UKWIR Reports Catalogue

January 2007

Drinking water quality & health

vol. 2 Cryptosporidium, algal toxins and metals

The UKWIR research programme is currently divided into the following topic areas: drinking water quality and health; toxicology; water resources; climate change; wastewater treatment; biosolids; water mains and services as well as regulatory and customer issues. This catalogue lists the reports on the subjects of cryptosporidium, algal toxins and metals in the **Drinking water quality & health** programme area. Earlier volumes dealt with distribution, data services, epidemiology and microbiological studies and distribution systems.

A small number of high profile outbreaks of cryptosporidiosis in the UK in the 1980s led to the establishment of the Badenoch Committee. The Committee reported in 1995 with the basic message that, given current knowledge and techniques, cryptosporidium can be controlled by the application of good treatment practices and proper control measures.

UKWIR developed a programme of research to address issues raised by the Badenoch Committee concentrating on how different types of treatment can ensure the removal of particulate matter (and hence the oocysts) and also on the effect of different disinfection methods.

This research has been carried out in collaboration with the Drinking Water Inspectorate.

At the same time UKWIR developed a programme to address the issues of algal toxins. This research concentrated determining the maximum safe concentrations in drinking water and developing a range of treatment methods.

There are many types of algal toxins such as hepatotoxins, neurotoxins and lipolysaccharides affecting the liver, nervous and gastro-intestinal systems respectively. Of the hepatotoxins microcystin-LR is the most common. Of the neurotoxins, anatoxin-a occurs most frequently.

On 25 December 2003, the standard for lead in drinking water at the customer's tap was reduced from 50 to 25 µg/litre. The EU Drinking Water Directive requires a standard of 10 µg/litre by the end of 2013.

UKWIR have been collaborating with the Drinking Water Inspectorate in identifying short-term and long-term collaborative research projects to meet lead standards in the most effective manner.

This lead research has been complemented by research into communication pipe replacement *Strategic Lead Communication Pipe Replacement: Initial Review of Water Company Pilot Trials* (05/WM/02/20) in the water mains and sewers programme area.

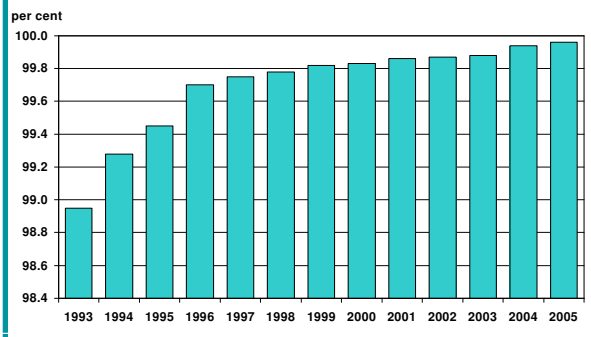
UKWIR reports can only be purchased via the UKWIR website:

www.ukwir.org

The website also provides information about current and proposed UKWIR research programmes

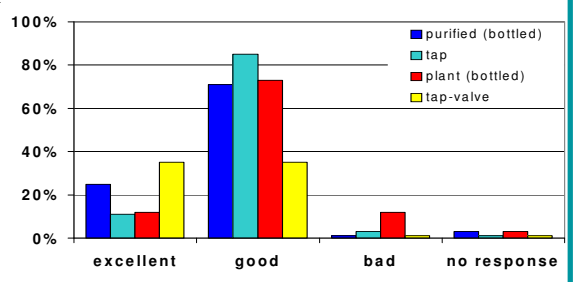
You can also download the latest version of UKWIR NEWS to obtain an update on recent projects, publications and technology transfer workshops

Drinking water compliance in England & Wales



Source: DWI

Perception of water quality in four observation groups based on 36,000+ responses



Source: UKWIR report 99/DW/01/2

UKWIR was set up by the UK water industry in 1993 to provide a framework for the procurement of a common research programme for UK water operators on 'one voice' issues. UKWIR's subscribers comprise 24 water and sewerage undertakers in England and Wales, Scotland and Northern Ireland to whom these publications are freely available.

Work is often carried out in collaboration with government departments and regulators including the Department for Environment, Food and Rural Affairs; the Drinking Water Inspectorate and the Environment Agency. Work is also done in collaboration with research organisations internationally, including the Global Water Research Coalition.

