

EXPOSURE TO ENDOCRINE DISRUPTERS VIA  
MATERIALS IN CONTACT WITH DRINKING WATER  
- PHASE 2 -

DWI 70/2/88(II)

Report Date Sept 2001

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Final Report to DEFRA/DWI

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## EXECUTIVE SUMMARY

In December 1999 the DETR appointed the Water Quality Centre (Wq<sup>C</sup>) as contractor to carry out a study to assess consumer exposure to endocrine disrupters and other toxic substances from drinking water tank materials.

The objectives of the contract were to:

1. Review the initial WRc report ("Exposure to Endocrine Disrupters via Materials in Contact with Drinking Water" report number DETR/DWI 4711/2) and recommend product types which warrant further study to characterise consumer exposure arising from in-service use.
2. To propose suites of analysis for each product type which provide a representative selection of parameters comprising endocrine and other toxic substances
3. To propose a programme of monitoring to characterise consumer exposure in premises served by new or refurbished drinking water storage tanks.

The duration of the study was initially twelve months but was extended by a further three months to accommodate difficulties with obtaining suitable sites for monitoring.

The sampling and analysis programme focused on materials leaching from new and refurbished drinking water storage tanks. The availability of suitable sites proved to be severely limited, however four sites were investigated where the following type of work was being undertaken:

- Replacement tank- GRP replacement (two sites)
- Relined tank- butyl rubber liner relining (two sites)

From the review of the existing report, a decision was made that samples from the four sites would be analysed for the following selection of known potential endocrine disrupting groups of chemicals:

- Alkyl phenols- nonyl phenyl; octyl phenol
- Bisphenols- bisphenol-A; bisphenol-F and their corresponding diglycidyl ethers.
- Phthalates - bis 1-octylphthalate; bis nonylphthalate; bis 2-ethylhexylphthalate; bis ethylphthalate; bis butylphthalate; bis iso-butylphthalate; benzylbutylphthalate; bis hexylphthalate; bis methylphthalate.
- Styrene.

Additional information about site and environmental conditions were recorded. TOC and general GC-MS scan analysis were carried out for each site.

For each site samples were taken pre- and post-installation, comprising feed-to-tank, dip sample from the tank and a nearby point of distribution from the tank.

Acute exposure risks only were monitored.

No significant increase between pre- and post installation analysis results for the target analytes or TOC were recorded.

The GC-MS scan analysis detected a small number of non-targeted analytes (concentration ranging from <1.0 - 12.0 µg/l) in some samples. Details of the GC-MS scan analysis are included in the final report.

The results of the analysis of the targeted analytes indicated that there is negligible risk to the consumer from these potential endocrine disrupting chemicals following correctly installed or refurbished water storage tanks.

Due to the limited number of sites involved in this study it is recommended that further studies be undertaken to ensure a representative data set is obtained. As knowledge of the subject of endocrine disrupters is growing rapidly a regular review of the subject should be undertaken to incorporate the most recent understandings of the topic.

# **Exposure To Endocrine Disrupters Via Materials In Contact With Drinking Water: A review of report number DETR/DWI 4711/2 and an overview of current interest and research into suspected endocrine disrupting chemicals in the environment.**

March 2000 updated January 2001

## **SUMMARY**

The authors of the WRc report under review ("Exposure to Endocrine Disrupters via Materials in Contact with Drinking", Report number DETR/DWI 4711/2) reported on the likely occurrence of suspected endocrine disrupting chemicals in materials that come into contact with drinking water. A variety of factory and site applied products were tested for the leaching of potential endocrine disrupters.

The study reported initial high rates of short-term leaching of a number of target compounds. Rates of leaching rapidly fell and in the majority, but not all cases, the concentration found in leachate samples were below the limits of detection (circa  $< 2 \mu\text{g l}^{-1}$ ) after 73 hours from the start of testing.

Additional field testing of products was recommended to reliably assess consumer exposure to these chemicals.

The report failed to fully evaluate the current inadequacies in identifying and quantifying the chemicals which may pose a threat to health, based on their suspected endocrine disrupter properties.

We endorse further in situ testing of materials in contact with drinking water but the above point must be addressed before an effective programme can be implemented. Possible points for consideration are outlined within this review.

## **INTRODUCTION**

In 1997 the DETR commissioned a study on the potential for approved polymeric water supply products to constitute a source of exposure to endocrine disrupters. The resulting report, whilst reassuring did conclude that it was difficult to be confident as to what constitutes worst case in terms of consumer exposure. In response to increasing public and scientific concern regarding the presence of oestrogen mimicking compounds or endocrine disrupters in the environment, the WRc were commissioned to report to the DWI. The subsequent report submitted by the WRc (Report DETR/DWI4711) specifically addressed the potential for endocrine disrupters to leach from materials in contact with drinking water to enter the water supply and pose a risk to the public. The report stated that for the potential risks to the public to be reliably assessed key areas should be considered. The concern was mainly with products used on consumers' premises rather than the public water supply. These concerns were related to whether sufficient flushing was carried out to disperse initial high levels of leaching. Also, that elevated temperatures within roof spaces may accelerate leaching.

The following areas were singled out for attention:

- identifying their presence in products in contact with drinking water
- chemical toxicity
- their levels of use
- the rate of leaching of those compounds identified.

A related issue was the fact that a number of polymeric lining materials which conform to BS 6920:1990 have been refused approval under regulation 25. The Chemicals Committee's assessments of leaching test data for these products indicate a higher migration rate and wider range of compounds leaching than are observed with equivalent regulation 25 approved products. This observation raised the question as to whether the BS6920 test requirements are sufficiently rigorous for high surface area to volume/long contact use, as may be found in a drinking water storage tank. In response, the aim of this current review is to assess the information provided in the report and report on any recent scientific findings available since the initial 1997 publication.

## COMMENT

The following section reviews in detail specific sections of the WRc report ("Exposure to Endocrine Disrupters via Materials in Contact with Drinking Water" report number DETR/DWI 4711/2) and recommends product types which warrant further study to characterise consumer exposure arising from in-service use.

### Part 1 - "Introduction and Literature Review"

The introduction to the report provided an overview of the main areas of concern, however, there was no mention of:

- the by-products of polymer chemistry produced during the curing of epoxy resins,
- the relative toxicology of the various oligomers and isomeric impurities present in commercial materials
- the occurrence of chlorination by-products following curing of epoxy resins or their endocrine disrupting potential if present.

### Part 2 - "Endocrine Disrupters"

Data was presented which illustrated the endocrine disruption potential of a number of compounds relative to 17- $\beta$ -oestradiol. The information was useful and informative but must be qualified as limited in scope and there were doubts raised to the reliability of the different test methods employed in the studies. This included data presented from Soto *et al.* 1995, for 10 alkyl phenols, Perez *et al.* 1998 for 17 bisphenols, Harris *et al.* 1997 for 35 phthalates. As presented it provided a clear but not necessarily comparable data set. The data did appear to indicate that phthalates had the lowest relative potency compared to the other compounds tested.

In a recent study from the UK Laboratory of the Government Chemist (LGC) phthalates were identified as a case for concern. The exposure of children to phthalates leaching from PVC toys was investigated and standardised methods were recommended for adoption (LGC technical report number LGC/1999/DTI/004). The WRc report went on to recommend the need for further studies on antioxidants and their alkylphenolic degradation products, a recommendation we would endorse. In section 2.3 of the report, acknowledgement was made that due to synergistic effects it would be difficult to duplicate mammalian toxicology studies.

### Part 3 - "Survey of Manufacturers"

The question arises as to the reliability of the data supplied by manufacturers in response to the survey undertaken, taking into account that the exact composition or formulation of raw materials may not be available to the manufacturers, the information provided may have been incomplete or unintentionally misleading.

#### Part 4 - "Material Testing in the Laboratory"

Methods adopted were generally in line with DWI/CCM guidelines and wholly appropriate, however the method used for the analysis for bisphenol-A, bisphenol-F and their diglycidyl-ethers was relatively non-selective. For example, an alternative to HPLC with UV detection would have utilised HPLC with mass spectrometry detection.

Spiked procedural blank results for bisphenol-F and nonylphenol should have been included. We also had some concern over the low level and non-reproducible efficiency of recovery data for BFDGE analysis reported between <40% to just over 60%. We would recommend the use of mass spectrometry and the inclusion of appropriate labelled internal standards to aid in the quantification of these compounds.

It is not clear why TOC results were absent from the analysis of some products.

The routine use of GC-MS in scan mode when analysing leachates does mean that both target and non-target non-polar compounds can be positively identified and quantified against appropriate standard reference materials where available. There is a case for using this approach rather than target compound analysis if the same sample preparation and GC-MS analysis is used for specific determinand analysis.

It is clear that GC-MS analysis does not account for all of the leachable material identified by TOC analysis. Unfortunately there are no validated methods currently available for the routine screening of non-volatile polar congeners comparable to BS6920 part 4. LC-MS and LC-MS/MS are now widely available. Using automated MS/MS in 'full scan' or by using selected reaction monitoring, the nearest equivalent to GC-MS full scan techniques, the screening and quantitation of endocrine disrupters in potable water is a real possibility and warrants investigation.

We believe there is a need for the development of generic LC-MS-MS methods for the routine screening of compounds leached from materials in contact with drinking water. Current techniques using single quadrupole LC-MS instruments in APCI mode will, under optimal conditions, produce a strong M+H parent ion, or in the presence of some reagents, M+Na, M+NH<sub>4</sub> ions etc. This technique is more specific than UV or fluorescence detection but still provides little information regarding the confirmation of chemical identity.

