## **A.3 SAMPLING PROCEDURE**

### **Paperwork**

Personal DWI ID and introductory letter.

Sample Location Form – completed as far as possible prior to sampling.

Sample Record Form – to be completed on site.

Pre printed labels for sample bottles.

Address Labels for WRC-NSF lab in Reading.

Packing box with ice packs if necessary for transportation of samples to lab by courier.

### **Equipment**

Chlorine residual test meter and reagent sachets

Digital thermometer and probe

Sample bottles – 1 × 100 ml polyethylene bottle

2 × 1-litre glass bottles containing 2 ml of 1 g/l ascorbic acid

100ml Glass/Plastic Beaker

Stopwatch

Digital Camera (Photograph location of tap sampled and tap model)

Suitable equipment bottle/carry box

### **Procedure**

The property (or area) for sampling will be identified on the Sample Location Form. If a precise address is not identified, select a suitable property in the area.

On arrival at a property, introduce yourself, show your identity card, and request permission to take water samples.

If the property is unoccupied or permission is refused, approach other properties in the same area until a suitable site for sampling is found.

NOTE: Only domestic properties should be sampled; not businesses or public buildings.

Locate a suitable drinking water tap – this will usually be the cold-water tap in the kitchen.

Open the tap fully and run water to waste for at least three minutes to flush water that has been standing in the domestic pipework.

Take one sample into a 100 ml polyethylene bottle and two others into 1-litre glass bottles. Fill the bottles to the top leaving no headspace.

NOTE: Do not rinse or drain the bottles prior to sampling.

Take a further sample into a beaker. Measure the free chlorine concentration using the test meter and measure the water temperature using the digital thermometer.

Complete the Sample Record Form.



## APPENDIX B TOC DATA

Table 15 Paired TOC data – Phase 1

TOC mg/l	Blank TOC mg/l
0.94	0.85
0.65	1.11
1.36	1.68
2.00	1.71
1.91	1.70
0.83	0.98
0.31	0.40
1.04	0.81
1.08	1.50
0.35	0.81
1.96	1.83
1.76	1.83
1.76	1.77
1.44	1.47
1.66	1.47
0.91	1.76
1.24	1.16
1.05	1.33
1.66	1.99
1.11	1.73
0.72	0.63
1.07	0.63
0.86	0.82
0.45	0.92
0.98	0.92
0.41	0.39
0.62	0.62
1.55	1.55
0.90	0.80
1.35	2.29
1.11	0.89
0.99	0.89
1.03	0.89
0.93	0.89
1.02	0.89
1.17	1.11
0.78	1.11