The work is undertaken by a wide range of companies, academic institutions and other organisations in the UK and overseas. Project management is undertaken by both UKWIR members and individuals employed by UKWIR.

Cryptosporidium, giardia and other parasites

Establishing the Relationship between Farm Re-stocking and Cryptosporidia: The Caldew Catchment Study

Contractor: Centre for Research and Environmental Health

Ref: 05/DW/06/19, ISBN 1 84057 374 0, 80pp, £100

Details an investigation into the relationship between farm re-stocking and cryptosporidia. The study took place following the foot and mouth disease (FMD) related cull within the River Caldew catchment, Cumbria. The effects of restocking on the species and subtypes of cryptosporidium in farmed livestock, wild animals and surface waters, were compared with isolates from farms that had been continually stocked. Field studies took place in two phases with the aim of taking samples before and after re-stocking. Whilst differences were observed between the phases, the prevalence of cryptosporidium oocysts in the catchment was similar. This may be related to the rapid restocking of the catchment following the FMD cull and the relative resistance of cryptosporidium in the environment during the de-stocked period.

Reassessing cryptosporidium Risk: Treatment Security, Regulatory Monitoring and Epidemiology

Contractor: WRc plc

Ref: 03/DW/06/16, ISBN 1 84057 299 X, 100pp, £500

Companies can re-assess sites designated as 'at significant risk' to have them removed from the regulatory monitoring category. Reviews the regulatory monitoring data for cryptosporidium, examines approaches some companies have taken to reclassify or reduce risk, and evaluates the feasibility of identifying association between oocyst concentrations in water supplies and incidence of human cryptosporidiosis. The primary objective was to provide alternative or complementary approaches relating to water treatment plant operation, to allow companies to select those appropriate to specific sites.

Application of Statistical Process Control in Water Treatment for Managing Cryptosporidium Risk

Contractor: Natural Environment Research Council

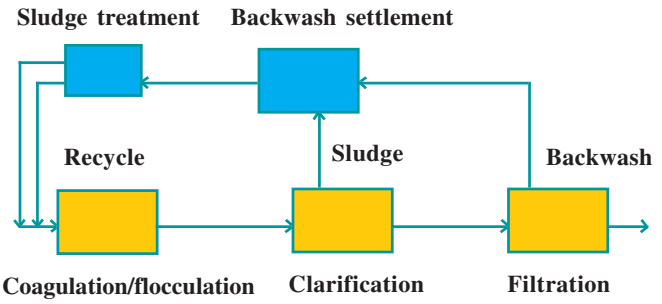
Ref: 00/DW/06/15, ISBN 1 84057 214 0, 54pp, £150

Demonstrates the use of SPC in water treatment, to enable companies to identify techniques of potential value to their operating regimes, and to assist in their implementation. With respect to management of cryptosporidium risk at surface water treatment works, technieques have been reviewed to provide:

* sensitive analysis of turbidity trends in final water to rapidly identify any deterioration in treatment performance
* comparison of the performance of individual filters, with the potential to allow individual filters to be managed based on clearly defined statistical targets
* a statistical basis for setting turbity alarms for final water.

For groundwaters, data vailable from two sites indicated that short-term turbitity spikes associated with flowrate changes could be clearly distringuished from longer term trends associated with rainfall. The operational capacity to differentiate between these would help manage cryptosporidium risks associated with rapid surface water ingress, and detailed analysis of previous turbidity data is likely to be beneficial in setting of appropriate alarms.

Fig. 1. Areas for attention to minimise risk of oocyst breakthrough



Cryptosporidium: Implications for Variable Declining-Rate Filtration

Contractor: Natural Environment Research Council

Ref: 00/DW/06/14, ISBN 1 84057 201 9, 25pp, £100

Reviews the principles of variable declining rate (VDR) filtration and the implication for cryptosporidium risk, in comparison with constant rate filtration, particularly in a UK context. Results are provided for a survey of UK water companies, which suggested that up to 50 per cent of filters may operate with declining rate characteristics. Consideration of the mode of operation and review of the literature suggested that flow surges may be of lesser concern than for constant rate filters, and average turbidity should be no higher for VDR. However, the higher flowrate at the beginning of the run could increase the impact of the ripening period. This could be dealt with in the same way as for constant rate filters, for example by slow start or run to waste.