#### Part 5 - "Materials testing in the field"

Several products were subject to leachate tests broadly in line with accepted methods.

For product M there was significant leaching of BFDGE and BADGE (78 mg m<sup>-2</sup> h<sup>-1</sup>) even after 1002 hours at one site but was below the LOD at 5 other sites. This type of inter-site variation is a cause for concern.

The reviewer supports in general the conclusions regarding the leachate tests as presented but would further add that any new controls on the application of site applied products should be supported by post application monitoring. This should at least consist of a GC-MS survey supported by specific determinand analysis of any relevant polar analytes.

There is still considerable debate over the relative risks posed by the different oestrogen mimics in the environment and was highlighted by Renner (1997).

It is accepted that TOC levels in leachates do not correlate with material quantified on the basis of GC-MS scan analysis nor is there a close correlation between TOC and taste, odour or biological growth on incubation. However, there is often significant material present in leachates with no indication of the nature of the compounds involved. They may be polar, non-volatile compounds potentially presenting a significant toxicological risk but which are

not identified or quantified using current accepted procedures. This issue needs to be addressed.

The compound styrene is listed by Keith (1997) in a handbook of property data of endocrine disrupters and is regarded by the US EPA as an endocrine disrupter. The dimer and trimer of styrene were listed in the original WRc report, however, the monomer was not considered as a suspected endocrine disrupter. Styrene was not included in the analytical tests applied to leachate samples collected from the products under test. Whilst the status of styrene as an endocrine disrupter may be subject to debate we believe its presence in many products may constitute a hazard and products potentially containing the compound should be subject to analysis. Glass Reinforced Polyester (GRP) tanks are made from a resin solution. This is usually by dissolving an unsaturated polyester resin into styrene which is then used to make a polyester moulding compound by mixing together the resin solution with fillers, thickening agents and other manufacturing additives. Styrene analysis should routinely be carried out for this type of product.

## RECENT DEVELOPMENTS

### Regulatory

There is still a large area of uncertainty as to the risk posed to human health by the wide range of compounds considered as potential endocrine disrupters in the environment.

The EC Committee on Industry, External Trade, Research and Energy prepared a report for the Committee on the Environment, Public Health and Consumer Policy on the effects of endocrine disrupters on human and animal health (COM (1999) 706-C5-0107/2000-2000/2071(COS)). The report states that although there was strong evidence available for impaired reproduction and development in wildlife there is still little evidence of a causal link to endocrine disruption. This was based on findings of the EU Scientific Committee on Toxicology and the Environment (CSTEE) within the report: Opinion on Human and Wildlife Health Effects of Endocrine Disrupting Chemicals, with Emphasis on Wildlife and Ecotoxicological Test Methods, by the European Scientific Committee for Toxicology, Ecotoxicology and the Environment (CSTEE), EC-DG Consumer Policy and Consumer Health Protection, Brussels, 1999.

There is continuing debate as to the so called "low-dose" effects of some potential endocrine disrupters. This includes conflicting claims that bisphenol-A should be phased out on the one hand and industry support for its continued use on the other. Reports emanating from the US indicate the occurrence of low dose effects, for example bisphenol-A, but not for octylphenol, in mice (Nagel *et al.* 1997; vom Saal *et al.* 1997). Several reports in Nature have followed developments in the activity of the US EPA regarding setting priorities for endocrine disrupters but to date there appears to be no consensus of opinion of how regulation should be managed (Macilwain 1998, 1999).

The EC report (COM (1999) 706-C5-0107/2000-2000/2071(COS)) detailed recent research funded under the FRAMEWORK IV programme which included studies into the effects of endocrine disrupters on human sperm counts and increased incidence of testicular cancer and the development of bioassays for endocrine disrupters. Current research under FRAMEWORK V will consolidate and develop these areas. The report concludes by noting that: an interdisciplinary approach is required and that more work should be done to clearly identify the active compounds. There is a dearth of standard validated methods for routine analysis and it recognised that there are problems in standardising oestrogenicity testing. Also, there is a need to closely investigate the 560 compounds identified as suspected endocrine disrupting compounds. Currently an EU sponsored study is being carried out reviewing the literature on 116 compounds that were identified as being produced in the



largest quantities. The report proposed that future research should include the interactive effect when there is exposure to a number of endocrine disrupters, for example synthetic oestrogens and phytoestrogens. This is particularly important when considering materials in contact with drinking water that may contain a blend of related compounds, isomers and oligomers. A screening programme for endocrine disrupting activity of all synthetic compounds in the environment was proposed.

Proposed for immediate action was to establish a list of substances that are confirmed or suspected endocrine disrupters by 2001 with the expected number to be over 560. The aim would then be to identify by mid 2001 those compounds on the list that should be restricted, phased out or immediately withdrawn from use.

It is clear that we are still some way from having a definitive list of suspected endocrine disrupters that is based on reliable human toxicology with respect to their endocrine disrupting potential. Target compounds must be selected for attention based on a precautionary approach until research into this area presents a clearer picture. Additionally, there is a need for establishing a universally acceptable definition of what constitutes an endocrine disrupter. Substances may act to disrupt the endocrine system in a number of ways, including:

- mimicking endogenous human hormones such as oestrogen or testosterone

But effects may also include:

- blocking hormone receptors thus inhibiting normal hormone activity
- affecting the metabolism, biosynthesis or transport of natural hormones leading to imbalance

Currently, an internationally agreed working definition of endocrine disrupters is:

"An endocrine disrupter is an exogenous substance or mixture that alters function(s) of the endocrine system and consequently causes health effects in an intact organism, or its progeny, or (sub) populations."

as stated in the 'Opinion of the committee on Industry, External Trade, Research and Energy for the Committee on the Environment, Public Health and Consumer Policy; European Parliament COM (1999) 706-C5-0107/2000-2000/2071(COS.)'.

Concern has focused on reduced human sperm counts. Although no causal link has yet been established, it is inferred that, compounds commonly identified as present in the environment may interfere with the human endocrine system. These compounds may include organochlorine pesticides, PCBs, alkylphenyl ethoxylates, bisphenol-A and phthalates (Carsen *et al.* 1999). A large source of information on research into this whole area can be found at the web site of the Global Endocrine Disrupter Research Inventory ([http://oaspub.epa.gov/endocrinepack\\_edri.All\\_Page](http://oaspub.epa.gov/endocrinepack_edri.All_Page)).

## Methodology

For a review of modern analytical methods for alkylphenols and their ethoxylates see Lee (1998). Importantly, recommendations for sample handling are made. A short review of extraction techniques for aqueous samples was presented including application of liquid-liquid and solid phase extraction (SPE) to a variety of raw water and wastewater matrices. More recent methods include HPLC with atmospheric pressure ionisation (API) mass spectrometry (MS) with electrospray (ES) or chemical ionisation (CI) modes. These techniques are often more sensitive than conventional methods and much more specific, than HPLC with fluorescence or UV detection. There is generally a greater degree of confidence attached to the results obtained with the use of mass spectrometry.

Important EU funded research into environmental endocrine disrupters is ongoing as part of the European Waste Water Cluster which encompasses 5 related EU projects. Although it excludes potable water analysis many of the emerging techniques and technologies can be applied to this area. For example, one project includes the analysis of NP and NPEO using SPE and LC-MS and another is developing biosensor and ELISA testing for endocrine disrupters or endocrine disrupter activity. Investigations also include the use of MS/MS techniques for screening purposes. These studies fall within the project: "Priority Surfactants and their Toxic Metabolites in Waste Effluent Discharges - An Integrated study" (PRISTINE) (Project ENV4-CT97-0494).

The routine application of LC-MS for a number of suspected endocrine disrupters has been recently demonstrated by Petrovic and Barceló (2000a) and similar methods are now being implemented by the UK Environment Agency, National Laboratory Service. Many environmental laboratories are now taking advantage of the current generation of bench-top LC-MS systems that are available and are cheaper and more robust than previously.

The stability of suspected endocrine disrupters during sample storage is important if qualitative or quantitative analysis is to be carried out. A recent study of groundwater and wastewater investigated the stability of a number of non-ionic surfactants and linear alkylbenzene-sulphonates (LAS). The study recommended that samples should be extracted as soon after collection as possible, ideally onto SPE cartridges and stored at <4°C prior to analysis. Many compounds were found to be more stable when stored on these cartridges than if stored in the aqueous phase (Petrovic and Barceló (2000b)). Microbial degradation was presumably responsible for the breakdown of these compounds in raw water but this would probably not be the case for potable water. We are not aware of comparable work with drinking water, however, preliminary results from short term (2-10 day) stability studies carried out in our own laboratory indicated that significant degradation of diglycidyl ethers did take place in chlorinated water. The products of this degradation were not identified.

A number of research programmes are being undertaken in Europe, the US and Canada for the analysis of selected target compounds, however, there is little consideration for the production of chlorination by-products either as part of tertiary wastewater treatment or in the potable water supply. Ozone, chlorine and monochloramine are all used, sometimes in combination, as part of water treatment processes. Dosing of epoxy linings with high levels of chlorine as part of the curing process is likely to produce high levels of chloramination products. Chloramines have been responsible for taste and odour complaints in some circumstances. There is a need for further investigations into the nature of these by-products and whether they represent a potential risk of endocrine disrupting activity. LC-MS was applied to the monitoring of chlorine and bromine substituted by-products in raw waters and sediments (Ferguson *et al.* 2000) and Ball *et al.* (1989) undertook a study into the fate of halogenated and non-halogenated octylphenyl ethoxylates in wastewater treatment.

