JOINT POSITION STATEMENT

Trihalomethanes and Haloacetic Acids in Drinking Water

This position paper has been developed by the Health Service Executive and the Environmental Protection Agency. It provides a summary of legislation, health impacts and interventions in relation to trihalomethanes and haloacetic acids in drinking water.

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KEY MESSAGES

If a water supply exceeds the parametric value for a disinfection by-product (DBP), efforts must be made to reduce DBP levels to below the parametric limit within a reasonable timeframe.

The current levels of DBP, including trihalomethanes (THMs) in water supplies in Ireland do not pose an acute risk to human health to warrant the introduction of prohibitive action(s). However, careful consideration should be applied around chronic risk to human health, given the seasonal variation in THM levels; these levels should therefore be reviewed on an individual supply basis to better quantify the overall risk to human health and the measures required for mitigation.

The potential risk to human health from THMs is much less than the risks from consuming water that has not been disinfected.

INTRODUCTION

Disinfection is a critical part of drinking water treatment in 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, which can lead to the formation of DBPs such as trihalomethanes (THMs) and haloacetic acids (HAAs). These are groups of organic chemicals, formed when chlorine reacts with naturally occurring organic matter or with bromine in water.

Total THMs in drinking water has a limit of 100 µg/l in the European Union (Drinking Water) Regulations of 2023.[1] Total THMs are made up of a group of four chemicals: chloroform, bromoform, dibromochloromethane (DBCM) and bromodichloromethane (BDCM). The Drinking Water Regulations introduced a new limit of 60 µg/l for total HAAs, a group of five chemicals. The individual components of total HAAs are monochloroacetic acid (MCA), dichloroacetic acid (DCA), trichloroacetic acid (TCA), monobromoacetic acid (MBA) and dibromoacetic acid (DBA). The new limit on HAAs will come into effect on 12 January 2026.

Most water supplies in Ireland are sourced from surface waters (i.e. rivers and lakes) and some groundwater sources are influenced by surface water, so raw water is likely to contain high levels of organic matter. THMs are formed when there is inadequate treatment of the water and/or poor control over the disinfection process itself. Optimising drinking water treatment processes, such as coagulation, flocculation and clarification (CFC) and filtration, before disinfection is therefore important in preventing the formation of DBPs.

Chlorine is used as a primary disinfectant in water treatment. It also provides a stable disinfectant residual, preserving the quality of the water through the distribution network up to

[1] Irish Statute Book, 2023. *S.I. No. 99/2023 – European Union (Drinking Water) Regulations 2023*. Available online: https://www.irishstatutebook.ie/eli/2023/si/99/made/en/print (date accessed: 18 February 2024).

the consumer's tap. This characteristic of chlorine makes it most suitable as a disinfectant, but also increases the risk of DBP formation by extending the contact time between chlorine and any organic matter in the water. Additional chlorine may be added at points in the distribution network to maintain disinfection throughout the distribution system.

Guideline levels are calculated to protect the most vulnerable sections of the population; for biochemical parameters in drinking water, this is generally small babies. Up to about 10 kg, babies require between 100–120 ml of fluid per kg of body weight. This is the time of greatest liquid consumption per body weight. Adults require approximately 30 ml of fluid per kg of 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.**

Guideline values are established on the basis of international risk assessments of the health effects associated with exposure to the chemical in water. **In developing national drinking water standards (or health-based targets) based on these guideline values, it will be necessary to take into consideration a variety of environmental, social, cultural, economic, dietary and other conditions affecting potential exposure, as well as the default assumptions that are used to derive the guideline values.** Exposure from chemicals in drinking water is typically minor in comparison with exposure from other sources (e.g. food, consumer products and air), with a few important exceptions (e.g. arsenic and fluoride). This may lead to national targets that differ appreciably from the guideline values. In some cases, it may be appropriate to take action to prevent exposure to a chemical from sources other than drinking water (e.g. lead from soldered cans and from petrol).

Table 1 shows the Drinking Water Regulations parametric value for total THMs. It also shows several World Health Organization (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.