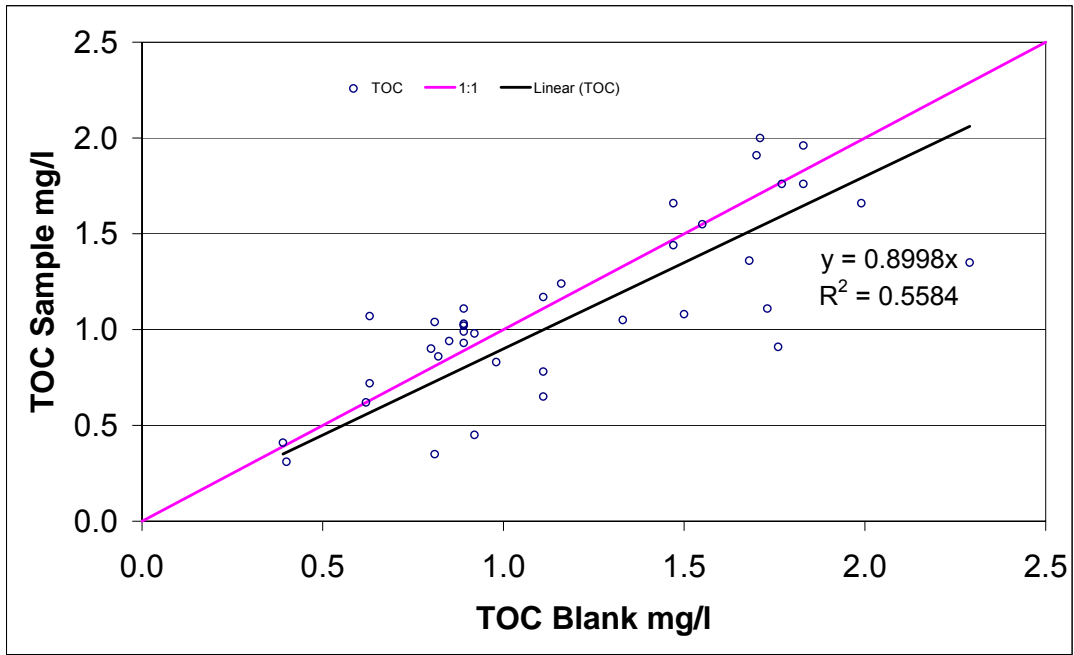


Figure 1 Scatter plot of TOC versus blank TOC – Phase 1

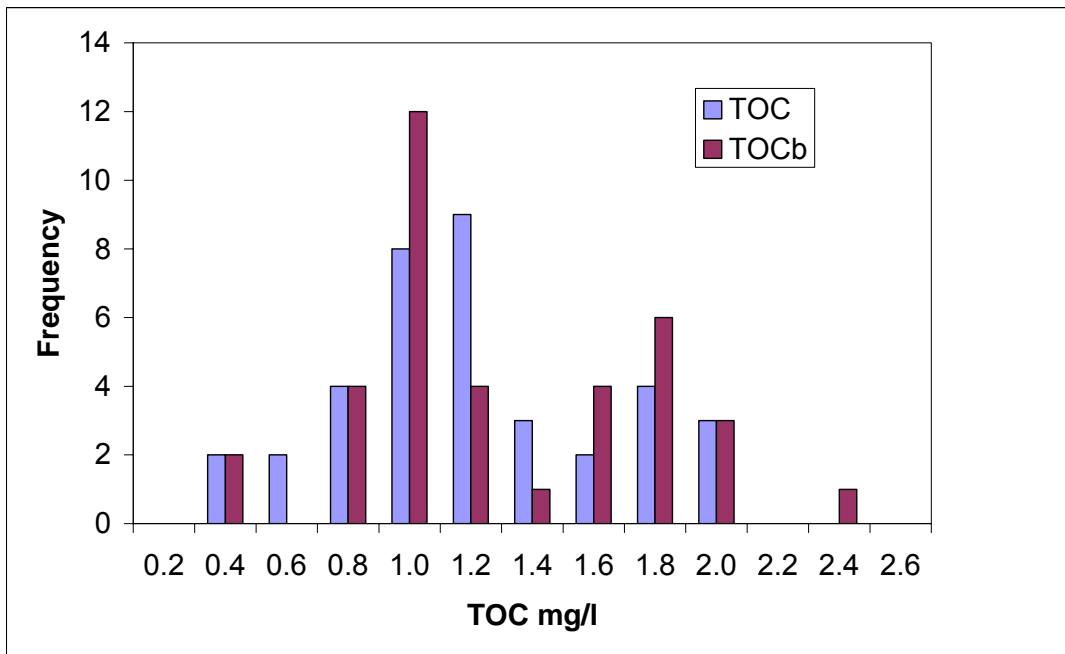


Figure 2 Histograms of TOC and blank TOC – Phase 1



**Table 16**      **t-Test: two-sample assuming equal variances – Phase 1**

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	Blank TOC	TOC
Mean	1.192703	1.107027
Variance	0.232337	0.201288
Observations	37	37
Pooled Variance	0.216813	
Hypothesized Mean Difference	0	
df	72	
t Stat	0.791409	NOT significant, p=0.05
P(T<=t) one-tail	0.215652	
t Critical one-tail	1.666294	
P(T<=t) two-tail	0.431305	
t Critical two-tail	1.993462	

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**Table 17 Paired TOC data – Phase 2**

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TOC mg/l	Blank TOC mg/l
1.11	1.06
1.00	1.06
0.92	1.02
0.87	1.07
1.10	1.07
1.51	2.35
1.43	0.92
1.06	0.92
1.30	0.92
0.86	0.92
1.17	0.92
2.15	2.00
1.89	2.00
1.90	1.92
1.15	1.30
1.22	1.30
1.60	1.78
1.44	1.50
1.77	2.41
1.05	0.95
1.25	1.26
0.70	0.69
0.73	0.69
0.86	0.83
0.22	0.25
0.75	0.56
1.37	1.20
0.98	1.00
0.87	0.75
0.19	0.24
1.26	1.54
1.47	1.54
0.94	1.06
0.51	0.74