## CONCLUSIONS AND RECOMMENDATIONS

The field test results presented in the WRc report indicated that chronic exposure to suspected endocrine disrupters is unlikely to pose a significant risk to consumers, however, acute exposure may be significant. For example, in the time following the commissioning of epoxy relined pipes or water storage tanks exposure may be unacceptably high.

There is currently in place a code of practice for the use of epoxy lining for use in mains rehabilitation (WRc). There is a clear need for a similar code of practice for factory-applied products and for site application with respect to water storage tanks.

A statutory programme of post application field-testing using suitable screening techniques should be adopted. A minimum requirement would be a GC-MS scan analysis, as used in

BS 6920 part 4. It is unreasonable to expect conditions during bench tests or pilot rig tests to be consistent with routine field application. Leachates from such tests may provide a useful indication of the types of compounds leached but this may not be representative of the quantities leached under field conditions in the short or long term.

Many proprietary ingredients are a mixture of isomers and may contain oligomeric blends. Thus attributing toxicological properties based on specific pure components may be unreliable as it takes no account of exposure to multiple compounds. The potential impact of mixtures possibly resulting in synergistic effects must be the subject of future investigation. The chemical analysis of these products is severely hampered by the use of generic CAS numbers and polymer naming protocol based on US EPA accepted guidelines which give an inadequate chemical description of what may be impure mixtures.

There appears to be little consideration that chlorination by-products, from the curing process of site applied materials, may impact on endocrine activity. Consequently, there appears to be few references in the literature for the prevalence of these putative by-products, their suspected identity or methods for their analysis.

Future research needs have recently been identified by the DETR Interdepartmental Group on Endocrine Disrupters and included the effects on female reproductive health and non-reproductive effects in humans in line with the EU research funding priorities. There are plans to commission a literature review to cover the latter area and this may lead to the funding of basic research. The DETR Group has published a summary of the research being supported on endocrine disrupters (DETR 1999).

Many investigations have been carried out in the area of food packaging and human exposure to suspected endocrine disrupters. We suggest a review of that area of research may be helpful when considering exposure from materials in contact with drinking water.

There are indications that there may be EC funding available possibly through the FRAMEWORK VI programme for the updating of validated test methods, quantifying exposure levels for example, from food. There are expected to be strong moves from the EU to encourage the use of alternatives to compounds identified as endocrine disrupters particularly as difficulties are foreseen in setting limit values.

Most recently a draft EU priority list has been produced for the European Commission's Environment Directorate "*Towards the establishment of a priority list of substances for further evaluation of their role in endocrine disruption*" by consultants BKH Consulting engineers (Delft, The Netherlands) and TNO Nutrition and Food Research (Zeist, The Netherlands) (Goshart and Okkerman 2000). The list consisted of 66 compounds which were produced from an initial candidate list of 533 substances. A list of 147 substances were evaluated by a group of experts. Information on the endocrine disrupting effects on both human health and wildlife were documented and assessed in the report. The reception to the report from both industry and environmental groups has been very mixed as highlighted by a recent ENDS report (ENDS 2000). Also CSTE published an Opinion on the report which was quite critical particularly with respect to the omission of dose-response/potency considerations when selecting candidates for the list. The criteria of production volume and environmental persistence, as applied in the report, were viewed as too restrictive. The European Chemical Industry Council (CEFIC) through the Endocrine Modulator Study Group (EMSG) has commented itself and supplied data to the CSTE for consideration (CSTE 2000). Industrial chemicals included on the priority list and assigned "of high exposure concern" include butylbenzyl phthalate, di-n-butyl phthalate and di-(2-ethylhexyl) phthalate, styrene, bisphenol-A and those given a "medium" status included 4-tert-octylphenol and nonylphenol. It may be sometime, however, before such a list will utilise dose response data essential for reliable risk assessments to be produced for materials in contact with drinking water. Such a list could be more useful if it included some form of environmental endocrine disrupter index which could incorporate exposure potential (production volume and environmental persistence) and estrogenic potency.

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## **EXPOSURE TO ENDOCRINE DISRUPTERS VIA MATERIALS IN CONTACT WITH DRINKING WATER PHASE 2**

### **SAMPLING PROGRAMME**

The original sampling plans were to investigate the likely endocrine disrupting potential of different approved materials including:

- Butyl linings
- Glass reinforced plastic
- Polyurethane coatings
- Bitumin coatings
- Epoxy resins

Only one water type would be used for the study although water hardness may have an effect on the leaching characteristics.

The conditions at the site were to be monitored for:

- time of day to avoid bias in sampling
- the water temperature as this may affect leaching rates
- chlorine levels in the water as this may affect by-product or artefact formation.

Details about the installation site would include where possible water throughput, tank dimensions, numbers of people exposed to risk and where possible a photographic record of the site would be taken.

Both acute and chronic risk of exposure to the potential endocrine disrupting substances was to be assessed. It was hoped to study at least three different contractors for each type of relining product to evaluate the effect of the relining process on the risk of exposure to potential endocrine disrupters.

The Water Quality Centre contacted a number of local authorities and water treatment companies to assist with the research project.

From the outset there were difficulties enlisting the help of water treatment companies, because many felt that the Water Quality Centre would be acting as a policing body, vetting their application procedures (e.g. cure times and temperatures etc.). Despite extensive efforts to develop this partnership, we only had success with two water treatment companies and one local authority. This had the result of severely limiting the scope of the proposed study.

Three local authorities expressed an interest in supporting the research project. Two of these specified that suitable sites would be identified for us to witness site applications, tank refurbishment and replacement. Unfortunately we were contacted by both authorities informing us in one instance that no funds were available to carryout any remedial works that had been identified and in the other instance that the available funds were to be used for another project.

The majority of the water treatment companies contacted stated that in most cases old tanks are replaced with new tanks, or alternatively they are re-lined with butyl liners. Due to this we were severely restricted to testing two butyl liners and two GRP tanks.

## **Sampling Programme**

A structured programme was adopted for sampling. For each site identified the following samples were taken:

### ***Pre-Installation or lining***

1. Incoming mains sample (**Inlet sample**) - This sample was taken to establish the quality of the supply entering the building.
2. Dip sample from tank (**Tank sample**) - sample taken to establish the quality of the water supply in the tank prior to re-lining or replacement.
3. Near point sample from tank (**Consumer tap**) - Sample taken from first draw off point from tank. Where possible this sample was taken from a point which presented maximum consumer exposure, for example a food preparation area.

### ***Post-installation or lining***

Following the re-lining or replacement of the tanks further samples (as above) were taken for analysis. In all cases a dip sample was taken from the tank, plus a sample from the nearest draw off point. In instances where the tank was re-lined within one working day, only one incoming mains sample was taken. The reason for this was because we did not expect the chemical composition of the supply to change significantly within the short time period involved.

## ANALYTICAL PROGRAMME

GRP tanks are made from a resin solution, usually by dissolving an unsaturated polyester resin in styrene which is used to make a polyester moulding compound by mixing together the resin solution, fillers, thickening agents and other manufacturing additives.

After the resin has been moulded, the product is cured either at room temperature (Lay-up GRP products) or at high temperatures (Sheet Moulding Compound GRP). Most domestic / small water tanks are manufactured using Lay-up GRP and bigger industrial / multi-occupancy housing water tanks are manufactured using sheet mouldings of GRP, bolted together with rubber seals.

All forms of GRP can be subject to osmosis with water over time. In poorly made water tanks, the water can travel to the inside of the body of the GRP material and form blisters, de-laminating the surface of the tank resulting in deteriorating water quality over time. This can cause significant water quality problems with poorly made Lay-up GRP tanks if pockets of uncured resin / styrene are dissolved by the ingress of water, the leached material may then diffuse out to the main body of water in the tank.

Styrene is included as a potential endocrine disrupter in the European Commission list of probable endocrine disrupters but is not included in the EPA list of probable endocrine disrupters (ED's). As GRP products have the potential to significantly leach styrene into water and GRP tanks are the most commonly used type of water tank material styrene is included in this study.

Butyl rubber sheeting can be produced as a synthetic rubber membrane. An elastomer produced for example from the copolymerisation of iso-butylene and isoprene. Also, *cis*-polybutadiene rubber (BR), styrene and butadiene copolymer rubber (SBR), or ethylene-propylene monomer (EPM) and natural rubber simply *cis*-polyisoprene. The appropriate degree of cross-linking (vulcanisation) imparts the desired characteristics of elasticity and durability. The need for plasticiser additives, that are liable to leaching, is removed. This makes these materials ideal for applications such as liners for potable water tanks as well as fishponds.

GC-MS scan was primarily applied to identify potential endocrine disrupting compounds and other substances potentially leaching from materials under investigation. From the review of the WRc report and latest findings butylbenzophthalate, di-n-butyl phthalate, di-(2-ethylhexyl)phthalate, styrene and bisphenol-A are rated as high exposure concern whilst 4-tert-octylphenol and nonyl phenol were regarded as medium exposure concern. Based on this information an analysis programme was set primarily to measure these target analytes. Total organic carbon analysis was included as part of the analysis programme to indicate the presence of any organic material not identified by either the target analysis or GC-MS scan.



