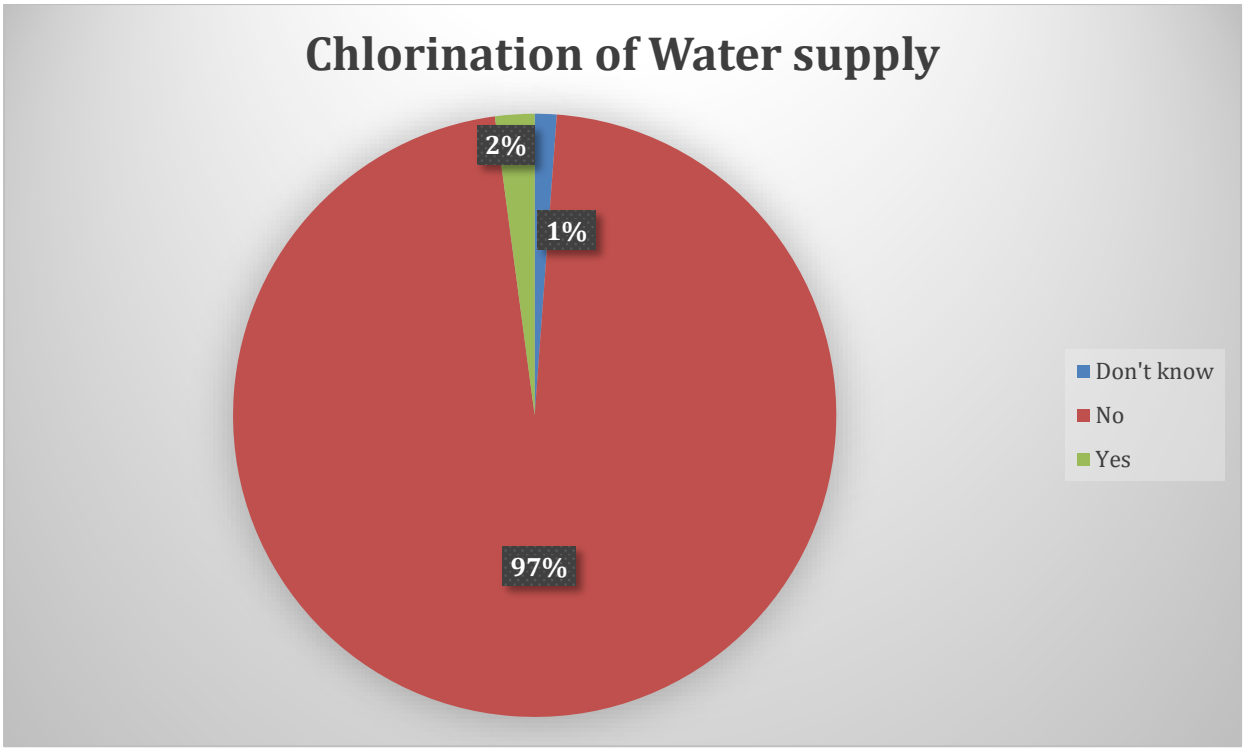
Long Term Plan 2018-28 Submissions Overview – Chlorination of the Geraldine and Pleasant Point Water Supplies

The Consultation Document notes a provision in the Long Term Plan budget for chlorination treatment upgrades for the Geraldine and Pleasant Point Water supplies.

427 submitters expressed a view on the chlorination of the Geraldine Water supply, with 97% opposing chlorination. In addition, there were two submissions opposing chlorination of the Pleasant Point Water Supply, and two submissions against chlorination of both water supplies.

In addition to these submissions, a petition signed by 296 people opposing the chlorination of the Geraldine Water supply has been received. A number of those who signed the petition also lodged a submission to the Long Term Plan.



Overview

Opposing chlorination

1 *"We do NOT want out drinking water chlorinated - evidence of health risks from chlorine are clear*
We do not want to drink water that smells like chlorinated swimming pools"

2 *"Do not chlorinate Geraldine drinking water. Why chlorinate? is there are alternative sources eg deep aquifers to prevent chlorination of water is a last resort?"*

3 *"Chlorination of Geraldine Water. I am totally against this action, and very worried by it. The Council has admitted that this is unnecessary and there is no definitive research to prove that it is a totally safe option. While there is some danger of contamination, the problem in Hastings was that it wasn't noticed in time. With regular testing this should prevent the need to pollute our clean water unless an actual problem occurs. Another option could be to provide each household with a filter- this would be cheaper than ongoing chlorination I'm sure (although I haven't researched this) and leaves us with the freedom of choice of whether to have chemically treated water or not."*

4 *"The UV (ultra - violet) treatment of the Geraldine water supply has provide a healthy, clean water quality for many years. I strongly object to chlorination of our drinking water as it is associated with substantially raising the risk of cancer. The suggestion is quite frankly bureaucratic nonsense."*

Supporting chlorination

5 *"Safety is paramount. While the water is now said to be safe there is no certainty that this will continue. The "adverse" effects of chlorine are not scientifically proven and where chlorine has been used for year, no adverse effects have been seen. Council must take proven safety measures BEFORE problems arise"*

6 *"If the science and experts suggest this - I support the experts.*
Not a fan of gastro issues if water is compromised, mitigation is key."