Table 1: *Legal limits and guideline values for trihalomethanes*

	EU (Drinking Water) Regulations 2023 parametric value (µg/l)	WHO guideline values (µg/l)	WHO TDI (µg/kg/day)
Trihalomethanes (total)	100	Ratio ≤ 1*	–
Chloroform	–	300	15.0
Bromoform	–	100	17.9
Dibromochloromethane	–	100	21.4
Bromodichloromethane	–	60	–

For authorities wishing to establish a total THM standard to account for additive toxicity, the following fractionation approach could be taken:

$$\frac{C_{bromoform}}{GV_{bromoform}} + \frac{C_{DBCM}}{GV_{DBCM}} + \frac{C_{BDCM}}{GV_{BDCM}} + \frac{C_{chloroform}}{GV_{chloroform}} \leq 1$$

where C = concentration and GV = guideline value.

2 **Abbreviations:** **EU:** European Union; **WHO**: World Health Organization; **TDI:** tolerable daily intake; **C:** concentration; **DBCM:** dibromochloromethane; **BDCM:** bromodichloromethane; **GV:** guideline value. * The sum of the ratio of the concentration of each to its respective guideline value should not exceed 1.Error! Bookmark not defined.

Table 2 shows the Drinking Water Regulations parametric value for total HAAs. It also shows the available WHO guideline levels for individual HAAs.

Table 2: *Legal limits and guideline values for haloacetic acids*

	EU (Drinking Water) Regulations 2023 parametric value (µg/l)	WHO guideline values (µg/l)	WHO TDI (µg/kg/day)
Haloacetic acids (total)	60*	–	**–**
Monochloroacetic acid	–	20	**3.5**
Dichloroacetic acid	–	50**	**–**
Trichloroacetic acid	–	200	**32.5**
Monobromoacetic acid	–	^	**–**
Dibromoacetic acid	–	^	**–**

Abbreviations:
EU: European Union; **WHO:** World Health Organization; **TDI:** Tolerable daily intake.

* Effective from 12 January 2026.
** The guideline value is designated as provisional on the basis of technical achievability.
^ Available data inadequate to permit derivation of health-based guideline value.

EXPOSURE

Approximately equal contributions to total exposure to THMs come from four areas: ingestion of drinking water; inhalation of indoor air largely due to THM volatilisation from drinking water; inhalation and dermal exposure during showering or bathing; and ingestion of food. All but exposure from food arise primarily from drinking water.

HAAs do not readily volatilise and they do not absorb very readily through the skin. Therefore, the primary route of exposure is oral consumption (i.e. through drinking or eating).

TRIHALOMETHANES

THMs are a group of compounds that can form when the chlorine used to disinfect drinking water reacts with naturally occurring organic matter (e.g. decaying leaves and vegetation). The use of chlorine in the treatment of drinking water has virtually eliminated waterborne diseases, because chlorine can kill or inactivate most microorganisms commonly found in water. In Ireland, the main form of disinfection used in water treatment is chlorination. The health risks from DBPs, including THMs, are much less than the risks from consuming water that has not been disinfected. **Water suppliers should make every effort to maintain concentrations of**

[2] World Health Organization (WHO) 2022. *Guidelines for drinking-water quality: fourth edition incorporating the first and second addenda.* Available URL: https://www.who.int/publications/ (date accessed: 18/02/2024)

all DBPs as low as reasonably achievable without compromising the effectiveness of disinfection.

The regulated THMs in drinking water are chloroform, BDCM, DBCM and bromoform. Of these, chloroform has been most extensively studied, and there are some scientific data available on BDCM. However, insufficient data are available to develop a guideline for either DBCM or bromoform. Since chloroform is the THM most often found in drinking water, and generally at the highest concentrations, the THM guideline is based on health risks linked to chloroform. This guideline applies to the total concentration of chloroform, BDCM, DBCM and bromoform.

Health Effects

Human studies are suggesting a link between exposure to THMs and certain cancers (i.e. colorectal and bladder cancers). Human studies also suggest a link between reproductive effects and exposure to high levels of THMs. However, an increase in the concentration of THMs could not be linked to an increase in risk, suggesting the need for more studies.[3,4,5]

Preliminary animal studies indicate that BDCM and other THMs that contain bromine may be more toxic than chlorinated THMs such as chloroform. For this reason, and based on the availability of scientific data for BDCM, a separate guideline was also developed for BDCM. BDCM is considered to be a probable carcinogen in humans, with sufficient evidence in animals and inadequate evidence in humans. Animal studies have shown tumours in the large intestine in rats. Among the four THMs commonly found in drinking water, BDCM appears to be the most potent rodent carcinogen, causing tumours at lower doses and at more target sites than the other three compounds.