The analysis was broken up into a series of suites according to suitable methodology and comprised the following:

Suite1.	<b>Alkyl Phenols</b>	Acronym
	Nonyl phenol	NP
	Octyl phenol	OP
Suite2.	<b>Bisphenols</b>	
	Bisphenol-A	BisA
	Bisphenol-A diglycidyl ether	BADGE
	Bisphenol-F	BisF
	Bisphenol-F diglycidyl ether	BFDGE
Suite3.	<b>GC-MS scan</b>	GC-MS
Suite4.	<b>Total Organic Carbon</b>	TOC
Suite5.	<b>Phthalates</b>	
	bis 1-octylphthalate	BOP
	bis nonylphthalate	BNP
	bis 2-ethylhexylphthalate	BEHP
	bis ethylphthalate	BEP
	di-n-butylphthalate	DBP
	bis iso-butylphthalate	BIBP
	benzylbutylphthalate	BBP
	bis hexylphthalate	BHP
	bis methylphthalate	BMP
Suite6.	<b>Styrene</b>	ST

Suites 1 and 5 were analysed under the same methodology.

## Site Parameters and Product Type

Site 1	Pre-installation			Post-installation		
	Inlet Sample	Tank Sample	Consumer Tap	Inlet Sample	Tank Sample	Consumer Tap
Date of sampling	17/09/00	17/09/00	17/09/00	05/10/00	05/10/00	05/10/00
Time of sampling	08:30	08:35	08:50	16:00	15:45	14:30
Water temperature °C	14.5	14.9	14.9	14.6	14.9	15.3
Free chlorine mg/l	0.16	0.15	0.15	0.15	0.16	0.16
Total chlorine mg/l	0.22	0.20	0.20	0.24	0.26	0.26

Type of building	Block of flats
People using building	200 residents
Tank capacity (pre- refurbishment)	2 x 7200 litre linked concrete tanks
Tank capacity (post-refurbishment)	2 x 3000 litre linked GRP tanks
Dimensions of refurbished tank	2.5m x 1.5m x 1.5mm. Each tank installed within existing concrete tank
Refurbishment product	Replacement GRP tank

Site 2	Pre-installation			Post-installation		
	Inlet Sample	Tank Sample	Consumer Tap	Inlet Sample	Tank Sample	Consumer Tap
Date of sampling	13/10/00	13/10/00	13/10/00	NT	13/10/00	13/10/00
Time of sampling	09:15	09:00	09:05	NT	15:15	15:30
Water temperature °C	12.7	13.8	13.9	NT	12.4	12.7
Free chlorine mg/l	0.16	0.07	0.10	NT	0.27	0.27
Total chlorine mg/l	0.21	0.07	0.11	NT	0.27	0.27

NT - sample not taken as refurbishment carried out within short time-scale. Source water parameters not expected to change significantly.

Type of building	Office with staff kitchen
People using building	100 staff
Tank capacity (pre- refurbishment)	1000 litre bitumin lined galvanised tank
Tank capacity (post-refurbishment)	1000 litre butyl rubber relining
Dimensions of refurbished tank	1.5m x 1.0m x 1.0m
Refurbishment product	Butyl rubber liner

Site 2 pre-installation



Site 2 post-installation



**Site 3**

	Pre-installation			Post-installation		
	Inlet Sample	Tank Sample	Consumer Tap	Inlet Sample	Tank Sample	Consumer Tap
Date of sampling	24/10/00	24/10/00	24/10/00	03/11/00	03/11/00	03/11/00
Time of sampling	10:50	10:35	11:40	14:05	14:50	15:45
Water temperature °C	11.1	10.6	12.9	10.9	10.6	11.9
Free chlorine mg/l	0.07	0.01	0.02	0.07	0.09	0.07
Total chlorine mg/l	0.08	0.02	0.03	0.1	0.11	0.08

Type of building	School
People using building	125 staff and pupils
Tank capacity (pre- refurbishment)	Not known
Tank capacity (post-refurbishment)	1589 litres GRP tank
Dimensions of refurbished tank	1.52m x 1.11m x 0.91m
Refurbishment product	Replacement GRP tank

Site 3 post -installation



**Site 4**

	Pre-installation			Post-installation		
	Inlet Sample	Tank Sample	Consumer Tap	Inlet Sample	Tank Sample	Consumer Tap
Date of sampling	19/11/00	19/11/00	19/11/00	NT	19/11/00	19/11/00
Time of sampling	08:50	09:00	09:10	NT	17:00	17:15
Water temperature °C	10.9	12.1	13.1	NT	10.8	10.8
Free chlorine mg/l	0.51	0.26	0.26	NT	0.02	0.02
Total chlorine mg/l	0.63	0.30	0.30	NT	0.05	0.05

NT - sample not taken as refurbishment carried out within short time-scale. Source water parameters not expected to change significantly

Type of building	Library
People using building	26 staff
Tank capacity (pre- refurbishment)	2250 litre butyl lined galvanised tank
Tank capacity (post-refurbishment)	2250 litre butyl lined galvanised tank
Dimensions of refurbished tank	1.82m x 1.22m x 1.22m
Refurbishment product	Butyl rubber liner

## ANALYTICAL METHODS

### 1. Total Organic Carbon

The method used for this analysis is based upon "The instrumental determination of total organic carbon, total oxygen and related determinants" (1979) (ISBN 0 11 751458 6), and uses the O.I Model 700 Carbon Analyser.

Samples were collected in 125 ml amber plastic bottles. Samples are kept in the refrigerator if analysis is not carried out immediately.

Samples (5ml) were treated with phosphoric acid (5%, 400µl) and purged with nitrogen to remove any inorganic carbon present. The samples were then treated with sodium persulphate solution (10%, 1.0 ml) at 100°C to convert any organic carbon in the sample into carbon dioxide and transferred with nitrogen onto the trap. The carbon dioxide was trapped and concentrated on an absorbent, which was subsequently rapidly heated to release it for measurement by a non-dispersive, near infra-red detector.

It should be noted that some loss of volatile organic compounds could occur during the initial purging process; however, the non-purgeable organic carbon content was generally acceptable.

Total organic carbon concentrations were calculated from a four point calibration curve which was determined daily using a stock solution of anhydrous potassium phthalate. A qualified service engineer checks the performance of the O.I. Model 700 Carbon analyser every three months.

An analytical quality control sample of known concentration was run at a random position within every batch of twenty samples.

Checks on the instrument response, using a known standard, and drift were also carried out.

The test method is included in the UKAS Accreditation Schedule for our laboratory.

#### Performance data.

	Concentration (µg/l)	Standard deviation (µg/l)	Degrees of freedom	Bias %
Low standard	2000	47	17	-1.07
High Standard	8000	78	12	+0.03
Sample	1200	67	13	

Limit of detection - 51 µg/l  
Reporting limit - 100 µg/l

Spiking recovery - 100.6%

## 2. GC-MS Scan

The method described in this report is suitable for the identification of unspecified organic substances present in the leachates of materials that have been placed in contact with water. The samples in this report have been tested in accordance with BS6920-4: 1997, Method of test - The GC-MS identification of water leachable organic substances (Wq<sup>c</sup> Method Code 429).

Samples are collected in 2 litre glass bottles. Samples are kept in the refrigerator if analysis is not carried out immediately.

The sample is de-chlorinated by adding 2 ml of ascorbic acid solution (0.4%) for each litre of sample.

A portion of sample (1 litre) was measured into a Teflon separating funnel (2 litres) and spiked with 100µl of the internal deuterated standards (see table 1) spiking solution. The sample was then adjusted to pH 2.0 using sulphuric acid solution.

The sample was extracted with 2 x 100 ml of DCM. The extracts were combined, frozen for 1 hour and filtered through sodium sulphate to remove ice crystals and any residual water. The dried extract was evaporated to 5 ml using a Kuderna-Danish apparatus and finally reduced to 200 µl using a stream of dry nitrogen.

GC-MS scan analysis was carried out using quadrupole GC-MS fitted with a DB-1 60 metre column at an initial temperature of 35°C for 6 minutes then raised to 300°C at 8°C per minute where it was held for 21 minutes. The detector was operated in electron impact ionisation mode.

Compounds were identified using a combination of manual interpretation of spectra, spectral library searching and comparing retention times with known standards.

**Note** - Identification of compounds is tentative only. Identification requires confirmation by comparison with authentic reference standards

Compound concentrations were calculated relative to the nearest eluting deuterated analogue.

**Table 1**

Typical Retention time (mins)	Internal Standard Reference Number	Internal Standard	Concentration µg/l
7.55	1	d <sub>5</sub> -benzene	2.0
12.99	2	d <sub>5</sub> -chlorobenzene	2.0
13.79	3	d <sub>10</sub> -p-xylene	1.0
16.76	4	d <sub>5</sub> -phenol	8.0
21.54	5	d <sub>8</sub> -naphthalene	1.0
27.36	6	d <sub>21</sub> -BHT	8.0
28.76	7	d <sub>34</sub> -hexadecane	1.0
31.56	8	d <sub>10</sub> -phenanthrene	2.0
41.37	9	d <sub>62</sub> -squalane	8.0

### 3. Styrene

The principle of the method is to spike the sample with internal standards and analyse the sample using headspace gas chromatography with a quadrupole mass spectrometer detector operating in SIM mode.

Samples were collected in 2 litre glass bottles. Samples are kept in the refrigerator if analysis is not carried out immediately.

Spike the sample (1000 ml) with deuterated benzene internal standard working solution. A sub-portion of the sample (5 ml) is transferred to a 22 ml headspace vial and capped immediately. The vial is placed onto the headspace autosampler unit connected to a gas-chromatograph fitted with a mass selective detector. Each vial is heated to 80 °C and equilibrated for 22 minutes prior to injection onto an HP 5MS column (60m x 0.25mm ID x 1µm film). The initial temperature is 35°C for 6 minutes, then ramp the temperature to 200°C at 10°C per minute and hold final temperature for 4 minutes. The quantitation is by reference to the internal standard using a multi-point calibration.