Topics/Sub-topics for Officer Comment (from Submitter Comments)

1) Health & Wellness (identified in 58 submissions)

Officer comment:

7 Chlorine has been used as a water disinfectant for over 100 years, it is a major factor in reducing illness and deaths due to waterborne diseases, and remains the most common disinfectant around the world. However, Chlorine itself is a dangerous chemical and there are misconceptions and misunderstandings related to the presence of chlorine in drinking water.

8 The International Agency for the Research of Cancer (IRAC) has evaluated the safety of chlorine in drinking water and has classified chlorine as neither a carcinogen nor a possible carcinogen. The Drinking Water Standards for New Zealand (DWSNZ) has set a maximum acceptable level for chlorine in drinking water, which is the same as the World Health Organisation (WHO) guideline value, at 5 mg/L. WHO indicate that this value is conservative, as no adverse effect level was identified, and typical levels in disinfected drinking water supplies are less than 1 mg/L.

9 There are some people that may be highly sensitive to low levels of chlorine in drinking water. However, this impacts on a very small percentage of the population. Council is not aware of any significant issue in any other of the reticulated drinking water systems in the district that are chlorinated. In very extreme cases measures can be made such as the installation of a tap filter for drinking water.

10 Drinking water, with relatively low levels of chlorine does not have any detrimental impact on plants through garden watering.

11 The other perceived health issue with the chlorination of drinking water is the formation of chlorination Disinfection By-Products (CxDBP). Chlorine, in reaction with natural organic matter (NOM) that may be present in source water, can form a wide range of by-products. In particular, trihalomethanes and haloacetic acids are CxDBPs identified in DWSNZ as Priority2 (P2) determinands. However, none of the DBPs that are P2 determinands are classified as carcinogens to humans by IRAC, and while the United States Environmental Protection Agency (USEPA) classifies some as likely human carcinogens, this has not been confirmed in any case.

12 So the USEPA have derived a 'cancer risk' for these compounds. The setting of Maximum Acceptable Values for chemical determinands in water is based on the possible effects of an individual drinking two litres a day for 70 years. The USEPA cancer risk from a lifetime exposure to drinking water with 1 microgram per litre of DBPs increases a person's chance of developing cancer by 0.2 to 2 chances in a million. In other words with a million people drinking that water there might be 0.2 to 2 additional cancer cases in a lifetime.

13 Dr Steve Hrudey from the University of Alberta is a world expert on DBP's, and has provided personal communications to Council on the subject. Dr Hrudey chaired an expert panel in 2014 for the Water Research Foundation in Washington which completed a complete overview of all the evidence to date concerning CxDBPs. Bladder cancer is the most plausible cancer outcome that might be associated with CxDPBs. However Dr Hrudey said "The hard reality is the evidence is not consistent and has not established causation". He also explained that it was an interdisciplinary expert panel and "be assured that if we had found any convincing evidence of public health risk that warranted more stringent regulation, this panel would have had no hesitation to declare a clear message for public health protection".

14 Dr Hrudey noted that "maintaining current precautionary guideline levels for CxDBPs is sensible, but there is no justification for any additional lowering of these values". The abstracts from two published papers by Dr Hrudey are attached.

15 The formation of CxDBPs is directly related to the NOM content of the raw water. So the lower the concentration of NOM the lower the potential for CxDBP production. A report has been produced by the Institute of Environmental Science and Research (ESR) for the Medical Officer of Health regarding

chlorination of the Geraldine and Pleasant Point water supplies, and further information provided by the Drinking Water Assessor (both attached). The Drinking Water Assessor states "Given the low turbidity and the fact both supplies are ground water they do not contain organic content such as you would find with surface water, and hence do not present a situation where there is a significant risk of byproduct formation". The ESR report makes an assessment of the likely worst case values for CxDBPs, and concludes "the levels of DBP formation in these supplies are likely to be well below levels causing a significant risk to health over a lifetime of consumption of the water".

16 All advice, including the Medical Officer of Health, the Drinking Water Assessor, ESR, WHO and the USEPA, all conclude that the risks to health from these byproducts are extremely small compared to the risks associated with inadequate disinfection. The Ministry of Health's Guidelines for Drinking-water Quality Management for New Zealand states that the microbiological quality of the water must never be sacrificed just to minimise disinfection by-product formation, (the bold highlight is included in the Guidelines).