Review of the Use of Tracers to Investigate Pathogen Transport and Attenuation in Groundwater

Contractor: Natural Environment Research Council

Ref: 00/DW/06/13, ISBN 1 84057 197 7, 51pp, £75

The wide range of tracers and test methods available are extremely useful tools for investigating hydroegeological problems although they have not been widely employed in pathogen transport investigations. Tracers may be particularly valuable for proving a hydraulic connection between a contaminant source and an abstraction borehole and for understanding the mechanisms controlling pathogen movement.

Monitoring Tools for Operational Detection of Rapid Influence of Surface recharge on the Quality of Groundwater

Contractor: WRc plc

Ref: 00/DW/06/12, ISBN 1 84057 196 9, 66pp, £150

Evaluates the usefulness of existing monitoring tools in fast flow assessments in UK aquifers, identifies other potentially applicable parameters and key areas for research. Analysis of water utility monitoring data suggests that no single parameter is useful in all situations and that microbiological determinands, turbidity, temperature and chlorine demand may all have a role. New parameters which should be assessed for operational use are particle counting and size index.

Transport and Fate of Crytosporidium and other Pathogens in Groundwater Systems

Contractor: North Cumbria Health Authority

Ref: 00/DW/06/11, ISBN 1 84057 195 0, 50pp, £150

Shows that there is little information on the fate and transport of pathogens in UK aquifers below the soil zone. cryptosporidium migration into the unsaturated zone will be attenuated by the soil, but pathways which allow soil-zone bypass are common on UK aquifer outcrops. Once oocysts have entered the subsurface survival for long periods seems likely.

Second Edition of a Guidance Manual Supporting the Water Treatment Recommendations from the Group of Experts on cryptosporidium

Contractor: WRc plc

Ref: 00/DW/06/10, ISBN 1 84057 189 6, 96pp, £200

The manual which supersedes the previous edition, provides guiding principles for water treatment works operation to minimise the risk from cryptosporidium, together with supporting information to demonstrate their validity. Separate sections are provided for individual unit processes, each beginning with a list of operational recommendations. Supporting information is given in sub-sections and in appendices, cross-referenced as appropriate. The manual is intended for use by treatment works managers and operational support staff, such as process scientists, with a working knowledge of water treatment.

Statistical Process Control and Other Techniques for Managing cryptosporidium Risk in Water Treatment

Contractor: WRc plc

Ref: 99/DW/06/9, ISBN 1 84057 177 2, 63pp, £200

Provides statistical techniques to allow operators to identify abnormal variations in final water turbidity which could pose an increased risk of cryptosporidium breakthrough, and to set alarms accordingly. Techniques are also provided to allow the performance of individual process units to be compared. Additionally, the application of risk assessment methodologies to water treatment are reviewed.

Visit www.ukwir.org to purchase reports

Chemical and Electrochemical Inactivation of Cryptosporidium

Contractor: WRc plc

Ref: 99/DW/06/8, ISBN 1 84057 166 7, 20pp, £100

Both ozone and medium pressure UV offer promise for oocyst inactivation. However, the inactivation option is not feasible for achieving the proposed Regulatory standard in the UK. This would not preclude it as part of an overall risk reduction strategy, however, particularly when the disinfectants may be installed for other purposes. At the present time there is disagreement over which of the techniques for assessing inactivation is the most valid, so that the benefits can be quantified. In the longer term, human cell culture techniques show promise in this respect. However, there is insufficient information currently available for confident design of systems for oocyst inactivation.

Cryptosporidium and Water Treatment: Particle and Spore Counting, GAC and Manganese Filtration, and Backwash Settlement

Contractor: WRc plc

Ref: 98/DW/06/7, ISBN 1 84057 148 9, 51pp, £100

Fills a number of gaps in knowledge of removal processes and monitoring of cryptosporidium during water treatment. The main findings are as follows.

* evidence of the potential benefits of spore measurement for further optimisation of plant performance is provided, although aggregation of spores needs to be considered when interpreting the results
* floc shear can impair the performance of settlement of backwash water with respect to oocyst removal, but the effect can be reversed by the use of polyelectrolyte
* ozonation greatly enhances particle removal by GAC filters
* suspensions of latex microspheres provide a practical technique for on-site checks of particle counter calibration.