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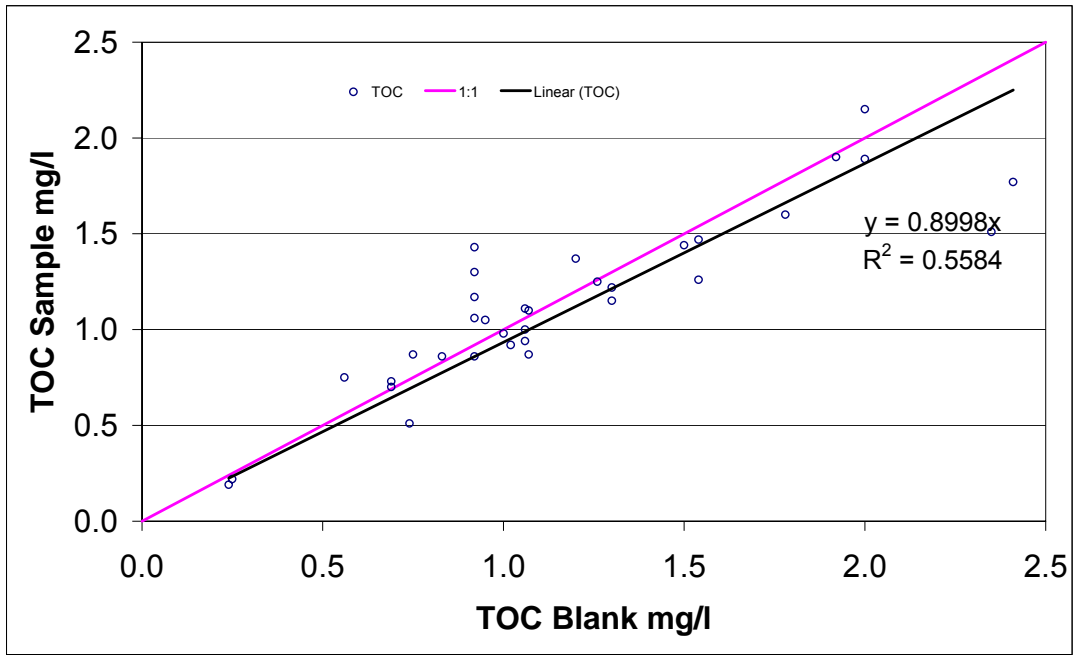


Figure 3 Scatter plot of TOC versus blank TOC – Phase 2

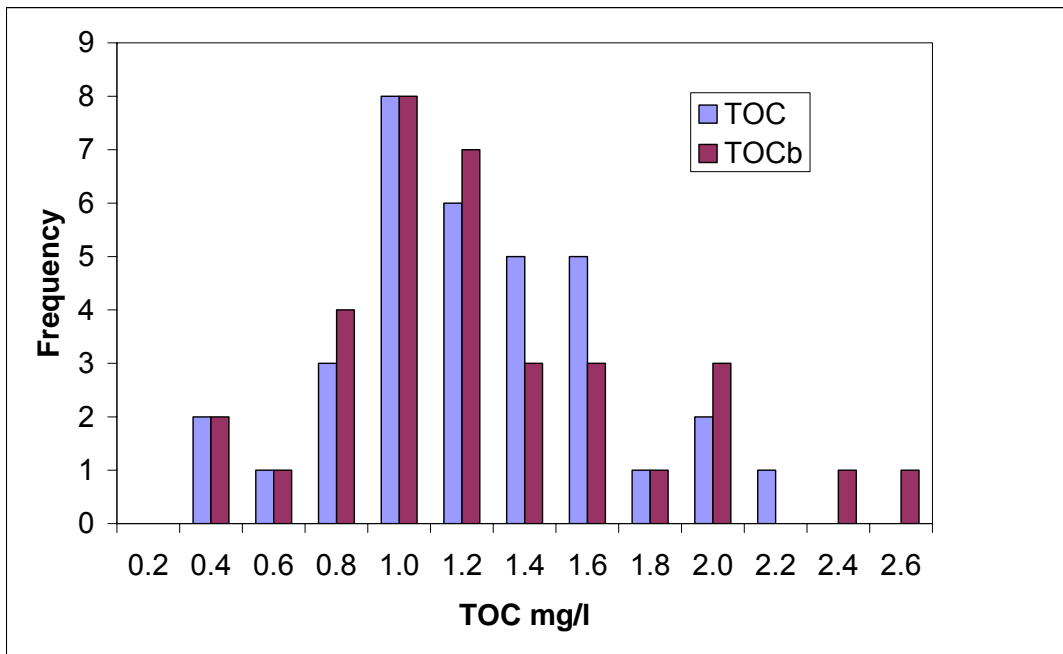


Figure 4 Histograms of TOC and blank TOC – Phase 2

**Table 18**      **t-Test: two-sample assuming equal variances – Phase 2**

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	Blank TOC	TOC
Mean	1.168824	1.135294
Variance	0.277502	0.194335
Observations	34	34
Pooled Variance	0.235918	
Hypothesized Mean Difference	0	
df	66	
t Stat	0.284623	NOT significant, p=0.05
P(T<=t) one-tail	0.388412	
t Critical one-tail	1.668271	
P(T<=t) two-tail	0.776824	
t Critical two-tail	1.996564	
P(T<=t) two-tail	0.776824	
t Critical two-tail	1.996564	

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