Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Feidhmeannacht na Seirbhíse Sláinte
Health Service Executive

# JOINT POSITION STATEMENT
# Trihalomethanes in Drinking Water
# November 2011

This position paper has been developed by the Health Service Executive (HSE) and the Environmental Protection Agency (EPA). It provides a summary of the issues in relation to trihalomethanes in drinking water including health, legislation and interventions.

## Introduction

Disinfection is a critical part of drinking water treatment and is fundamental to preventing the spread of waterborne infectious diseases. The use of disinfectant chemicals can result in the formation of disinfection by-products (DBPs). Chlorination is the most common disinfection method used in Ireland and chlorine use is regulated primarily to minimise the formation of DBPs, the most common of which are trihalomethanes (THMs). THMs are a group of organic chemicals, often present in drinking water and formed when chlorine reacts with naturally occurring organic matter in raw water. Chlorine is a powerful oxidising agent and it breaks down complex organic molecules which are the colouring agents of water, forming smaller reactive entities. These entities react with chlorine to form THMs. There is a direct relationship between the degree of colour in the water prior to chlorination and the concentration of THMs after chlorination.

THMs are a group of four chemicals – chloroform, bromoform, dibromochloromethane and bromodichloromethane. Chloroform tends to be present in the greatest concentration. Total THMs is a parameter on the chemical table in the 2007 Drinking Water Regulations[1]. A further group of chlorine associated DBPs, haloacetic acids (HAAs), are of increasing concern but are not included in the 2007 drinking water regulations although they may well be included in the future regulations.

Because most water supplies in Ireland are surface water sources and some of our groundwater sources may be influenced by surface water, raw water is likely to contain high levels of particulate and organic matter. This can be much greater after heavy rainfall or flooding. Trihalomethanes are formed when there is either inadequate pre-treatment of the water and/or poor control over the disinfection process itself. THM formation is dependant on several variables; the concentration and nature of the organic material in the raw water, chlorine contact time, the residual chlorine concentration in the water and the pH and temperature of the water. Optimum filtration and coagulation before disinfection is therefore important in preventing the formation of THMs.

Chlorine is used not only as a primary disinfectant in water treatment but is also added to provide a stable disinfectant residual to preserve the quality of the water throughout the distribution network. While this characteristic of chlorine makes it most suitable as a disinfectant it also means that it is more prone to DBP formation because it has more contact time with organic matter in the water that was not removed during treatment (coagulation and filtration). Additional chlorine may be added in order to maintain an adequate residual concentration throughout the distribution system particularly at end points. Temperature and pH of drinking water vary across supplies and from season to season. Optimum control over all of these factors is necessary to keep THMs to a minimum.

## Guideline Values

*Table I: Trihalomethane guideline values*

| | Drinking water regulations 2007 parametric value µg/l | WHO guideline values µg/l | WHO tolerable daily intake (TDI) µg/kg/day |
|---|---|---|---|
| Trihalomethanes (total) | 100 | * ratio of 1 | |
| Chloroform | | 300 | 15 |
| Bromoform | | 100 | 21.4 |
| Dibromochloromethane | | 100 | 17.9 |
| Bromodichloromethane | | 60 | - |

*The sum of the ratio of each of the four levels to their individual guideline value should not exceed 1(WHO 2005)[2]

Table I shows the 2007 EU drinking water regulations parametric value for total THMs. It also shows several World Health Organisation (WHO) guideline levels including individual THM levels, the sum of the ratio of each individual THM level to its guideline value and the provisional tolerable daily intake.

Guideline levels are calculated to protect the most vulnerable section of the population. For chemicals in drinking water this is generally small babies. Up to about 10kg, babies require between 100-120mls of fluid per kg of weight. This is the time of greatest liquid consumption per body weight. Adults require approximately 30mls of fluid per kg body weight. For this reason guideline levels are precautionary. In determining guideline levels, a lifetime of exposure at sustained levels is assumed and safety factors are built into the calculations.