An analytical quality control sample of known concentration was run at a random position within every batch of twenty samples.

This compound has been validated according to DWI CPP (formally CCM) requirements to BS6290 guidelines.

#### Performance Data

Validation Standard µg/l	Amount (µg/l)			Mean µg/l	Mean Difference µg/l	Standard Deviation µg/l
	Val 1	Val 2	Val3			
50.0	50.0	50.5	50.2	50.2	-0.2	0.3
10.0	9.2	9.4	9.6	9.4	0.6	0.2
5.0	4.6	4.6	4.5	4.6	0.4	0.1
1.0	0.9	0.9	0.9	0.9	0.1	0.0
0.0	0.1	0.0	0.0	0.0	0.0	0.0

LOD – 0.1 µg/l



#### 4. Phthalates and alkyl phenols

The principle of this method is to spike the sample with internal standard and extract and concentrate the sample by liquid-liquid extraction. The concentrated extracts are then analysed using gas chromatography with mass spectrometer detector operating in scan mode.

Samples are collected in 2 litre all glass bottles. Samples are kept in the refrigerator if analysis is not carried out immediately.

To 1 litre of sample was added 2 ml of ascorbic acid solution (0.4%). The sample was spiked with internal standard (benzyl benzoate) solution (50 µl). The sample was transferred to a 2 litre Teflon funnel and adjusted to pH 2 with sulphuric acid. The sample was extracted with 2 x 100 ml of DCM. The extracts were combined and frozen for 1 hour. The extracts were filtered through sodium sulphate to remove the ice and residual water. The extracts were evaporated to 5 ml using a Kuderna-Danish apparatus and then to 200 µl using a stream of nitrogen.

The extracts were analysed by gas chromatography (using a 60 metre DB1 column with an initial temperature of 35°C for 6 minutes then ramping the temperature to 300°C at 8°C per minute) and a mass spectrometer detector operating in scan mode.

Quantitation of results was by reference to the internal standards using a multi-point extracted calibration.

An analytical quality control sample of known concentration was extracted and run at a random position within every batch of twenty samples.

These compounds have been validated according to DWI CPP (formally CCM) requirements to BS6290 guidelines.

#### Performance data

Compound	RT	Cal 0.2						Bias
		VAL 1	VAL 2	VAL 3	Mean(µg/l)	SD (µg/l)	LOD (µg/l)	
Bis 1 octyl phthalate	39.97	0.20	0.26	0.19	0.22	0.04	0.18	8.3
Bis nonyl phthalate	39.36	0.19	0.26	0.19	0.21	0.04	0.19	6.7
Bis (2-ethylhexyl) phthalate	38.23	0.00	0.11	0.22	0.17	0.08	0.36	-17.5
Bis ethyl phthalate	26.69	0.19	0.24	0.20	0.21	0.03	0.12	5.0
Bis butyl phthalate	31.75	0.19	0.24	0.20	0.21	0.03	0.12	5.0
Bis iso butyl phthalate	30.59	0.21	0.25	0.17	0.21	0.04	0.19	5.0
4 octyl phenol	29.38	0.20	0.11	0.11	0.14	0.05	0.24	-30.0
Benzyl butyl phthalate	36.04	0.18	0.29	0.21	0.23	0.06	0.26	13.3
Bis hexyl phthalate	36.10	0.14	0.21	0.13	0.16	0.04	0.20	-20.0
Bis methyl phthalate	24.46	0.19	0.21	0.19	0.20	0.01	0.05	-1.7
Total nonyl phenol		0.24	0.40	0.25	0.30	0.09	0.42	48.1

## 5. Bisphenols

The principle of this method is that samples are spiked with internal standard and then extracted by liquid-liquid extraction. The resultant extracts are analysed by liquid chromatography with a mass spectrometer detector (LC-MS) operated in positive ion APCI mode using SIM.

Samples are received in 2 litre all glass bottles. Samples are kept in the refrigerator if analysis is not carried out immediately.

The samples were dechlorinated. To 1 litre of sample was added 2 ml of ascorbic acid solution (0.4%). A portion of sample (1 litre) was spiked with 100 µl of the internal deuterated standard (D5-atrazine) solution. The sample was transferred to a Teflon 2 litre flask and was extracted with 2 x 100 ml of DCM. The extracts were combined, frozen for 1 hour and filtered through sodium sulphate to remove ice crystals and any residual water. The dried extract was evaporated to 5 ml using a water bath set at 85°C. The extract was transferred to a test tube and placed in the Zymark Turbovap and gently evaporated to dryness using a stream of nitrogen. The extract was re-solubilised with methanol /water solution (60% v/v).

The extracts were analysed by liquid chromatography with a mass spectrometer detector operating in SIM mode.

Quantitation is by reference to the internal standard using a multi-point extracted calibration.

An analytical quality control sample of known concentration was extracted and run at a random position within every batch of twenty samples.

These compounds have been validated according to DWI CPP (formally CCM) requirements to BS6290 guidelines.

### Performance data

	Concentration µg/l	Mean µg/l	SD µg/l	RSD %	LOD µg/l	Bias %
Bisphenol-A	2.0	1.90	0.71	37.20	3.29	-5.00
Bisphenol-F	2.0	1.84	0.09	5.01	0.43	-8.30
BADGE	2.0	1.95	0.35	18.10	1.64	-2.50
BFDGE	2.0	2.35	0.07	3.01	0.33	17.50

## ANALYTICAL RESULTS

### 1. Site 1 - Concrete tanks replaced by new GRP tank

#### Target Analytes

Analyte	Pre-installation			Post-installation		
	Inlet Sample mg/l	Tank Sample mg/l	Consumer Tap mg/l	Inlet sample mg/l	Tank Sample mg/l	Consumer Tap mg/l
TOC	1.9	1.9	1.9	2.1	2.2	2.2

Analyte	Pre-installation			Post-installation		
	Inlet Sample µg/l	Tank Sample µg/l	Consumer Tap µg/l	Inlet sample µg/l	Tank Sample µg/l	Consumer Tap µg/l
Styrene	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
BOP	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
BNP	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
BEHP	<0.4	<0.4	<0.4	0.4	<0.4	<0.4
BEP	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
DBP	<0.2	<0.2	<0.2	0.2	<0.2	<0.2
BIBP	<0.2	<0.2	<0.2	0.2	<0.2	<0.2
BBP	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
BHP	<0.2	<0.2	<0.2	0.3	<0.2	<0.2
BMP	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
OP	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
NP	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BisA	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
BisF	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BADGE	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7
BFDGE	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4

*Comment* - The presence of phthalates near their limit of detection in the post-installation inlet sample is probably the result of laboratory contamination, not from the sample and is not a cause for concern. This could not be verified by re-analysis as there was no sample remaining.

## GC-MS scan tables pre-installation

### Blank

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.56	ethyl acetate	7.7	2
2	6.79	trimethyloxirane	1.8	2
3	8.16	pentenol	0.7	2
4	11.53	dimethyloxirane	2.0	2
5	26.07	dimethylphthalate	4.0	6
6	30.72	butylbenzenesulfonamide	4.7	8

### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.72	trimethyloxirane	2.6	2
2	7.28	methylbutanone	5.3	2
3	8.04	pentenol	1.3	2
4	8.36	bromodichloromethane	1.3	2
5	10.87	dibromochloromethane	5.5	2
6	13.51	bromoform	3.0	2
7	13.59	methylbromobutanol	0.6	2
8	13.72	dibromoacetonitrile	0.8	2
9	20.59	benzoic acid	0.5	6

*Comment* -Compounds 1,3 from blank. Compounds 4,5,6,7,8 are disinfection by-products

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.72	trimethyloxirane	2.2	2
2	7.29	methylbutanone	4.8	2
3	8.04	pentenol	1.4	2
4	8.36	bromodichloromethane	1.4	2
5	10.87	dibromochloromethane	5.9	2
6	13.51	bromoform	3.4	2
7	13.72	dibromoacetonitrile	1.0	2
8	39.69	bis(2-ethylhexyl)phthalate	1.1	9
9	53.18	unknown:71,73,55,100	8.5	9

*Comment* - Compounds 1,3 from blank. Compounds 4,5,6,7 are disinfection by-products. Compound 8 is a potential concrete additive. Compound 2 is from inlet water.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.69	trimethyloxirane	1.7	2
2	7.25	methylbutanone	4.4	2
3	8.02	pentenol	1.1	2
4	8.34	bromodichloromethane	1.6	2
5	10.86	dibromochloromethane	5.8	2
6	13.51	bromoform	3.1	2
7	13.71	dibromoacetonitrile	0.6	2
8	31.92	isobutylphthalate	0.5	8
9	39.67	bis(2-ethylhexyl)phthalate	0.6	9

*Comment* - Compound 1,3 from blank. Compound 2 from inlet water. Compound 4,5,6,7 disinfection by-products. Compound 8 contamination. Compound 9 potentially a concrete additive. This compound may pose a long-term low dose exposure risk of endocrine disruption but quantitation by target analysis (with the more accurate quantitation) did not verify its presence.

### GC-MS scan tables post-installation

#### Blank

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.71	cyclohexane	6.3	2
2	7.91	n-heptane	4.0	2
3	9.55	toluene	0.6	2
4	11.47	4-hydroxy-4-methylpentan-2-one	1.1	2
5	30.9	isobutylphthalate	<1.0	8

#### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.69	cyclohexane	20.7	2
2	7.27	dichloroacetonitrile	0.8	2
3	7.38	dichlorobromomethane	4.3	2
4	7.85	n-heptane	9.9	2
5	9.50	toluene	1.5	2
6	9.96	dibromochloromethane	16.4	2
7	12.66	tribromomethane	12.7	2
8	12.87	dibromoacetonitrile	2.6	2
9	19.67	benzoic acid	8.5	6
10	30.90	isobutyl phthalate	0.5	8

*Comment* - Compounds 1,4,5,10 are from the blank. Compounds 2,3,6,7,8 are disinfection by-products.