Theory and Guidance on Assessing and Managing Cryptosporidium Risk in Groundwaters

Contractor: WRc plc

Ref: 98/DW/06/6, ISBN 1 84057 146 2, 44pp, £100

Reviews and catergorises factors which influence the risk of contamination of groundwaters with cryptosporidium oocysts, in order to provide the basis for risk ranking of sources. Treatment processes for physical removal of oocysts from groundwaters are reviewed, particularly membrane systems and proprietary depth filtration devices. Novel high intensity UV units may also offer promise for inactivation of oocysts. Technical and indicative cost information on these treatments are provided to help in the selction of suitable techniques for particular groundwater applications.

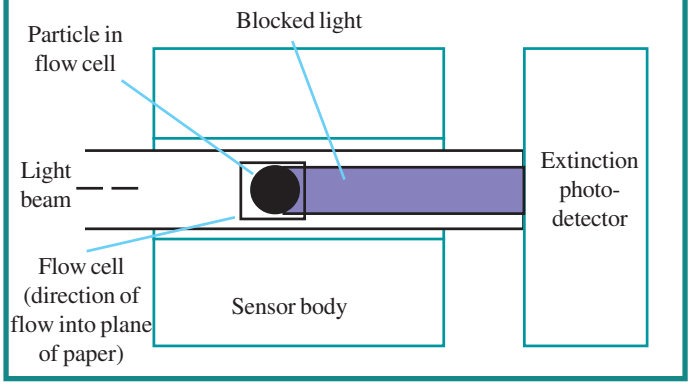
Particle Counting and Bacterial Spore Analysis for Water Treatment Works Monitoring

Contractor: WRc plc

Ref: 97/DW/06/4, ISBN 1 84057 028 8, 45pp, £100

Describes the results of monitoring at five water treatment works using bacterial spores and particle counting, to assess their potential as indicators of the risk of cryptosporidium oocyst breakthrough. Three alternative makes of particle counter showed very similar performance for monitoring filtered water. Particle counting was a more sensitive indicator than turbidity of the filtered water quality changes which occur at the beginning of a filter run. Bacterial spore measurement, particularly using aerobic bacillus spores, showed potential as an indicator of treatment performance for particle removal from the raw water.

Figure 2. Schematic of particle counter



Cryptosporidium Removal During Water Treatment

Contractor: WRc plc

Ref: 96/DW/06/3, ISBN 1 84057 058 X, 45pp, £50

This report is a continuation of a 1994/95 UKWIR contract investigating aspects of water treatment plant operation which influence removal or inactivation of cryptosporidium oocysts. The results have provided further evidence of the effectiveness of conventional water treatment processes for oocyst removal, and have highlighted the importance of the early part of the filter run with regard to the risk of oocyst breakthrough from rapid gravity filters. The objectives of this work were:

* to assess the use of particle counters as tools to assist in filter operation
* to demonstrate the extent to which operational practices on rapid gravity filters can influence the risk of cryptosporidium breakthrough
* to evaluate the performance of slow sand filtration for oocyst removal
* to assess the effect of environmental exposure of oocysts on their susceptibility to disinfection
* to identify the potential for spores of aerobic bacteria to act as surrogates for oocysts during water treatment.

Removal of cryptosporidium during Water Treatment

Contractor: WRc plc

Ref: 95/DW/06/1, ISBN 1 84057 015 6, 41pp, £150

Describes in detail the work undertaken to identify cryptosporidium risks associated with water treatment plant operation, and ways of overcoming these risks. Particular areas for investigation are:-

* aspects of rapid gravity filter operation which can influence the risk of cryptosporidium oocyst breakthrough into the filtered water
* use of particle size monitors as indicators of filtration performance, compared with turbidimeters
* effects of recycling of settled backwash water supernatants plus potential for penetration of oocysts into a slow sand filter bed
* potential of ozone and UV irradiation as disinfectants for cryptosporidium;
* potential for microfiltration for control of cryptosporidium in water treatment;
* use of bacterial spores as surrogates for cryptosporidium during water treatment.

Algal toxins

A Status Report on Algal Toxins & Water Treatment

Contractor: WRc plc

Ref: 00/DW/07/6, ISBN 1 84057 209 4, 63pp, £50

Updates papers published on the removal of algal toxins by water treatment, and to review the significance of toxins to water supplies worldwide through surveys in the UK and overseas. In general, papers published since 1995 serve to support the findings from work funded by FWR and UKWIR. The occurrence of algal toxins in recent years would appear to be regional or localised. Generally, UK companies have appropriate measures in place for monitoring and control, and are keeping pace with relevant developments. Dominant algal species and toxins vary between countries. Some countries appear to have implemented extensive programmes of research, often collaboratively. However, many countries have yet to identify whether algal toxins pose a threat to their water sources, and this may in part be due to lack of funding.