## Exposure

People can be exposed to THMs in drinking water in a number of ways. THMs are volatile substances and are ultimately transferred to air either at room temperature or by rapid evaporation on boiling. Approximately equal contributions to total exposure come from four areas: ingestion of drinking water, inhalation of indoor air largely due to volatilisation from drinking-water, inhalation and dermal exposure during showering or bathing and ingestion of food. All but food exposure arises primarily from drinking-water.

## Public Health Implications

The potential adverse human health risks associated with low levels of disinfection by-products in drinking water is currently an area of strong scientific interest. It attracts funding and scientific papers on the health effects of disinfection by-products are regularly published in the literature.

The WHO as well as other national agencies which have a role in advising on the health of populations such as the Committee on the Toxicity Chemicals in Food, Consumer Products and the Environment committee (COT) (UK), Agency For Toxic Substances and

Disease Registry (ATSDR) (USA) and Health Canada etc., regularly assess the evidence as it is emerges and publish position statements on THMs and drinking water. In particular, the COT (UK) assesses the evidence using systematic methods, whereby the studies reviewed are listed and the methods used to evaluate them are explicit, allowing the conclusions to be reproduced.

## Health

Acute effects of THMs in drinking water are rare. Two main long-term health outcomes are studied with regard to THMs and drinking water: cancer and reproductive outcomes.

## Cancer

The International Agency for Research on Cancer (IARC) reviews published studies and classifies in a standardised way the carcinogenic potential of a chemical. The categories and definitions IARC uses are given in Table II below.[3]

The IARC reviewed Chlorinated Drinking Water in 1991 and updated it in 1997[4]. Chlorinated drinking water was not classified as to its carcinogenicity to humans (Group 3). Both chloroform and Bromodichloromethane, two individual THMS, were classified as possibly carcinogenic to humans (Group 2B). This category is used for agents for which there is inadequate evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in experimental animals. Bromoform or Chlorodibromomethane were not classified as to their carcinogenicity (Group 3).

*Table II: IARC Classification of Agents as to the carcinogenicity to humans*

| | |
|---|---|
| Group 1 | Carcinogenic to humans |
| Group 2a | Probably carcinogenic to humans |
| Group 2b | Possibly carcinogenic to humans |
| Group 3 | Not classified as to its carcinogenicity to humans |
| Group 4 | Probably not carcinogenic to humans |

In May 2008 the COT (UK) produced a statement on chlorinated drinking water and cancer[5]. They reviewed the new epidemiological studies that had been published since their previous statement on the issue in 1999[6]. Some studies did show an association between cancer and THMs in drinking water and others showed no association. The role of the COT is to assess the quality and totality of the evidence and come to a conclusion. They concluded;

*'Problems remain in the interpretation of published studies. These include the small relative risks recorded, the possibility of residual confounding, and the problems with exposure assessment'. They conclude 'the evidence for a causal association between cancer and exposure to chlorination by-products is limited and any such association is unlikely to be strong. Efforts to minimise chlorination by-products in drinking water should continue but must be balanced against the need for effective disinfection of drinking water'.*

## Reproductive heath

In the 1990s a number of studies from California were published suggesting that chlorination by-products in drinking-water were associated with adverse reproductive outcomes. In 1998, COT considered the findings of the published epidemiological evidence, concluding that there was no causal relationship found in the data reviewed. Further research was recommended to reduce the uncertainties of the reported associations. The Committee endorsed precautionary measures by water companies to minimise consumer's exposure to chlorinated by-products in tap water, providing that they do not compromise the efficiency of disinfection of drinking water.

In 2008, the COT reviewed the evidence with regard to reproductive health again[7]. This report considered three separate analyses. Firstly it considered a study by the Small Area Health Statistics Unit (SAHSU) (UK) which looked at total THM concentration in drinking water and 1 million records of birthweight and stillbirths across three large areas of the UK. There was some suggestion of a small adverse effect between total THMs and adverse pregnancy outcomes but it was considered to be due to residual confounding by socio-economic status.