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.69	cyclohexane	6.7	2
2	7.39	dichlorobromomethane	0.9	2
3	7.85	n-heptane	3.5	2
4	9.50	toluene	0.8	2
5	9.97	dibromochloromethane	3.6	2
6	11.42	4-hydroxy-4-methylpentan-2-one	4.0*	2
7	12.54	1 methoxy 2 propylester of acetic acid	1.7	2
8	12.66	tribromomethane	2.5	2
9	12.88	dibromoacetonitrile	0.5	2
10	13.39	xylene	0.8	2
11	16.12	1-(2-methoxy-1-methylethoxy)-2-propanol	2.5	2
12	16.21	1-(2-methoxy-1-methylethoxy)-2-propanol	2.4	2
13	16.33	unknown:101,57,73,45	0.6	2
14	16.45	1-(2-methoxypropoxy)-2-propanol	2.8	2
15	17.42	1-phenylethanone	0.6	2
16	19.72	benzoic acid	3.5	6
17	22.78	1-phthalanone	1.9	8
18	35.36	abieta-8,11,3-trien-7-one	11.1	9
19	36.96	abieta-8,11,3-trien-7-one	12.4	9
20	35.98	unknown:204,148,130,187	10.9	9
21	36.96	triphenylphosphate	7.6	9
22	38.58	di-(2-ethylhexyl)phthalate	0.5	9
23	48.35	beta-stigmasterol	0.6	9

\* blank subtracted value

*Comment* - Compound 1,3,4,6 are from the blank. Compounds 2,5,8,9 are disinfection by-products. Compound 16 is from the inlet water. Compounds 11,12 14 are isomers of dipropylene glycol mono methyl ether a solvent commonly used in coatings and adhesives. Compound 17 is also known as phthalic anhydride a precursor to phthalic acid and its presence is a concern as it should hydrolyse in water to phthalic acid. The extraction of phthalic acid may not have been efficient and an alternative method for the extraction and analysis would be required for the target analysis of this compound to provide a more reliable quantitation and estimate of risk due to the presence of potential endocrine disrupters. Compound 13 is tentatively di-sec-butylacetal, compound 15 is acetophenone a catalyst for the polymerisation of olefins.

Compound 18,19 are isomers probably from the material either as an impurity in the raw material or as a reaction by-product from abietic acid or methyl abietate (used in resin manufacture). The compounds apparently leaching from the material decrease in concentration in the consumer tap sample. Compound 20 is possibly a C9 alkyl benzene.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.69	cyclohexane	10	2
2	7.38	dichlorobromomethane	0.9	2
3	7.85	n-heptane	4.4	2
4	9.49	toluene	0.9	2
5	9.96	dibromochloromethane	3.7	2
6	11.41	4-hydroxy-4-methylpentan-2-one	4.7*	2
7	12.54	1-methoxy-2-propylester of acetic acid	1.9	2
8	12.66	tribromomethane	2.4	2
9	12.86	dibromoacetonitrile	0.5	2
10	13.39	xylene	0.9	2
11	16.11	1-(2-methoxy-1-methylethoxy)-2-propanol	2.9	2
12	16.20	1-(2-methoxy-1-methylethoxy)-2-propanol	2.7	2
13	16.33	unknown:101,57,73,45	0.8	2
14	16.44	1-(2-methoxypropoxy)-2-propanol	3.2	2
15	17.42	1-phenylethanone	0.7	2
16	19.67	benzoic acid	1.0	6
17	35.36	abieta-8,11,3-trien-7-one	0.9	9
18	35.52	abieta-8,11,3-trien-7-one	1.1	9
19	35.97	unknown:204,148,130,187	0.5	9
20	38.59	di-(2-ethylhexyl)phthalate	0.8	9
21	48.37	beta-stigmasterol	0.9	9

\* blank subtracted value

*Comment* - Compound 1,3,4,6 are from the blank. Compounds 2,5,8,9 are disinfection by-products. Compound 16 is from the inlet water. Compounds 11,12 14 are isomers of dipropylene glycol mono methyl ether a solvent commonly used in coatings and adhesives. Compound 13 is tentatively di-sec-butylacetal. Compound 15 is acetophenone a catalyst for polymerisation of olefins. Compound 16 is from the inlet water. Compound 17,18 are isomers probably from material either as impurity in raw material or as a reaction by-product from abietic acid or methyl abietate (used in resin manufacture). These compounds decrease in concentration in the consumer tap sample. Compound 19 is possibly a C9 alkyl benzene. The presence of potential endocrine disrupting compound ethylhexyl phthalate is low and would not be considered a short term exposure risk. The presence of stigmasterol is more of a concern. It is a near analogue of the oestrogens and would be expected to have high endocrine disrupting activity. It's presence in these samples is not easily explained and warrants further investigation.

## Site 2 - Bitumen coating replaced with butyl liner

	Pre-installation			Post-installation		
Analyte	Inlet Sample mg/l	Tank Sample mg/l	Consumer Tap mg/l	Inlet sample mg/l	Tank Sample mg/l	Consumer Tap mg/l
TOC	0.9	1.0	0.9	NT	1.0	0.9

	Pre-installation			Post-installation		
Analyte	Inlet Sample µg/l	Tank Sample µg/l	Consumer Tap µg/l	Inlet sample µg/l	Tank Sample µg/l	Consumer Tap µg/l
Styrene	<0.1	<0.1	<0.1	NT	<0.1	<0.1
BOP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
BNP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
BEHP	<0.4	0.4	<0.4	NT	<0.4	<0.4
BEP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
DBP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
BIBP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
BBP	<0.3	<0.3	<0.3	NT	<0.3	<0.3
BHP	<0.2	<0.2	<0.2	Nt	<0.2	<0.2
BMP	<0.1	<0.1	<0.1	NT	<0.1	<0.1
OP	<0.3	<0.3	<0.3	NT	<0.3	<0.3
NP	<0.5	<0.5	<0.5	NT	<0.5	<0.5
BisA	<3.3	<3.3	<3.3	NT	<3.3	<3.3
BisF	<0.5	<0.5	<0.5	NT	<0.5	<0.5
BADGE	<1.7	<1.7	<1.7	NT	<1.7	<1.7
BFDGE	<0.4	<0.4	<0.4	NT	<0.4	<0.4

NT - Sample not taken

*Comment* - Pre and post installation inlet sample is the same as the timescale for installation was short.

## GC-MS scan tables pre-installation

### Blank

Compound N <sup>o</sup>	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.80	cyclohexane	7.4	2
2	8.99	n-heptane	4.4	2
3	10.68	toluene	0.7	2
4	12.58	4-hydroxy-4-methyl-2-pentanone	1.5	2



### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.79	cyclohexane	5.2*	2
2	8.53	bromodichloromethane	1.8	2
3	8.98	heptane	6.4	2
4	10.66	toluene	0.7	2
5	11.14	dibromochloromethane	1.1	2

*Comment* - Compounds 1,3,4 are from the blank. Compounds 2, 5 are disinfection by-products.

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.79	cyclohexane	7.0	2
2	8.52	bromodichloromethane	1.3	2
3	8.97	heptane	3.9	2
4	10.68	toluene	0.6	2
5	11.14	dibromochloromethane	0.9	2
6	12.58	4-hydroxy-4-methyl-2-pentanone	0.5	2
7	32.44	isobutyl phthalate	5.2	8

*Comment* - Compounds 1,3,4,6 are from the blank. Compounds 2, 5 are disinfection by-products.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.80	cyclohexane	7.5	2
2	8.55	bromodichloromethane	1.4	2
3	8.99	heptane	4.5	2
4	10.70	toluene	0.7	2
5	11.15	dibromochloromethane	0.9	2

*Comment* - Compounds 1,3,4 are from the blank. Compounds 2, 5 are disinfection by-products.

**GC-MS scan tables post-installation****Tank sample**

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.68	cyclohexane	2.5	2
2	8.92	unknown:91,76,92,78	4.5	2
3	8.99	heptane	1.6	2
4	10.68	toluene	14.8*	2
5	11.15	dibromochloromethane	1.0	2
6	13.11	unknown:184,43,141,127	1.1	2
7	18.09	phenylethanal	0.8	2
8	21.04	benzoic acid	0.6	6
9	23.71	N,N dibutylformamide	0.7	6
10	32.46	isobutyl phthalate	0.5	8

*Comment* - Compounds 1,3,4 are from the blank although level of compound 4 suggests it is also a solvent used in the relining. Compound 2 is probably a chlorinated nitrogen product, possibly chloramine. Compound 6 is possibly an iodo compound (tentatively ICH<sub>2</sub>OCH<sub>3</sub>) although at trace levels of unknown origin. Compounds 7,8,9 are probably from the product.

**Consumer tap sample**

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.78	cyclohexane	8.9	2
2	8.54	bromodichloromethane	1.1	2
3	8.96	heptane	5.0	2
4	10.67	toluene	0.7	2
5	11.14	dibromochloromethane	0.6	2

*Comment* - Compounds 1,3,4 from the blank. The other two are disinfection by-products.