2) No need (identified in 35 submissions)

Officer comment:

17 The raw water sources for the Geraldine and Pleasant Point water supplies are relatively shallow ground water bores. As noted in the Drinking Water Assessor's report attached, both supplies have turbidity that in most circumstances complies with the UV requirements for turbidity in the DWSNZ. Therefore the UV disinfection treatment of these supplies usually complies with the microbiological requirements of the DWSNZ, including for bacteria and protozoa. There is currently nothing more that needs to be done in association with the raw water treatment, for example increasing the size of the UV plant or installing a filtration plant or deeper bores.

18 The fundamental structure for the provision of safe drinking water in the DWSNZ is based on what is termed a 'multi barrier' approach. This approach relies on individual layers of treatment that collectively provide the protection that all water consumers expect in relation to health risks. There is always the potential for systems to fail, so although each treatment barrier itself may not be sufficient to adequately treat the water, the implementation of multiple barriers provides greater assurance that the water is safe.

19 This is likened to 'slices of Swiss cheese' where each slice may have a hole but if you put enough of them together all the holes are blocked.

20 It should be noted that in relation to the Havelock North incident, in effect there was only one barrier, which was the reliance on the bore water as being 'secure' (and unlikely to be contaminated). When this system failed there was no other protective barrier. Subsequently the secure groundwater classification has been withdrawn from the DWSNZ.

21 Although there are mitigation measures in place to minimise the potential of the UV treatment system not performing adequately, this does remain as a risk.

22 It should also be noted that insufficient information exists regarding the removal or inactivation of viruses through the various processes used in drinking-water treatment. Consequently, while DWSNZ does not include viral criteria, it is intended they will be included in a future standard. The Guidelines for Drinking-water Quality Management for New Zealand notes that UV treatment is less effective at killing viruses than the other disinfectants recognised in DWSNZ.

23 There are also risks to the safety of the drinking water delivered to the consumers through recontamination within the distribution system. This recontamination can occur via a number of routes such as: backflow of contaminated water from a property back into the reticulation; or in conjunction with damage to the reticulation network; cross contamination by someone working on the reticulation; or through 'regrowth' where the regrowth of microorganisms in a distribution system may occur, even after disinfection.

24 Although the risk of recontamination within the distribution system may not be high, if such an incident occurred there are currently no barriers in place to provide protection to every consumer.

25 Monitoring of the water quality within the distribution system is carried out. This monitoring provides a statistical confidence that there has not been a recontamination of the reticulated water, however this monitoring would only confirm a recontamination incident after the event had already occurred and if it was widespread. It also provides an indication of the need for improved water treatment if it identifies the presence of bacteria. The monitoring of the water within the Pleasant Point and Geraldine reticulations has at times shown the unexplained presence of bacteria.

26 A major advantage of chlorination is that it produces a residual disinfectant that is moderately persistent. It is not so persistent as to not breakdown or to remain indefinitely, as it will dissipate completely from drinking water over a period of time. However, this residual can offer protection for water in the distribution system pipework, and therefore provide another barrier for all drinking water consumers.

27 An option that could be considered is the replacement of all connection 'tobies' with new style models that include non-testable backflow prevention devices. Based on an estimate of the number of tobies that would need to be installed, along with the associated lateral connections that are greater than 50 years old, it is estimated that the cost for this would be approximately $2,000,000. It should be noted that this option only provides some mitigation to one recontamination route and does not provide a barrier for treatment plant failure.

28 The Guidelines for Drinking-water Quality Management for New Zealand, from the Ministry of Health, states:

29 *"Good microbiological quality of water at the consumer's tap is most reliably achieved by ensuring that the water entering the distribution system is microbiologically safe, and that there is a residual disinfectant in the distribution system to minimise the impact of any regrowth or contamination that enters the distribution system".*

30 It should also be noted that following the Havelock North drinking water contamination incident, the subsequent Government Inquiry recommended that:

31 *"Appropriate and effective treatment of drinking water should be mandated by law or through the DWSNZ for all supplies (networked and specified self-suppliers). This should include a residual disinfectant in the reticulation."*

and

32 *"Provision should be made for exemptions to mandatory treatment only in very limited circumstances."*

3) Retain/Adapt present treatment (identified in 25 submissions)

Officer comment:

33 As noted above, the existing UV treatment system is adequate to treat the raw water for bacteria and protozoa. The main risk at issue is that of recontamination or regrowth within the distribution system. This risk would not be addressed by modifying the existing treatment system, such as increased UV irradiation, filtration, or extending the depths of bores, unless a residual disinfectant was also included in the treatment.