Secondly, the COT report considered data from thirteen new epidemiological studies published after the original 1998 evaluation, which investigated associations between chlorinated drinking-water and pregnancy outcomes (not congenital malformations). Overall, the committee concluded that the data did not show a causal relationship between chlorinated drinking-water and pregnancy outcomes, namely: low birth weight, very low birthweight, stillbirth, spontaneous abortion, perinatal death, infant death, low Apgar score, infant's head circumference at birth, infant's body length, pre-term delivery, length of gestation, neonatal jaundice and neonatal hypo-thyroidism.

The third and final part of this report considers a study of congenital abnormalities, again by the SAHSU, the largest of its kind. The authors concluded that this large national study found little evidence for a relationship between THM concentrations in drinking water and risk of congenital anomalies. The 2008 COT report concludes *'We conclude that in human studies there is no consistent relationship between chlorinated drinking-water and adverse pregnancy outcomes, including low birth weight, pregnancy loss, pre-term delivery and congenital malformations. In animal studies, effects have largely been seen at high doses associated with maternal toxicity and these are not considered to be predictive of effects in humans exposed to far lower levels of DBPs'.*

## World Health Organisation (WHO)

The WHO has published detailed information on THMs in drinking water[8]. 'It is emphasized that adequate disinfection should never be compromised in attempting to meet guidelines for THMs … it is recommended that THM levels in drinking-water be kept as low as practicable.'

However, the microbial safety of drinking-water should never be compromised and effective disinfection to prevent waterborne infectious diseases must take precedence.

## Understanding the limitations of the scientific evidence

Because of the nature of studying drinking water and health, robust conclusions can be difficult to reach. Even in well-designed studies, it is difficult to assess a person's individual exposure to levels of a particular chemical in drinking water over a long period of time. Other factors may explain the results and it can be difficult to control these. Positive adverse associations are often just very small increased risks. These can occur randomly and it is difficult for a scientist to say with absolute certainty that the increase is due entirely to the chemical being studied. All of the above factors are even more pronounced when the health outcome is a chronic disease that takes 20 to 40 years to develop e.g. cancer. In order for findings to be valid, they must be reproduced, as policy generally cannot rely on one study.

These methodological limitations are not unique to trihalomethanes and drinking water. They are common to many environment and health issues. Exposures in the environment are often measured at group level and not individual level. However, in Public Health matters such as these, the precautionary principle applies[9]. Where evidence with regard to the environment and health is uncertain, exposure to the hazard should be reduced. It is important to note that precautionary action should be proportional to likely benefits and potential harms.

## THM Monitoring in Ireland

The EC Drinking Water Regulations 2007 specified a parametric value of 150µg/l for THMs. The parametric value was reduced to its current value of 100µg/l on the 25th of December 2008.

There was an increased level of monitoring in 2010 with 1,938 samples analysed in 1,006 water supply zones. The results, as shown in Table III, show that the trihalomethanes parametric value was exceeded, at least once, in 12.9% of the water supplies tested during 2010, an improvement from 15.6% in 2009. Compliance with the trihalomethane parametric value in public water supplies improved from 83.9% in 2009 to 86.5% in 2010. Public water supplies are monitored more frequently for trihalomethanes than other supply types as frequency of monitoring is based on either the volume of water produced by the supply or the number of people on a particular supply. Non-compliance may be more common in supplies monitored less frequently.

*Table III: Compliance with the Trihalomethanes (total) Parametric Value (100ug/l) in 2010.*

| | No. of *WSZs Monitored | No. of Non-compliant WSZs | No. of Samples Analysed | No. of Non-compliant Samples |
|---|---|---|---|---|
| Public Water Supplies | 652 | 88 (13.5%) | 1,514 | 162 (10.7%) |
| Public Group Water Schemes | 95 | 24 (25.3%) | 105 | 25 (23.8%) |
| Private Group Water Schemes | 248 | 17 (6.9%) | 296 | 43 (14.5%) |
| Small Private Supplies | 11 | 1 (9.1%) | 23 | 4 (17.4%) |
| Overall: | 1006 | 130 (12.9%) | 1938 | 234 (12.1%) |

* water supply zones

The majority of THM failures are the result of either no treatment barrier to remove organic matter or sub-optimal removal of organic matter, which is a precursor to THMs[10].