**Site 3 - Galvanised tank replaced with GRP tank**

	Pre-installation			Post-installation		
Analyte	Inlet Sample mg/l	Tank Sample mg/l	Consumer Tap mg/l	Inlet sample mg/l	Tank Sample mg/l	Consumer Tap mg/l
TOC	0.6	0.6	0.6	0.6	0.7	0.6

	Pre-installation			Post-installation		
Analyte	Inlet Sample µg/l	Tank Sample µg/l	Consumer Tap µg/l	Inlet sample µg/l	Tank Sample µg/l	Consumer Tap µg/l
Styrene	<0.1	<0.1	<0.1	<0.1	0.5	<0.1
BOP	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
BNP	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
BEHP	0.4	0.7	0.7	0.4	1.0	0.5
BEP	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
DBP	0.2	0.2	<0.2	<0.2	<0.2	<0.2
BIBP	<0.2	0.2	<0.2	<0.2	<0.2	<0.2
BBP	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
BHP	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
BMP	<0.1	<0.1	<0.1	<0.1	0.9	0.3
OP	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
NP	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BisA	<3.3	<3.3	<3.3	<3.3	<3.3	<3.3
BisF	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
BADGE	<1.7	<1.7	<1.7	<1.7	<1.7	<1.7
BFDGE	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4

## GC-MS scan tables pre-installation

### Blank

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.79	dichloroacetaldehyde	3.1	1
2	7.02	3-methyl-2-butanone	5.7	1
3	7.88	1,2-dichloropropane	1.9	1
4	7.98	1-chloro-2-methyl-2-butene	1.4	1
5	8.11	2,2,3,3-tetramethylbutane	2.4	1
6	9.06	unknown:48,49,50,29	2.1	1
7	11.38	tetrachloroethylene	8.7	2

### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.48	trimethyloxirane	1.4	1
2	6.78	dichloroacetaldehyde	1.6	1
3	7.87	1,2-dichloropropane	2.6	1
4	7.96	1-chloro-2-methyl-2-butene	4.2	1
5	8.11	2,2,3,3-tetramethylbutane	6.0	1
6	10.52	dibromochloromethane	0.9	2
7	11.36	tetrachloroethylene	5.5	2
8	11.58	2,3-dichloro-2-methyl-butane	0.9	2
9	13.03	tribromomethane	2.8	2
10	13.32	dibromoacetonitrile	1.0	2
11	13.64	unknown:	0.6	2
12	25.13	unknown:66,174,46,172	1.0	6

*Comment* - Compound 1 commonly found in blanks. Compounds 2,3,4,5,7 are from the blank. Compounds 6,8,9,10 are disinfection by-products. Compounds 11,12 difficult to identify due to likely co-elution.

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.51	tetramethyloxirane	3.3	1
2	6.84	dichloroacetaldehyde	3.8	1
3	7.05	3-methyl-2-butanone	13.0	1
4	7.92	1,2-dichloropropane	2.8	1
5	8.01	1-chloro-2-methyl-2-butene	2.4	1
6	9.07	unknown:48,49,50,29	2.4	1
7	10.55	dibromochloromethane	0.5	2
8	10.99	unknown:59,43,107,41	1.1	2
9	11.40	tetrachloroethylene	5.1	2
10	11.59	unknown:43,87,58,77	1.3	2
11	13.05	tribromomethane	1.7	2
12	13.14	unknown:59,43,41,151	0.7	2
13	25.13	unknown:66,174,46,172	0.9	6
14	31.83	palmitic acid	0.5	8
15	37.97	bis(2-ethylhexyl)phthalate	0.5	9

*Comment* - Compound 1 commonly found in blanks. Compounds 2,3,4,5 are from the blank. Compounds 7,9,11 are disinfection by-products. Compounds 8,12,13 are difficult to identify co-eluting substance.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.45	tetramethyloxirane	14.8	1
2	7.01	unknown:43,41,86,39	35.0	1
3	7.88	1,2-dichloropropane	2.1	1
4	7.98	1-chloro-2-methyl-2-butene	3.5	1
5	8.11	2,2,3,3-tetramethylbutane	3.9	1
6	9.12	hexan-2-one	0.8	2
7	11.38	tetrachloroethylene	2.1	2
8	13.04	tribromomethane	1.8	2
9	13.13	unknown:59,43,41,151	1.3	2
10	25.14	unknown:66,174,46,172	0.6	6
11	29.79	unknown:57,55,58,43	2.2	8

*Comment* - Compound 1 commonly found in blanks. Compounds 3,4,5,7 are present in the blank. Compound 8 is a disinfection by-product. Compounds 9,10 difficult to identify due to co-elution.

## GC-MS scan tables post-installation

### Blank

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.03	3-methyl-2-butanone	5.2	2
2	7.30	1-chloro-2-propanone	6.5	2
3	11.39	tetrachloroethylene	25.7	2
4	12.74	unknown:93,63,95,49	2.9	2
5	13.42	unknown:83,85,81,36	31.2	2
6	24.74	(1-chloroethyl)benzene	0.6	6
7	31.84	palmitic acid	0.7	8

*Comment* - High levels of contamination possibly originating from the laboratory water purification system. Compounds 4 and 5 were tentatively identified as haloforms, thus likely disinfection by-products or contaminants from the dichloromethane used for analysis.

### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.81	dichloroacetaldehyde	1.2	1
2	7.02	3-methyl-2-butanone	11.8	1
3	7.28	1-chloro-2-propanone	15.1	1
4	10.53	dibromochloromethane	0.8	2
5	11.38	tetrachloroethylene	25.8	2
6	12.73	unknown:93,63,95,49	1.9	2
7	13.04	tribromomethane	1.6	2
8	13.39	unknown:83,85,81,36	12.7	2
9	23.69	unknown:191,160,159,193	5.6	6

*Comment* - Compounds 2,3,5,6,8 are present in the blank. Compounds 1,4,7 are disinfection by-products. Compound 9 is only present in the inlet.

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.81	dichloroacetaldehyde	1.1	1
2	7.02	3-methyl-2-butanone	11.8	1
3	7.28	1-chloro-2-propanone	25.3	1
4	8.77	1,1-dichloro-2-propanone	0.9	1
5	10.53	dibromochloromethane	0.7	2
6	11.38	tetrachloroethylene	22.5	2
7	12.73	unknown:93,63,95,49	3.7	2
8	13.04	tribromomethane	1.5	2
9	13.39	unknown:83,85,81,36	20.5	2
10	18.83	(1-chloroethenyl)benzene	1.4	6
11	21.42	1,2(dichloroethyl)benzene	1.5	6
12	24.73	(1-chloroethyl)benzene	1.7	6
13	37.97	bis(2-ethylhexyl)phthalate	0.6	9

*Comment* - Compounds 2,3,4,6,7,9,12 are present in the blank. Compounds 1,5,8 are disinfection by-products from humic substances from the source water. Compounds 10,11 are chlorinated solvents of unknown origin, possibly disinfection by-products derived from the tank material. Compound 13 is from the tank material.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	7.02	3-methyl-2-butanone	9.8	2
2	7.28	1-chloro-2-propanone	11.4	2
3	11.39	tetrachloroethylene	25.7	2
4	12.74	Unknown:93,63,95,49	2.0	2
5	13.04	tribromomethane	1.8	2
6	13.40	unknown:83,85,81,36	39.5	2
7	18.83	(1-chloroethenyl)benzene	1.8	6
8	21.42	1,2-dichloroethylbenzene	1.9	6
9	23.69	unknown:191,160,159,193	1.6	6
10	24.73	(1-chloroethyl)benzene	1.7	6

*Comment* - Compounds 1,2,3,4,6,10 are found in the blank. Compounds 7,8 are possibly chlorinated humic acid by-products. Compound 5 is disinfection by-product. Compound 9 is from the inlet water.

**Site 4 - Butyl lined galvanised tank relined with butyl rubber liner**

**Target Analytes**

	Pre-installation			Post-installation		
Analyte	Inlet Sample mg/l	Tank Sample mg/l	Consumer Tap mg/l	Inlet sample mg/l	Tank Sample mg/l	Consumer Tap mg/l
TOC	2.3	2.4	2.3	NT	2.5	2.4

	Pre-installation			Post-installation		
Analyte	Inlet Sample µg/l	Tank Sample µg/l	Consumer Tap µg/l	Inlet sample µg/l	Tank Sample µg/l	Consumer Tap µg/l
Styrene	0.2	<0.1	0.2	NT	<0.1	<0.1
BOP	<0.2	<0.2	0.3	NT	<0.2	<0.2
BNP	<0.2	<0.2	0.3	NT	<0.2	<0.2
BEHP	<0.4	<0.4	0.8	NT	0.4	0.3
BEP	<0.2	<0.2	<0.2	NT	<0.2	<0.2
DBP	<0.2	<0.2	0.2	NT	0.2	<0.2
BIBP	<0.2	<0.2	<0.2	NT	0.3	<0.2
BBP	<0.3	<0.3	<0.3	NT	<0.3	<0.3
BHP	<0.2	<0.2	0.3	NT	<0.2	<0.2
BMP	<0.1	<0.1	0.1	NT	<0.1	<0.1
OP	<0.3	<0.3	0.3	NT	<0.3	<0.3
NP	<0.5	<0.5	<0.5	NT	<0.5	<0.5
BisA	<3.3	<3.3	<3.3	NT	<3.3	<3.3
BisF	<0.5	<0.5	<0.5	NT	<0.5	<0.5
BADGE	<1.7	<1.7	<1.7	NT	<1.7	<1.7
BFDGE	<0.4	<0.4	<0.4	NT	<0.4	<0.4

NT - Sample not taken

*Comment* - Pre and post-installation inlet samples are the same due to the short time-scale between sampling.