4) Use chlorine in emergencies (identified in 9 submissions)

Officer comment:

34 As noted above, monitoring of the water quality within the reticulation is carried out, as is required by the DWSNZ, however this is only a very small fraction of the water supplied. If the presence of bacteria is identified in routine monitoring, a 'shock' dose of chlorine is usually applied to the water supply and further sampling carried out. Based on the sampling results there are procedures set out in DWSNZ where the water supplier's response can escalate to issuing a "Boil Water Notice". These procedures would remain even with chlorination, in the event of an incident. A major constraint is the time delay between when an incident occurs and when results from sampling are available.

35 There are also standard procedures set for carrying out work and maintenance on the reticulation to minimise the risk of contamination. This includes swabbing pipes and fittings with chlorine mixtures, and assessing work in relation to risk and taking samples from the reticulation in the vicinity of work sites.

5) Taste/Smell (identified in 17 submissions)

Officer comment:

36 The DWSNZ and the Ministry of Health's Guidelines for Drinking-water Quality Management for New Zealand also make it clear that the microbiological quality of the water must never be sacrificed for the sake of aesthetic characteristics. The taste and odour of drinking water is purely a personal preference, while the safety of those consuming the drinking water is the utmost priority.

37 As noted in the report from ESR (attached), when a previously unchlorinated water supply is then chlorinated, there is likely to be a period of production of chlorinous tastes and odours as the natural biofilm on the inside of the distribution system is 'burnt' off. These potential elevated levels of tastes and odours will dissipate once the reaction with the biofilm is complete. The taste and odour will not be as pronounced as swimming pool water.

6) Other (identified in 27 submissions)

38 (This ranges from comments on cost, investigate other systems, address industry pollution, improve water quality, freedom of choice)

Officer comment:

39 Chlorination is the most efficient and effective method for providing a disinfectant residual within the distribution system, with less potential operational issues than other processes such as treating with chloramines, iodine or potassium permanganate, or in comparison with installing filters on all properties.

40 Council is working closely with the Regional Council to better manage the implementation of controls in the Community Drinking Water Supply Protection Zones. These zones identify the areas of greatest risk of having detrimental impacts on the quality of the water supplies, and have been established in order to minimise those risks by controlling the land use activities in those areas. Council is also represented on the OTOP Zone Committee which is recommending the implementation of various land use controls.

41 The issue with having freedom of choice in relation to chlorinating drinking water is that as there is no other practical choice than the reticulated water supply, if there is a contamination incident it would likely occur without any warning or indication until unsuspecting consumers were already infected.

Attached Documents:

- #1153994 Chlorination of the Geraldine and Pleasant Point water supplies, by Peter Cressey and Chris Nokes from ESR
- #1154081 Geraldine and Pleasant Point Chlorination - emails from Medical Officer of Health Cheryl Brunton and Drinking Water Assessor Denise Tully
- #1153998 Chlorination of Drinking-water – Health and Practical Considerations, by Scott Rostron from the Ministry of Health
- #1154163 Abstracts from two published papers by Dr Steve Hrudey
- #1153996 Cancer Myths by the Western Australia Cancer Council, provided by the Drinking Water Assessor

Not Attached, but referenced

- Drinking-water Standards for New Zealand 2005 (Revised 2008)
- Guidelines for Drinking-water Quality Management for New Zealand (Updated March 2018)

Attachment 1: Chlorination of the Geraldine and Pleasant Point water supplies, by Peter Cressey and Chris Nokes from ESR

17 April 2018

Prepared by Peter Cressey and Chris Nokes

Risk & Response and Social Systems Group, ESR

Introduction

Community and Public health (CPH) has sought advice concerning the proposed chlorination of the Geraldine and Pleasant Point water supplies. The advice requested is aimed at addressing questions the communities may have regarding disinfection by-products formed in the supplies as the result of chlorination.

This note is in three sections. The first section provides generic information about disinfection by-product (DBP) toxicity, the second section discusses likely DBP formation specifically in the Geraldine and Pleasant Point supplies and the third section provides more general observations about the introduction of chlorine into unchlorinated supplies.

Summary

None of the DBPs that have been assigned as P2 determinands (ie, found at concentrations greater than 50% of their MAV) in New Zealand are presently classified as carcinogenic to humans by IARC.

Although determinands, such as total/dissolved organic carbon and bromide, which would be helpful to estimate likely levels of DBP formation in the Geraldine and Pleasant Point water supplies are unavailable, estimates can be made based on UV percentage transmittance measurements. On the basis of the water quality data available, the levels of DBP formation in these supplies are likely to be well below levels causing a significant risk to health over a lifetime of consumption of the water, based on our present knowledge of DBP toxicity.