These data (Table III) denote whether there was, over the course of 2010, ever an exceedance of THMs in a particular supply. They do not reflect the magnitude of the exceedance, whether the exceedance was sustained or sporadic or any potential health impact.

## Risk assessment

Risk assessments of public water supplies with THM exceedances are undertaken in consultation between the Water Services Authority (WSA) and the HSE.

*Chemical exceedances*

A typical risk assessment in respect of a chemical exceedance would consider: the concentration of the particular chemical; the potential for acute toxicity at concentration detected; the potential for chronic toxicity at the range of concentrations detected having regard to remediation timeframe; checks to assess if the sample is representative of the supply or localised; remedial actions already taken by the WSA; source, treatment operation, storage and distribution of water; previous history of the supply, availability of alternative supplies; recent changes to water supply system; extreme weather incidents, complaints / reported illness and if there are any vulnerable groups among consumers. Consequently each assessment is specific in time, location and population. In considering the action to be taken the WSA/HSE also has regard to the risk to human health that would be caused by the interruption of supply or restriction of use.

*THM exceedances*

In addition to the above, there are further risk assessment considerations specifically for THMs. Total THMs are monitored under the regulations but a specific breakdown of individual THMs should be requested. THM levels may be persistently elevated or an exceedance may be sporadic. Consideration should be given to whether a specific result is representative of the mean THM concentration in the supply and of mean continuous exposure of an individual. Finally, in an effort to reduce THMs there is a risk of inadequate chlorination. This could result in microbiological contamination and a possible serious *Ecoli* 0157 outbreak for example, and should be avoided.

## Legislative Framework/Regulatory System

The *European Communities (Drinking Water) (No. 2) Regulations 2007 (S.I. No. 278 of 2007)* set down the drinking water requirements and enforcement procedures. Water services authorities, 34 City and County Councils throughout Ireland, are responsible for the production, distribution and monitoring of public water supplies. The Environmental Protection Agency (EPA) is the supervisory authority in relation to public water supplies and the local authority is the supervisory authority in relation to private water supplies. Both the Local Authority and the EPA have enforcement powers under the regulations.

The 2007 drinking water regulations require each Sanitary Authority (WSA) to immediately investigate any failure to meet a parametric value specified in the water regulations in order to identify the cause of such failure, to ensure that the remedial action necessary to restore the quality of the water is taken as soon as possible and to notify the EPA. Regulation 9 obliges both the WSA and the EPA to consult with and get the agreement of the HSE in respect of certain matters.

### Regulation 9(1)

*"Where a sanitary authority, in consultation with the Health Service Executive, considers that a supply of water intended for human consumption constitutes a potential danger to human health, the authority shall, subject to agreement with the Health Service Executive, ensure that—*

*(a) the supply of such water is prohibited, or the use of such water is restricted, or such other action is taken as is necessary to protect human health,*

*(b) consumers are informed promptly thereof and given the necessary advice, and*

*(c) in the case of a public water supply, the Agency is informed promptly."*

### Regulation 9(2)

*"For the purposes of paragraph (1), and subject to agreement with the Health Service Executive, where a supervisory authority is of the opinion that—*

*(a) non-compliance with a water quality standard or other parametric value specified in Part 1 of the Schedule, or*

*(b) the presence of any substance or micro-organism for which no water quality standard has been prescribed, in water intended for human consumption, or the inefficiency of related disinfection treatment, constitutes, or may constitute, a risk to human health, the supervisory authority shall issue such direction to the relevant water supplier as it considers necessary to ensure that appropriate measures are taken for the purposes of preventing, limiting, eliminating or abating such risk, and the water supplier shall comply with such a direction."*