## GC-MS scan tables pre-installation

### Blank

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.60	bromodichloromethane	1.0	1
2	8.66	toluene	2.0	2
3	9.14	dibromochloromethane	1.0	2
4	11.98	cyclohexanone	4.2	2
5	12.32	styrene	<1.0	2
6	12.96	2-cyclohexen-1-one	2.2	2
7	16.36	1-phenylethanone	<1.0	2
8	16.91	benzyl alcohol	2.5	2
9	23.74	dimethylbenzene ethanol	<1.0	6
10	29.31	isobutyl phthalate	<1.0	8

### Inlet sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	5.83	tetrachloromethane	1.0	1
2	6.55	dichloroacetonitrile	1.7	1
3	6.60	bromodichloromethane	4.3	1
4	7.31	1,1-dichloro acetone	1.1	1
5	9.15	dibromochloromethane	5.4	2
6	9.28	bromochloroacetonitrile	<1.0	2
7	11.79	tribromomethane	1.0	2
8	11.88	bromomethyl butanol	4.0	2
9	12.03	dibromoacetonitrile	1.3	2
10	14.42	branched aliphatic alcohol	<1.0	2
11	23.86	unknown: 174,66,192,46	<1.0	6
12	29.31	isobutyl phthalate	<1.0	8

*Comment* - Compounds 1,2,4,6,7,8,9 are disinfection by-products. Compound 3,5,12 are present in the blank.

### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.60	bromodichloromethane	2.2	1
2	9.14	dibromochloromethane	2.2	1
3	11.75	tribromomethane	1.0	2
4	19.50	2-phenoxyethanol	<1.0	6
5	23.86	unknown:174,66,192,46	1.0	6
6	29.31	isobutyl phthalate	<1.0	8

*Comment* - Compound 3 is a disinfection by-product. Compound 4 is a plasticiser. Compounds 1,2, 6 are present in the blank.

### Consumer tap sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	5.84	tetrachloromethane	<1.0	1
2	6.61	bromodichloromethane	2.6	1
3	9.15	dibromochloromethane	2.6	2
4	11.76	tribromomethane	1.5	2
5	12.03	dibromoacetonitrile	<1.0	2
6	19.58	benzothiazole	<1.0	6
7	23.86	unknown:174,66,192,46	2.3	6
8	25.37	lauric acid	1.5	6
9	29.31	isobutyl phthalate	<1.0	8
10	35.36	tri(2-butoxyethyl)phosphate	2.4	9
11	36.80	di-octylphthalate	2.8	9

*Comment* - Compounds 1,4,5 are disinfection by-products. Compounds 2,3,9 are from the blank. Compounds 6,10 are plasticisers. Compound 7 identified in inlet sample thus not from the tank.

### GC-MS scan tables post-installation

#### Tank sample

Compound N°	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.60	bromodichloromethane	4.6	1
2	9.14	dibromochloromethane	2.1	2
3	11.75	tribromomethane	<1.0	2
4	19.57	benzothiazole	<1.0	6
5	36.79	di-octylphthalate	9.4	9

*Comment* - Compounds 1,2,3 are disinfection by-products. Compounds 4,5 are plasticisers

**Consumer tap**

Compound N <sup>o</sup>	Retention Time Minutes	Compound Name	Concentration µg/l	IS Ref No
1	6.05	trimethyloxirane	1.8	1
2	6.89	tetrachloromethane	<1.0	1
3	7.68	bromodichloromethane	3.5	1
4	8.78	4-methyl-2-pentanone	1.7	2
5	9.72	toluene	<1.0	2
6	10.19	dibromochloromethane	4.8	2
7	12.75	tribromomethane	1.4	2
8	30.24	isobutyl phthalate	<1.0	8

*Comment* - Compounds 2,3,6,7 are disinfection by-products. Compounds 1,4,5,8 have been identified in blanks.

**CONCLUSIONS****Site 1**

There were no significant differences in TOC levels pre- and post-installation of the GRP tank. There was no significant affect of the tank material on consumer tap TOC levels. There were no discernible levels of target analytes leaching into the water supply pre- or post-installation.

Clearly there is a significant level of material leaching from this product. Approximately 38 µg/l present in the tank leachate and 5 µg/l at the consumer tap may pose an acute risk but further studies would have to be carried out to demonstrate a chronic risk of exposure to potential endocrine disruption.

There is little evidence of risk from recognised endocrine disrupting substances. It is of some concern that there appears to be a significant level of other substances leaching from the GRP tank as measured by the GC-MS scan analysis. It is not clear if this is from the tank material, from fittings or from other materials used during installation. There are good grounds in this case for a need for more long term *in situ* monitoring.

**Site 2**

In the first butyl liner under test there were no significant differences in TOC levels pre- and post-installation of the tank lining. There was no significant affect of the tank material on consumer tap TOC levels. There were no discernible levels of target analytes leaching into the water supply pre- or post-installation. There is little evidence of risk from recognised endocrine disrupting substances resulting from target or GC-MS scan analysis. The GC-MS scan did identify the presence of isobutylphthalate but this appeared commonly throughout this study. There was a presence of iodinated species of unknown origin in the tank sample and high levels (14.8 µg/l) of toluene reported, possibly from materials used in the preparation of fittings for the installation.

**Site 3**

There were low levels of styrene identified in the leachates from the second GRP tank. Styrene at 0.5 µg/l was detected in the dip samples of the newly installed tank but not in the consumer tap sample. The presence of BEHP identified in the post-installation dip sample using GC-MS scan analysis was confirmed as present at 1.0 µg/l from target analysis. It was

also found to be present in the pre- and post-installation inlet samples at 0.4 µg/l. As there were also levels of 0.3 and 0.5 µg/l of BMP and BEHP in consumer tap samples there is a risk of continued chronic exposure to low levels of these potential endocrine disrupters.

A small number of substances present at low levels, approximately <1.5 µg/l, were found to be difficult to identify due to interference from one or more co-eluting components. Without further information on the identity of these compounds, it is impossible to say whether they could pose a potential risk.

#### **Site 4**

There were no significant differences in TOC levels pre- and post-installation of the butyl liner. There was no significant effect of the material on consumer tap TOC levels. There were no high levels of target analytes leaching into the water supply pre- or post-installation.

There were low levels of phthalates (2.0 µg/l), styrene (0.2 µg/l) and trace levels of 4-octyl phenol (0.3 µg/l) identified in the leachates from the consumer tap prior to installation of the second butyl liner in this study. Only trace levels of BEHP were identified during target analysis of the consumer tap following re-lining of the tank minimising any potential risk to the consumer. Levels of di-octyl phthalate up to 9.4 µg/l were identified by GC-MS scan in the pre-installation consumer tap and re-lined tank samples but did not appear in the consumer tap following refurbishment. Levels of isobutyl phthalate were not verified by target analysis. Levels of haloforms were detected in all samples up to 5.4 µg/l and are indicative of the disinfection process and the breakdown of humic acids during water treatment. In conclusion there is presented no risk from endocrine disrupters from water in contact with the type of butyl liner or fittings used in this installation.

#### **General observations**

Phthalates are ubiquitous in the modern environment and consequently there is a high potential for sample contamination. This may arise during sample handling from, for example, contaminated glassware or reagents. Obtaining blanks with minimal contamination can be a challenge in itself and this study highlights the need for rigorous procedures for cleaning glassware and maintaining a supply of dedicated glassware for this type of work. However, other blank contamination in this study was investigated. This included the occurrence of halogenated disinfection by-products of water treatment particularly for the analysis of site 3 and 4. Problems with the water purification system in the laboratory were identified and rectified.

Fatty acids palmitic and lauric acids were identified in some samples at low levels but pose no risk to health. The presence of benzothiazole was noted in some samples and although it presents no endocrine disrupting risk it is classed as a toxic irritant. At the levels present in this case (<1.0 µg/l) risk to the consumer was minimal.

Although this study was limited in scope it does indicate a small potential risk of exposure to endocrine disrupters but without further studies it is not possible to be more conclusive. There is a wide range of materials in circulation for handling potable water and a number of companies installing these products. A programme of regular independent spot audits may be desirable. Without a programme of monitoring consumer water supplies it will be difficult to gather sufficient information to adequately evaluate the potential risk of exposure to endocrine disrupters through the water supply.

## GLOSSARY

APCI	Atmospheric pressure chemical ionisation
BADGE	Bisphenol-A diglycidyl ether
BFDGE	Bisphenol-F diglycidyl ether
CAS	Chemical abstracts service
CCM	Committee on Chemicals and Materials of Construction for use in Public Water Supply and Swimming Pools
CPP	Committee on Products and Processes for Use in Public Water Supply
DCM	Dichloromethane
DETR	Department of the Environment, Transport and the Regions
DWI	Drinking Water Inspectorate
EA	UK Environment Agency
ELISA	Enzyme linked immunosorbent assay
EPA	US Environment Protection Agency
GC-MS	Tandem gas chromatography - mass spectrometry
GRP	Glass reinforced polyester
HPLC	High performance liquid chromatography
LC-MS	Liquid chromatography - mass spectrometry
LCMS-MS	Liquid chromatography - tandem mass spectrometry
LGC	Laboratory of the Government Chemist
LOD	Limit of detection
SIM	Selected ion monitoring
SPE	Solid phase extraction
TOC	Total organic carbon
UKAS	United Kingdom Accreditation Service
UV	Ultra violet
Wq <sup>c</sup>	Water Quality Centre
WRc	Water Research Centre