In the light of this finding, it is reasonable to conclude that the public health risks (bacterial or viral infection) from not chlorinating these supplies would be greater than the risks associated with the chronic ingestion of the low DBP concentrations expected from chlorinating the supplies.

Cancer risks associated with disinfection by-products

While a wide range of compounds may be formed by the reaction of chlorine disinfectants with other components present in water only trihalomethanes (THM) and haloacetic acids (HAA) in total or specific THM (bromodichloromethane) or HAA (dichloroacetic acid, trichloroacetic acid) have been assigned as Priority 2 (P2) determinands for drinking-water supplies in New Zealand.

THM

Under the *Drinking-water Standards for New Zealand 2005 (revised 2008)* (the Standards), THM includes the single halogen species chloroform ($CHCl_3$) and bromoform ($CHBr_3$) and the mixed species bromodichloromethane ($CHBrCl_2$) and dibromochloromethane ($CHClBr_2$). Six iodine-containing THM may occur, but these are not currently included in the definition of THM under the Standards. Given the known low iodine status of the New Zealand environment (Hercus et al., 1925), elevated levels of iodo-THMs in New Zealand drinking-waters is unlikely.

Chloroform is usually the dominant THM present in chlorine-disinfected waters (Ministry of Health, 2005; WHO, 2011).

For the four compounds included in the definition of THM, evidence for carcinogenicity is equivocal (WHO, 2011). More recent epidemiological studies have generally not found associations between exposure to THM in drinking water and a variety of cancer types (Do et al., 2005; Font-Ribera et al., 2018; Infante-Rivard et al., 2001; Villanueva et al., 2017; Vinceti et al., 2004). Specifically:

- Chloroform has been considered by the International Agency for Research on Cancer (IARC), which concluded that there was sufficient evidence for the carcinogenicity of chloroform in laboratory animals, but inadequate evidence for human carcinogenicity (Group 2B possibly carcinogenic to humans) (IARC, 1999a). There is only weak evidence for the genotoxicity of chloroform and it does not appear to be mutagenic.

- Bromoform has been considered by IARC, which concluded that there was no relevant epidemiological data and limited evidence for the carcinogenicity of bromoform in laboratory animals. IARC concluded that bromoform was not classifiable with respect to human carcinogenicity (Group 3) (IARC, 1999b). Some recent epidemiological studies have supported an association between cancer and bromoform exposure (Bove et al., 2007a; b; Min and Min, 2016; Rahman et al., 2014). The US Environmental Protection Agency (USEPA) have derived an oral cancer slope factor for bromoform of 7.9×10^{-3} $(mg/kg\ bw/day)^{-1}$ [1].

- Bromodichloromethane (BDCM) has been considered by IARC, which concluded that there was no relevant epidemiological data, but sufficient evidence for the carcinogenicity of BDCM in laboratory animals. IARC concluded that BDCM was possibly carcinogenic to humans (Group 2B) (IARC, 1999b). BDCM has been shown to induce tumours (liver, kidney, large intestine) in both rats and mice and cancer slope factors in the range $4.2\text{-}4.8 \times 10^{-3}$ $(mg/kg\ bw/day)^{-1}$ have been derived (IPCS, 2000). A greater slope factor was derived by USEPA (6.2×10^{-2} $(mg/kg\ bw/day)^{-1}$) [2]. BDCM was marginally associated with an increased rectal cancer risk in an epidemiological study (Bove et al., 2007b).

[1] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0214_summary.pdf Accessed 16 April 2018

[2] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0213_summary.pdf Accessed 16 April 2018

- Dibromochloromethane (DBCM) has been considered by IARC, which concluded that there was no relevant epidemiological data and limited evidence for the carcinogenicity of DBCM in laboratory animals. IARC concluded that DBCM was not classifiable with respect to human carcinogenicity (Group 3) (IARC, 1999b). Some subsequent epidemiological studies have provided evidence of positive associations between DBCM exposure and cancer endpoints (Min and Min, 2016). The USEPA have derived an oral cancer slope factor for DBCM of 8.4×10^{-2} $(mg/kg\ bw/day)^{-1}$ [3].

Chloroform does not appear to be carcinogenic. There is some evidence of carcinogenicity for the brominated THMs.

HAA

In New Zealand, maximum acceptable values (MAVs) have been assigned for three HAA: monochloroacetic acid, dichloroacetic acid and trichloroacetic acid. While brominated acetic acids may form in waters containing bromide ions, WHO concluded that there was insufficient data on these compounds to propose a guidance value (WHO, 2011). No studies were found in the scientific literature to update this opinion. With reference to the chlorinated acetic acids:

- Monochloroacetic acid (MCAA) has not been shown to be carcinogenic in animal studies (WHO, 2011) and has not been assessed by IARC or USEPA. No recent epidemiological studies were found relating MCAA exposure to cancer endpoints.