Algal Toxins: Occurrence and Treatability of Anatoxin and Microcystins.

Contractor: WRc plc

Ref: 97/DW/07/5, ISBN 1 84057 029 6, 15pp, £40

Laboratory cultures of a wide range of algal strains, primarily anabaena species, failed to produce anatoxin a at high enough concentrations to allow investigation of treatability, despite the presence of very high concentrations of algal biomass. Sampling of reservoir with appropriate algal blooms also failed to identify high concentrations of anatoxin-a. Anatoxin-a may therefore present less of a risk to water supplies than previously thought. The treatability of microcystin variants other than microcystin-LR was predicted through modelling techniques. The results of this exercise suggest that any strategies which are based on the known amenability of microcystin-LR to treatment should be suitable for removal of the other microcystin variants.

The Fate of Intracellular Microcystin-LR during Water Treatment

Contractor: WRc plc

Ref: 96/DW/07/4, ISBN 1 84057 098 9, 18pp, £30

Microcystin-LR is a toxin produced by blue-green algae. The presence of these algae in water supply reservoirs is a potential source of contamination of drinking water. Algal toxins can be stored within the algal cells until they die and lyse. Healthy algal cells could conceivably pass through treatment works intact and reach the customer's tap, or treatment processes may cause cell lysis and release of the toxins into the water. Assesses the impact of water treatment processes on toxic algal cells containing microcystin-LR, and quantified the amount of toxin that could be released during cell lysis. The processes investigated were physical mixing and pumping, pH adjustment, coagulation and chemical oxidation. The results show that some processes remove the cells altogether, whereas other cells cause cell lysis, and some are effective at destroying the toxin. Recommendations which processes to use where algal toxins are considered a risk.

Synthesis of an Internal Standard for the Determination of Anatoxin-A in Water

Contractor: WRc plc

Ref: 96/DW/07/3, ISBN 1 84057 060 1, 10pp, £40

Anatoxin-A is a neurotoxin, produced by blue-green algae. A method for the determination of anatoxin-a in reservoir water was developed in 1993, which involves high performance liquid chromatography with ultraviolet detection. Its use has led to the detection of low levels of the chemicals in some waters. It was considered that an internal standard would improve performance of the method. Various potential internal standards were considered and one was found to be suitable (trideuterohomoanatoxin-a). This compound was synthesised and sufficient material made available for an inter-laboratory performance testing exercise of the anatoxin-a method. Preliminary testing has shown an improvement in performance of the method when using this internal standard.

The Toxicity and Significance of Toxins from Blue-Green Algae

Contractor: WRc

Ref: 96/DW/07/2, ISBN 1 84057 007 5, 18pp, £50

Blue-green algae are sometimes found in water supply reservoirs. Some algae produce toxins, and because of the possibility of these toxins reaching the customer's tap, it is appropriate to set limits for them in drinking water. In order to do this, it is necessary to know how toxic they are. Reviews the data available on algal toxins, recommends limits for them in drinking water, and points to areas where more data is needed. The two main algal toxins of concern are microcystin-LR (a hepatoxin) and anatoxin-a (a neurotoxin). A limit of 1µg/1 for total microcystins, and 1µg/1 for anatoxin-a, were suggested as being appropriate to ensure that no adverse response occurs.

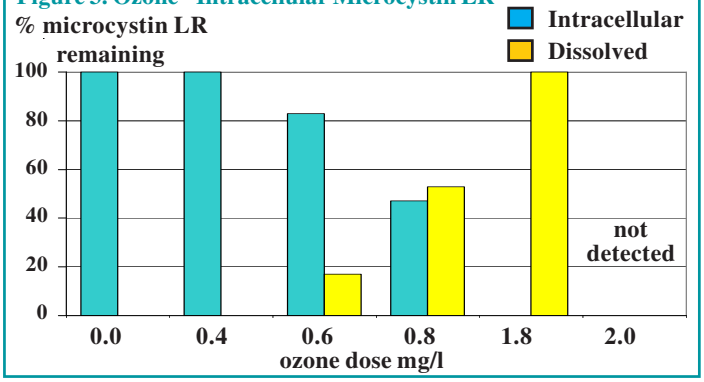
Pilot Scale GAC Tests to Evaluate Toxin Removal