Exposure to BDCM at levels higher than the guideline value has also been linked to a possible increase in reproductive effects (specifically, increased risk for spontaneous abortion or stillbirth has been demonstrated in both animal and human studies) above what can normally be expected. Further studies are required to confirm these effects.

Chloroform

The weight of evidence for genotoxicity of chloroform is considered negative.[6] The International Agency for Research on Cancer (IARC) has classified chloroform as possibly carcinogenic to humans (Group 2B) based on limited evidence of carcinogenicity in humans

[3] Evlampidou, I., *et al*., 2020. Trihalomethanes in Drinking Water and Bladder Cancer Burden in the European Union. *Environmental Health Perspectives* 128(1): 017001. https://doi.org/10.1289/EHP4495
[4] World Health Organization (WHO), 2022. *Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First and Second Addenda*. Available online: https://www.who.int/publications/i/item/9789240045064 (date accessed: 29 July 2024).
[5] Health Canada, 2024. *Guidelines for Canadian Drinking Water Quality – Summary Tables*. Available online: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/reports-publications/water-quality/guidelines-canadian-drinking-water-quality-summary-table.html (date accessed: 29 July 2024).
[6] World Health Organization (WHO), 2022. *Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First and Second Addenda*. Available online: https://www.who.int/publications/i/item/9789240045064 (date accessed: 29 July 2024).

but sufficient evidence of carcinogenicity in experimental animals.[7] The weight of evidence for liver tumours in mice is consistent with a threshold mechanism of induction. Although it is plausible that kidney tumours in rats may similarly be associated with a threshold mechanism, there are some limitations of the database in this regard. The most universally observed toxic effect of chloroform is damage to the centrilobular region of the liver. The severity of these effects per unit dose administered depends on the species, vehicle and method by which the chloroform is administered.

Bromoform

In a National Toxicology Program (NTP)[8] bioassay, bromoform induced a small increase in relatively rare tumours of the large intestine in rats of both sexes but did not induce tumours in mice. Data from a variety of assays on the genotoxicity of bromoform are equivocal. IARC has classified bromoform in Group 3 (i.e. not classifiable as to its carcinogenicity to humans).[7]

Dibromochloromethane

In an NTP bioassay, DBCM induced hepatic tumours in female mice and possibly in male mice but not in rats. The genotoxicity of DBCM has been studied in a number of assays, but the available data are considered inconclusive. IARC has classified DBCM in Group 3 (not classifiable as to its carcinogenicity to humans) [7]

Bromodichloromethane

IARC has classified BDCM in Group 2B (possibly carcinogenic to humans).[7] BDCM gave both positive and negative results in a variety of *in vitro* and *in vivo* genotoxicity assays. In an NTP bioassay, BDCM induced renal adenomas and adenocarcinomas in both sexes of rats and in male mice; rare tumours of the large intestine (adenomatous polyps and adenocarcinomas) in both sexes of rats; and hepatocellular adenomas and adenocarcinomas in female mice. However, BDCM was negative for carcinogenicity in a recent NTP bioassay in which it was dosed in drinking water. Exposure to BDCM above the guideline value has also been linked to a possible increase in reproductive effects (specifically, increased risk for spontaneous abortion or stillbirth). This has been demonstrated in both animal and human studies.

HALOACETIC ACIDS

Like THMs, HAAs are a group of compounds that can form when the chlorine used to disinfect drinking water reacts with naturally occurring organic matter (e.g. decaying leaves and vegetation).

The regulated HAAs are MCA, DCA, TCA, MBA and DBA. Of these, DCA and TCA have been most extensively studied, and there are some scientific data available on MCA and DBA. However, insufficient data were available to allow the development of an individual guideline for MBA.