- Dichloroacetic acid (DCAA) has been considered by IARC, which concluded that there was sufficient evidence for the carcinogenicity of DCAA in laboratory animals, but inadequate evidence for human carcinogenicity (Group 2B possibly carcinogenic to humans) (IARC, 2014). While liver tumours were induced in rats and mice treated with DCAA, genotoxicity data were inconclusive (WHO, 2011). No further epidemiological studies were found to update the IARC opinion. USEPA have derived an oral cancer slope factor of 5×10^{-2} $(mg/kg\ bw/day)^{-1}$ [4].

- Trichloroacetic acid (TCAA) has been considered by IARC, which concluded that there was sufficient evidence for the carcinogenicity of TCAA in laboratory animals, but inadequate evidence for human carcinogenicity (Group 2B possibly carcinogenic to humans) (IARC, 2014). WHO concluded that the weight of evidence suggests that TCAA is not a genotoxic carcinogen (WHO, 2011). USEPA concluded that there was suggestive evidence of carcinogenic potential for TCAA and derived an oral cancer slope factor of 7×10^{-2} $(mg/kg\ bw/day)^{-1}$ [5].

Conclusions

None of the disinfection by-products that have been assigned as P2 determinands in New Zealand are classified as carcinogenic to humans by IARC. While USEPA classifies

[3] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0222_summary.pdf Accessed 16 April 2018

[4] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0654_summary.pdf Accessed 16 April 2018

[5] https://cfpub.epa.gov/ncea/iris/iris_documents/documents/subst/0655_summary.pdf Accessed 16 April 2018

some of these compounds as likely human carcinogens, this has not been confirmed in any case. The most frequently detected disinfection by-product (chloroform) is also the most studied and the weight of evidence suggests that chloroform is unlikely to be carcinogenic. While there is somewhat more evidence implicating the brominated THM in cancer causation, these compounds will only be formed where there is a significant concentration of bromide ions in the source water. This is little evidence to assess the human carcinogenicity of HAA.

Given these comments, USEPA have derived oral cancer slope factors for many of these compounds, with values in the range 0.79-8.4 x 10^{-2} (mg/kg bw/day)$^{-1}$. For a drinking-water containing a concentration of 1 µg/L of one of these compounds, this would equate to a cancer risk of 0.2-2 x 10^{-6}. The risk would be proportionally higher for higher concentrations.

Potential disinfection by-product formation

The natural organic matter (NOM) content of the raw water of a supply is the precursor material with which chlorine reacts to form DBPs. Consequently, to be able to forecast the level of DBP formation, even qualitatively, an indication of the NOM concentration in both of these waters is needed. The total organic carbon (TOC), or dissolved organic carbon (DOC), concentration in the water is often used as a measure of the NOM concentration. Knowing the bromide concentration is also important in understanding which DBPs will form and their relative concentrations. (Bromide is oxidised to bromine by chlorine and in this form it too reacts with the NOM, to form the brominated DBPs.)

Although test results are unavailable for TOC or DOC and bromide, as a result of monitoring for the UV treatment at these supplies, there are percent transmittance (%T) results that can be used in place of TOC/DOC to **estimate** NOM concentration. No substitute is available for bromide.

CPH reported the minimum %T values of 94% and 89% for Geraldine and Pleasant Point raw waters, respectively. Using the relationship between %T and absorbance @254nm (A_{254}) on p. 124 of the Standards, it is possible to convert these to A_{254} values of **0.027 AU** and **0.051 AU.**

In 1999, ESR collated DBP data from the P2 Programme and a parallel laboratory DBP study to look for relationships between DBP concentrations and other relevant determinands, such as TOC and A_{254}. Relationships determined in this report (Nokes 1999) provide **a very approximate guide** to the total THM (TTHM) and total HAA (THAA) concentrations that may form in the included supplies.

The approximate nature of the guidance arises because the data used to derive the relationship were collected under a range of field conditions, most of which were unknown, and the nature of the NOM (and therefore its DBP formation potential) from the various sources was likely to be different. Because of these limitations, the DBP concentrations estimated from the relationship (Table 1) and the A_{254} concentrations should not be assumed to provide accurate concentration estimates. A much coarser

classification of the concentrations is more realistic: are the concentrations likely to be well below the MAV, about the MAV or well above the MAV?