Contractor: WRc

Ref: 96/DW/07/1, ISBN 1 84057 059 8, 8pp, £50

Blooms of blue-green algae on reservoirs can give rise to the production of toxins that may contaminate freshwaters. There is a potential risk of the toxins entering drinking water supplies and posing a health risk to consumers. There is, therefore, a clear need to identify treatment processes for removing and treating toxin contaminated water. Describes work which investigated the removal of anatoxin-a by pilot scale GAC (granular activated carbon) adsorbers, and assessed the importance of biodegration. It also investigated microcystin-LR removal, using higher concentrations than in a previous study. Concludes that GAC filters are highly effective in removal of both toxins, and recommends a suitable contact time for complete removal.

Figure 3. Ozone - Intracellular Microcystin LR



Metals

Maintaining and Improving Water Quality in Domestic Pipework and Fittings - Review of Developments for Meeting Lead Compliance

Contractor: WRc Plc

Ref: 99/DW/04/9, ISBN 1 84057 176 4, 23pp, £100

The statistical method used to interpret utility data is crucial in understanding the degree of compliance with the interim and final lead regulations. Analysis of data has indicated that control of particulate lead is important in reaching compliance. Relining or replacement is the only serious option to achieve compliance an 10µg/1. The techniques available need further development before becoming feasible, cost effective options. Remote detection of lead pipes is currently not technically possible without direct access to the pipe.

Concentration of Lead at Customers' Taps': Trends in Monitoring Data 1990-1998

Contractor: WRc plc

Ref: 99/DW/04/8, ISBN 1 84057 175 6, 54pp, £100

Concentration of Lead at Customers' Taps: Trends in Monitoring Data from 1990 - 1996

Ref: 98/DW/04/5, ISBN 1 84057 147 0, 57pp, £100

Lead statutory monitoring data from UK water companies were collected and entered into an industry database. Three methods of statistical analysis (arithmetic mean, geometric mean and median) were used to assess whether water quality zones would comply with the current and future maximum permissible lead concentrations in drinking water (i.e. 50,25, or 10 µg/1). The results were incorporated with earlier data to show trends in lead compliance between 1990 and 1998. The effect of phosphate dosing was assessed for some companies.

Approaches for Controlling Plumbosolvency

Contractor: WRc plc

Ref: 97/DW/04/4, ISBN 1 84057 100 4, 59pp, £100

Gives causes and extent of plumbosolvency in the UK in the context of the proposed EC Directives changes. provides a survey of current techniques and potential for application for a range of sample waters. Describes and compares pH control, alkalinity altering and orthophosphite dosing, pipe replacement and relining techniques. Discusses situation in Europe, Japan and USA.

Concentration of Lead at Customers' Taps: A Statistical Approach

Contractor: WRc plc

Ref: 97/DW/04/2, ISBN 1 84057 030 X, 119pp, £50

Uses real data from 1990 to 1995 from 24 water companies to test a wide range of possible statistical interpretations that are likely to emerge from the revised Drinking Water Directive. Shows the wide variation in compliance when using arithmetic and geometric mean, maximal values, percentiles etc. and when applying different sample sizes in water supply zones.

Metals arising from Domestic Pipework and Fittings

Contractor: WRc plc

Ref: 97/DW/04/1, ISBN 1 84057 099 7, 40pp, £50

Examines fifteen metal contaminants in drinking water and their likely sources using reported prescribed concentration or values exceedences. Major source of contamination is from materials used in the distribution system with only lead being of significance from the domestic plumbing system. Discusses problems of non-approved fittings and use of corrosion inhibitors. Considers current methods of sampling the customer's tap and implications of new EC lead standard.

Table 1. Comparing %ile & 'permitted % sample failures' methods

	% zones failing limit based on individual values			percentile	
	% of samples allowed to fail in one zone				
limit	**0**	**5%**	**10%**	**85%ile**	**95%ile**
10µg/l	96.0	83.3	72.0	64.3	86.7
25µg/l	84.7	62.3	43.7	30.3	68.0
50µg/l	65.0	29.3	14.0	7.7	36.3

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