[7] International Agency for Research on Cancer (IARC), 2019. *IARC Monographs on the Identification of Carcinogenic Hazards to Humans*. Available online: https://monographs.iarc.who.int/home/iarc-monographs-general-information/ (date accessed: 18 February 2024).
[8] National Toxicology Program .US Department of Health and Human Services https://ntp.niehs.nih.gov

Levels of HAAs are generally higher in treated surface water than in treated groundwater, because of the high organic content in lakes and rivers. Levels of HAAs are usually higher in warmer months, because of the higher concentrations of precursor organic materials in the raw water and especially because the rate of formation of DBPs increases at higher temperatures. It should be noted that the presence of by-products such as MBA and DBA will also depend on the presence of bromine in the source water.

Available data suggest that drinking water may be a significant source of exposure to HAAs, but there are few data available to determine the exposure from other sources, such as food and air.

Health Effects

The health effects associated with exposure to HAAs will vary with the specific compound. The EU (Drinking Water) Regulations 2023 parametric value for total HAAs is 60µg/l. WHO guideline values are established for three of the five individual HAAs as set out in table 2 above.

Monochloroacetic acid

No evidence of carcinogenicity of MCA was found in 2-year gavage bioassays with rats and mice. MCA has given mixed results in a limited number of mutagenicity assays and has been negative for clastogenicity in genotoxicity studies. IARC has not classified the carcinogenicity of MCA.[7]

Dichloroacetic acid

DCA has been used as a therapeutic agent to treat lactic acidosis, diabetes and familial hyperlipidaemia in humans. IARC reclassified DCA as Group 2B (possibly carcinogenic to humans) in 2002, based on the absence of data on human carcinogenicity and sufficient evidence of its carcinogenicity in experimental animals.[7] This classification was based primarily on findings of liver tumours in rats and mice. Genotoxicity data are considered to be inconclusive, particularly at lower doses. Glycogen deposition, peroxisome proliferation, changes in signal transduction pathways and DNA hypo-methylation have all been observed following DCA exposure and have been hypothesised to be involved in its carcinogenicity. However, the available data are not sufficient to establish a cancer mode of action with reasonable certainty, especially at the very low exposure levels expected to apply to humans ingesting chlorinated drinking water. Recent data suggest that there may be more than one mechanism leading to tumours, as altered hepatic foci from treated mice were found to have three different types of cellular characteristics.

Trichloroacetic acid

TCA has been shown to induce tumours in the liver of mice. It has given mixed results in *in vitro* assays for mutations and chromosomal aberrations and has been reported to cause chromosomal aberrations in *in vivo* studies. IARC has classified TCA in Group 3 (not classifiable as to its carcinogenicity to humans).[7] The weight of evidence indicates that TCA is not a genotoxic carcinogen.

Monobromoacetic acid

MBA is unclassifiable with respect to carcinogenicity in humans, based on inadequate data from animal studies.

Dibromoacetic acid

DBA is considered to be probably carcinogenic in humans, based on sufficient evidence in animals and inadequate evidence in humans. Animal studies have shown links between exposure to DBA and tumours in several organs in both mice and rats.

There is only one study currently available looking at the incidence or significance of health effects associated with human exposure to HAAs. A small population-based study that was conducted did not find a link between exposure to HAAs and risk of stillbirths. Other human studies on the incidence of cancer or reproductive effects have been conducted with chlorinated disinfection by-products, but not specifically with HAAs.

Some animal studies suggest a possible link between developmental effects (heart defects) and exposure to DCA or TCA, whereas other studies fail to show a link. Animal studies also suggest a possible link between male reproductive effects (on sperm and sperm formation) and exposure to DCA or DBA at levels significantly higher than those found in drinking water. Further studies are required to confirm these effects as well as their long-term significance to human health.

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CAVEAT AROUND UNDERSTANDING 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 THMs 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. **Where evidence with regard to the environment and health is uncertain, human exposure to the hazard should be minimised/reduced (i.e. where exceedances are persistent and remedial actions are required to minimise human health impacts, the level and duration of exposure should be as low and short as possible).** It is important to note that precautionary action should be proportional to likely benefits and potential harms.

TRIHALOMETHANE AND HALOACETIC ACID MONITORING

The Drinking Water Regulations have specified a limit (parametric value) of 100 µg/l for THMs in drinking water since 2008.[1]

The 60 µg/l limit (parametric value) for HAAs was introduced with the 2023 Drinking Water Regulations.[1] Monitoring of HAAs was not previously required in Ireland, and the new limit will come into effect on 12 January 2026.