### Regulation 9(3)

*For the purposes of paragraph (2), a supervisory authority shall decide what action should be taken under this Regulation having due regard to the risks to human health that would be caused by an interruption of the supply or a restriction in the use of water intended for human consumption.*

## Interventions

The formation of THMs in drinking water are dependent on the concentration and nature of organic material in the raw water, free chlorine in the water, chlorine contact time, pH and temperature. Optimum control over all of these factors is necessary to keep THMs to a minimum. The quality of the raw water is important. The main mechanism employed to prevent the formation of THMs and other by-products of chlorine disinfection is the removal of organic matter, through optimal coagulation and filtration before chlorination. Chlorinated water is sometimes used for filter backwashing. There may be some potential for THM formation with organic material within the filter. Temperature and pH of drinking water vary across supplies and from season to season.

The EPA's Water Treatment Manual on Disinfection 2011[11] identifies best practice in the treatment of water to reduce THMs as including consideration of:

i. Protection of the source of the water supply from organic and other sources of pollution from agriculture, industry, forestry, peat extraction etc to reduce the level of organic matter to be removed by the water treatment plant;

ii. Optimisation of the operation of chemical dosing, coagulation, clarification and filtration treatment stages at the water treatment plant;

iii. Avoid chlorinating raw surface water and treat water to remove precursors (colour, TOC, UV absorbance) as far as possible;

iv. Limit free chlorine concentrations and contact times to the minimum required for the process (and distribution systems);

v. Dechlorinate as soon as possible after breakpoint chlorination;

vi. Consider using chloramination to provide a residual in disinfection;

vii. Keep pH low as THM formation increases with pH increase;

viii. Consider the use of an alternative chemical disinfectant or UV for primary disinfection. UV may not be suitable if transmissitivity requirements are not met due to high organic matter.

ix. Manage the distribution network to prevent the build up of organic matter in the pipework (e.g. flushing of mains, cleaning of reservoirs etc).

Whilst it is possible to remove THMs using air stripping or GAC, this approach is costly compared with minimising formation, and is used infrequently.

## EPA Remedial Action List

The elimination of all THMs exceedances is a priority of the EPA and it is for this reason that all supplies with persistent or intermittent THM exceedances have been included on the EPA's Remedial Action List. The majority of these supplies have action programmes in place and are expected to be completed before 2014. Where no action programmes have been received by the EPA, it has issued legally binding Directions in 2011 to require that appropriate actions are taken to eliminate THM exceedances.

## WHO Water Safety Plans

The EPA has adopted the WHO Water Safety Plan[12] approach to ensuring drinking water is both "safe" and "secure". A supply is deemed 'safe' if it meets the relevant standards at the tap and 'secure' if a management system is in place that identifies all potential risks and procedures are in place to manage these risks. Water Services Authorities should implement the (WHO) Water Safety Plan approach to the management of water supplies. Implementation of this approach will lead to a reduction in the levels of THMs in drinking water.

## Conclusion

Trihalomethanes are formed when chlorine, the most commonly used disinfection agent in Ireland, reacts with naturally occurring organic matter in raw water.

In 2010 there was a drop in the number of total THM exceedances in public drinking water supplies. Overall the situation is improving and the downward trend is expected to continue with the completion of remedial works on supplies on the Remedial Action List. However, exceedances in THM levels continue to be notified.

Studies examining the association between THMs and drinking water show that there may be associations with cancer. These associations are weak, are not consistently demonstrated in scientific studies and are unlikely to be large. However, the possibility that they exist remains.

When uncertainty such as this emerges in environment and health, a precautionary approach is needed.

EU and WHO drinking water standards are precautionary in that they include a substantial safety factor and are set at a level that protects the most vulnerable over a lifetime of consumption.