Table 1

	Geraldine	**Pleasant Point**	**Units**
A_{254}	0.027	0.051	AU
DBP	**Estimated DBP concentration**		
TTHM	0.02	0.04	mg/L
THAA	0.02	0.04	mg/L

The Table 1 estimates are likely to be worst case values, because the turbidity sometimes contributes to the %T values. Although turbidity will tend to increase the A_{254} value of the water, unless the turbidity arises from **organic** particulates, it will make little contribution to the waters' DBP formation potential.

In the majority of supplies that contributed data to the 1999 study, chloroform was the predominant THM. Thus, if we assume that the TTHM concentration is, in effect, the chloroform concentration, we can compare these approximate concentrations with the chloroform MAV to obtain a crude indication of the health risk likely to be associated with the THM for these supplies.

For HAA, dichloroacetic acid and trichloroacetic acid are the two major contributors to the total HAA concentration. If we assume that they are present in approximately equal concentrations, (ie, each having a concentration of 0.01 mg/L in Geraldine and 0.02 mg/L in Pleasant Point), that will provide a guide to levels of risk from these substances.

Table 2 expresses the estimated individual DBP concentrations in both DBP families as percentages of the MAVs. All the projected concentrations are less than 50% of the MAV, ie, well below the level that might have adverse health effects over a lifetime of consumption of the water.

Table 2

DBP	MAV (mg/L)	Estimated concentration at Geraldine	% of MAV	Estimated concentration at Pleasant Point	% of MAV
Chloroform	0.4	0.02	5%	0.04	10%
DCAA	0.05	0.01	20%	0.02	40%
TCAA	0.2	0.01	5%	0.02	10%

Estimated levels are higher in the Pleasant Point supply because of the %T value of 89% used in the calculation. If the value is typically closer to 93%, as CPH intimated, the figures for Pleasant Point will be closer to those of Geraldine.

Other factors affecting DBP formation

a) Unknown bromide concentrations

We do not know the bromide concentration in either of these waters. If there is a significant bromide concentration in the water, the contribution to the total DBP concentration make by the brominated members of these DBP families will increase. As discussed in the toxicology note, the risk associated with the brominated DBPs appears higher than the fully chlorinated family members.

b) DBP formation from biofilms

If these supplies have been unchlorinated for some time, there may be substantial amounts of biofilm on the pipework. We have no data to guide us in estimating the levels of DBP that may form from reaction with the biofilm. However, even if DBP levels are initially elevated for this reason, they will reduce with time as the biofilm is "burnt" off pipes surfaces by the chlorine. As the risks associated with DBPs result from chronic exposure (lifetime), the relatively brief initial exposure to elevated concentrations does not present a significant risk to health.

Relative risks between DBP formation and an unchlorinated system

CPH has already noted the WHO statement on the risk of an unchlorinated supply compared with risk resulting from DBP formation.

The information provided above supports this statement with respect to these two supplies. As the source waters of these two systems are groundwaters of good chemical quality, the expected levels of DBP formation are low, and correspondingly so are the health risks associated with DBPs. On the other hand, should an event allow the ingress of bacterial or viral contaminants into the distribution system (post UV treatment) the absence of a chlorine residual will make the likelihood of illness greater than the likelihood of illness arising from chronic exposure to DBPs.

Conclusion

Based on the data available, the levels of DBP formation in these supplies are likely to be well below levels causing a significant risk to health over a lifetime of consumption of the water, based on our present knowledge of DBP toxicity.

In the light of this finding, it is reasonable to conclude that the public health risks (bacterial or viral infection) from not chlorinating these supplies would be greater than the risks associated with the chronic ingestion of the low DBP concentrations expected from chlorinating the supplies.

Other considerations in chlorinating the supplies

a) Taste and odour formation

The more noticeable consequence for consumers of chlorinating an unchlorinated system, other than health significant DBPs, is the likely production of chlorinous tastes and odours as the biofilm is "burnt" off reticulation system surfaces. We cannot provide guidance on how long this is likely to take.

b) Levels of chlorination

Once reaction of the chlorine with the biofilm is complete, the chlorine dose required to provide an adequate protective residual in the system should be low: another factor that will lower the likely levels of DBP formation.

References

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Attachment 2: Geraldine and Pleasant Point Chlorination - emails from Medical Officer of Health Cheryl Brunton and Drinking Water Assessor Denise Tully

From: Cheryl Brunton

To: Judy Blakemore; Bede Carran

Subject: Pleasant Point and Geraldine water supplies - chlorination

Kia ora Bede and Judy

Please find attached information prepared by ESR at our request regarding chlorination the Geraldine and Pleasant Point water supplies. This is intended to supplement the information that Denise has already provided to Judy (see below).