The Environmental Protection Agency (EPA) publishes annual reports on both public and private drinking water supplies, which include summary details of THM compliance. These drinking water reports can be found on the EPA website[9].

The frequency of monitoring required by the regulations is based on the size of a drinking water supply. Water suppliers also carry out additional investigative or operational monitoring for DBPs to evaluate the risk of DBP formation. The results of such monitoring are also subject to the THM and HAA parametric values.

RISK ASSESSMENT

Where a THM exceedance is determined, a water supplier should carry out a risk assessment (RA). If following the RA, there is a perceived risk to human health, the water suppliers shall consult with the Health Service Executive (HSE) (Regulation 15, Drinking Water Regulations 2023).[1]

CHEMICAL EXCEEDANCES

A typical RA in respect of a chemical exceedance considers: 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 a remediation timeframe; checks to assess if the sample is representative of the supply or localised; remedial actions already taken by the water supplier(s); 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 by the water supplier(s), the HSE also has regard to the risk to human health that would be caused by the interruption of the water supply or restriction of water use.

Exceedances of Trihalomethanes

In addition to the above, there are further risk assessment considerations specifically for THMs. Total THMs are monitored under the Drinking Water 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

[9] Available online: https://www.epa.ie/publications/compliance--enforcement/drinking-water/annual-drinking-water-reports/

of an individual. More frequent testing may be required to assess this. Finally, in an effort to reduce THMs there is a risk of inadequate chlorination and incomplete disinfection, which may result in human health impacts such as individual or groups of individuals reporting gastrointestinal illnesses.

Exceedances of Haloacetic Acids

Evaluation for this will come into effect from 12th January 2026.

LEGISLATIVE REQUIREMENTS

The Drinking Water Regulations 2023 set out requirements for drinking water quality, safety and management, which apply to all regulated drinking water supplies.[1] The EPA is the supervisory authority in relation to public water supplies, and local authorities are supervisory authorities in relation to private water supplies. Both the EPA and local authorities have enforcement powers under the regulations.

The Drinking Water Regulations set drinking water quality limits, known as parametric values, which apply to all regulated drinking water supplies.[1] Each water supplier must investigate failures to meet a parametric value to identify the cause of the failure, and take action to restore drinking water quality. Where a failure is considered as a risk to human health, the water supplier must consult with the HSE on appropriate actions to protect human health. The regulations also require the water supplier to notify their supervisory authority of most failures.

INTERVENTIONS

The formation of THMs and HAAs are influenced by the concentration and nature of organic material in the raw water, the amount of free chlorine in the water, the length of chlorine contact time, the pH and temperature of the water, and the amount of organic matter in the water distribution network. Optimum control of all these factors is necessary to keep THM and HAA concentrations to a minimum.

The EPA's *Water Treatment Manual: Disinfection* (2011)[10] identifies best practices in the treatment of water to reduce THM formation:

- Protection of the source of the water supply to reduce the level of organic matter to be removed by the water treatment plant.
- Avoid chlorinating untreated surface water and treat water to remove precursors (colour, total organic carbon, ultraviolet (UV) light absorbance) as far as possible.
- Optimisation of chemical dosing, CFC and filtration treatment stages at the water treatment plant to remove organic matter.
- Limit free chlorine concentrations and contact times to the minimum required for the process (and distribution systems).
- Dechlorinate as soon as possible after breakpoint chlorination.

[10] Environmental Protection Agency (EPA), 2011. *Water Treatment Manual: Disinfection*. Available online: https://www.epa.ie/publications/compliance--enforcement/drinking-water/advice--guidance/Disinfection2_web.pdf (date accessed: 23 July 2024).

- Consider using chloramination to provide residual disinfection. In this disinfection process, chlorine is added as the primary disinfectant followed by ammonia to form monochloramine, which provides stable residual disinfection in the network.
- Keep water pH low, as THM formation increases with increasing pH.
- Consider the use of an alternative chemical disinfectant or UV light for primary disinfection.
- Manage the distribution network to prevent the build-up of organic matter in the pipework (e.g. by flushing mains or cleaning reservoirs).