The precautionary approach, however, must be proportional to the risk and should be balanced with other more immediate and known serious risks.

The approach in Ireland should therefore be as follows;

1. Great effort should be made to minimise THMs in drinking water.
2. Comprehensive risk assessment of all breaches of the total THM parametric value should take place.
3. All regulated drinking water supplies with persistent or intermittent exceedances should go on the EPA Remedial Action List and the WSA should have an agreed plan of works in place with a precise timescale.

4. The real risk of inadequate chlorination, which can occur as a reaction to breaches of the parametric value, outweighs the risk associated with THMs and should be avoided. A balance must be struck between an uncertain, small and long-term risk associated with elevated THMs and the significant, large, immediate and serious risk associated with inadequate chlorination e.g. EColi O157 outbreak.
5. Optimising the removal and treatment of organic matter in raw water is paramount to reducing THMs in drinking water.
6. The Water Safety Plan approach, which identifies hazards to drinking water quality from catchment to consumer, should be adopted to ensure that the drinking water supply is safe and secure. Implementation of this approach will lead to a reduction in the levels of THMs in drinking water.

## References

1. European Communities (Drinking Water) (No. 2) Regulations. SI. No. 278 of 2007. (http://www.irishstatutebook.ie/2007/en/si/0278.html) Accessed 25/11/2011
2. WHO. Summary Statement. Trihalomethanes (bromoform, bromodichloromethane, dibromochloromethane, chloroform). 2004. (http://www.who.int/water_sanitation_health/dwq/chemicals/trihalomethanes_summary_statement.pdf) Accessed 18/10/2011
3. WHO. Preamble to the IARC Monographs on the evaluation of carcinogenic risks to humans. 2006. Lyon. International Agency for Research on Cancer. (http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf) Accessed 25/11/2011
4. WHO. Chlorinated Drinking Water; Chlorinated By-Products; Some other Halogenated Compounds; Cobalt and Cobalt Compounds (updated 1997). (IARC Monograph 52)1991. (http://monographs.iarc.fr/ENG/Monographs/vol52/volume52.pdf) Accessed 25/11/2011
5. Committee on the Toxicity Chemicals in Food, Consumer Products and the Environment. Second Statement on Chlorinated Drinking Water and Cancer. COC/08/S1 - May 2008. (http://www.iacoc.org.uk/statements/documents/SecondstatementonCBPsandcancerCOC08.S1.pdf)
6. Department of Health. Chlorinated drinking water and cancer. COC statement COC/99/S2 - May 1999. London. (http://www.advisorybodies.doh.gov.uk/coc/drink.htm)
7. Committee on the Toxicity Chemicals in Food, Consumer Products and the Environment. COT Statement on a SAHSU Study on Chlorination Disinfection By-Products and Risk of Congenital Anomalies in England and Wales. 2008. (http://cot.food.gov.uk/pdfs/cotstatementdbp200802.pdf) Accessed 25/11/2011

8. WHO. Trihalomethanes in Drinking-water. 2005. (http://www.who.int/water_sanitation_health/dwq/chemicals/THM200605.pdf) Accessed 25/11/2011

9. European Environment Agency. Late lessons from early warnings: the precautionary principle 1896-2000. 2001. Copenhagen. (http://www.eea.europa.eu/publications/environmental_issue_report_2001_22)

10. EPA Office of Environmental Enforcement. The Provision and Quality of Drinking Water in Ireland: A Report for the Year 2010. 2011. (http://www.epa.ie/downloads/pubs/water/drinking/)

11. EPA Office of Environmental Enforcement. Water Treatment Manual: Disinfection. 2011. Wexford. (http://www.epa.ie/downloads/advice/water/drinkingwater/name,31721,en.html)

12. World Health Organisation. Water Safety Plan Manual. Step-by-step risk management for drinking water suppliers. 2009. (http://whqlibdoc.who.int/publications/2009/9789241562638_eng.pdf) Accessed 25/11/2011