The manual contains similar advice for minimising the formation of HAAs. One exception in terms of the chemistry of HAA formation is pH level, since HAA formation increases with decreasing pH.

The EPA has also published a technical advice note aimed at water suppliers, detailing how to investigate and reduce the formation of DBPs.[11]

Water Safety Plans

The EPA continues to endorse a risk management approach to ensuring drinking water is both safe and secure. A supply is deemed safe if it meets the required quality at the consumer's tap, and secure if a management system is in place that identifies potential risks, with measures in place to manage these risks, for example by implementing the WHO Water Safety Plan approach.[3] Water suppliers should implement water safety plan methodologies for the management of water supplies to reduce the formation of DBPs in drinking water. The Drinking Water Regulations 2023 introduced a legal requirement for water suppliers to use a Water Safety Plan method of risk assessment, which will come into effect from 12 January 2029.

Remedial Action List

The EPA has identified a list of "at-risk" public drinking water supplies called the Remedial Action List (RAL). Water supplies are considered at risk if safety and/or security of the supply is not acceptable. For each of the supplies on the RAL, the water supplier is required to put an action plan with timelines in place to rectify the issues identified. A supply with THM issues may be placed on the EPA's RAL if there are persistent failures to meet the 100 µg/l THM limit and if processes are not sufficient to maintain THM levels below the limit.

The list of public water supplies currently on the RAL, along with the proposed remedial measures and associated time frames, is available on the EPA website[12].

Water supplies removed from the RAL following works to restore THM compliance have usually been upgraded to provide enhanced levels of organic matter removal within the water

[11] Environmental Protection Agency (EPA), 2013. *EPA Drinking Water Guidance on Disinfection By-Products: Advice Note No. 4. Version 2. Disinfection By-Products in Drinking Water*. Available online: https://www.epa.ie/publications/compliance--enforcement/drinking-water/advice--guidance/DrinkingWaterGuide4_v8.pdf (date accessed: 23 July 2024).

[12] Available online: https://www.epa.ie/our-services/compliance--enforcement/drinking-water/remedial-action-list/

treatment plant, through improvements to chemical dose and pH control, CFC processes and filtration. The other main type of upgrade involves a change in disinfection process, such as a move to UV or chloramination, to reduce the reliance on chlorination. The success of the upgrades is measured though a programme of monitoring, to verify compliant THM results, before the EPA will remove the water supply from the RAL.

CONCLUSIONS

Although there is no conclusive evidence to suggest that THMs cause cancer in humans, some studies have indicated that high doses of THMs may result in cancers in animals such as mice and rats. Further research is necessary to determine the extent of the potential risks. As a precautionary measure, drinking water guidelines have been established to ensure that the potential health risks from THMs are extremely low over an average lifetime of exposure, which is typically around 70 years.

The health effects associated with exposure to HAAs vary with the specific compound. Long-term exposure to some types of HAAs may increase the risk of liver cancer. The guideline level for HAAs has been set at a level where exposure over a lifetime (set at 70 years) may have a low level of risk for the development of cancer.

The Drinking Water Regulations 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.[4]

The approach in Ireland should therefore be as follows:

- Great effort must be made to minimise DBPs in drinking water through optimising treatment for removal of organic matter and maintenance of distribution networks.
- Comprehensive risk assessment of all breaches of the total THM and HAA parametric value must take place.
- Public drinking water supplies with persistent exceedances will go on the EPA's RAL and the water supplier will be required to have an agreed plan of works in place with a timescale for restoring compliance.
- The real risk of inadequate chlorination outweighs the potential risk associated with DBPs and therefore inadequate chlorination should be avoided. A balance must be struck between an uncertain, small and long-term risk associated with elevated DBPs and the significant, large, immediate and serious risk associated with inadequate chlorination, e.g. sporadic cases or outbreaks of gastrointestinal illness.
- The Water Safety Plan approach, which identifies hazards to drinking water quality from catchment to consumer, must be adopted to ensure that drinking water supplies are safe and secure. Implementation of this approach will lead to a reduction in the levels of DBPs in drinking water and will be a legal requirement for drinking water supplies from 12 January 2029.