I draw your attention to the summary in the attached document and have highlighted the conclusions of the authors:

Summary

None of the disinfection by products (DBPs) that have been assigned as P2 determinands (ie, found at concentrations greater than 50% of their MAV) in New Zealand are presently classified as carcinogenic to humans by IARC. Although determinands, such as total/dissolved organic carbon and bromide, which would be helpful to estimate likely levels of DBP formation in the Geraldine and Pleasant Point water supplies are unavailable, estimates can be made based on UV percentage transmittance measurements. On the basis of the water quality data available, the levels of DBP formation in these supplies are likely to be well below levels causing a significant risk to health over a lifetime of consumption of the water, based on our present knowledge of DBP toxicity.

In the light of this finding, it is reasonable to conclude that the public health risks (bacterial or viral infection) from not chlorinating these supplies would be greater than the risks associated with the chronic ingestion of the low DBP concentrations expected from chlorinating the supplies.

CPH staff agree with these conclusions. We hope this is of assistance in addressing concerns expressed by members of these communities about chlorination.

Ngā mihi, Cheryl

Dr Cheryl Brunton

Medical Officer of Health/Āpiha Hauora o te Hauora

Community and Public Health/Te Mana Ora

Canterbury District Health Board/Te Poari Hauora ō Waitaha

Christchurch/Ōtautahi

This information relates to **Pleasant Point water** supply and **Geraldine** water supply.

Both supplies have turbidity that in most circumstances complies with the UV requirements for turbidity in the DWSNZ to be less than 1 NTU for 95% of the time and less than 2 NTU for any 3 minute period. In the last 9 months, the only instance when turbidity exceeded this requirement for Geraldine was July 2017 during a period of very heavy rain.

Given the low turbidity and the fact both supplies are ground water they do not contain an organic content such as you would find with surface water, and hence do not present a situation where there is a significant risk of byproduct formation by having chlorine react with organics.

Absorbance (A_{254}), also sometimes measured as transmittance, is a useful indication of the level of natural organic matter (mainly humic and fulvic substances) that may give rise to disinfection by-products following disinfection. In organic-rich waters, A_{254} should be measured prior to chlorination. This test (reported as UVT) is also needed when using UV light for disinfection. *(NZ Drinking Water Guidelines chapter 17*) UVT for Geraldine and Pleasant Point are consistently below 94% and 89% respectively.

The chemical analysis for both supplies does not indicate a situation where there are significant precursors to the formation of disinfection byproducts in the source water however total organic carbon and bromide are not included in the analysis.

The attached **fact sheet** was provided to me by the Ministry of Health. This fact sheet provides good information and also references WHO and IARC. The Cancer Council attachment also quotes IARC and provides good information.

The Ministry of Health also produce the Guidelines for Quality Drinking Water Management New Zealand and the disinfection chapter was updated in 2017. The guidelines state: *Natural organic matter contains compounds which disinfectants are able to react with to form disinfection by-products; the higher the organic matter concentration the greater the potential for disinfection by-product production. The major components of organic matter in water are humic and fulvic acids produced from the decay of vegetation. The concentration of organic matter in water may change markedly, and very rapidly, as the result of a rain event and even to the intensity of the rain, or more slowly on a seasonal basis. Most of the humic and fulvic acids that react with disinfectants to form disinfection by-products are small molecules, often with a molecular weight of less than 1000.* Note the previous comment regarding transmittance as an indicator of natural organic matter.

Unless groundwaters are in contact with buried organic matter, they generally contain low levels of organic matter due to the microbiological degradation and adsorption of organics, as the water percolates through subsurface strata.

The dose of chlorine into water supplies which have already received UV treatment, and hence, only for residual purposes is likely to be quite low.

DPB concentrations increase with increasing disinfectant concentration. The best-characterised relationship is between Trihalomethane (THM) production and chlorine

dose. There is a moderately steep increase in THM production as the chlorine dose is increased, until sufficient chlorine has been added to meet the full chlorine demand of the water. At doses beyond this value there is little increase in THM concentration as the chlorine concentration is increased.

The influence of pH on the concentration of DPBs depends upon the category of DPBs in question. Within the pH range of typical drinking-water, increasing the pH (up to pH 9.5) increases the concentrations of THMs; whereas the concentrations of trihaloacetic acids increase as the pH is decreased (maximum dichloroacetic acid production occurs at pH 7.0–7.5. (Water NZ)

The guidelines also state:

Factors affecting disinfection by-product formation include:

- the disinfectant, its dose, and mixing efficacy
- impurities in the disinfectant
- natural organic matter in the water being dosed (ie, precursors)
- other organic matter components (ie, precursors)
- pH of the water
- time that the disinfectant is in contact with the organic matter
- water temperature
- bromide ion concentration in the water, and to a lesser extent, iodide
- age of hypochlorite solutions: see perchlorate datasheet
- nitrite, or organic nitrogen concentration (applicable to chloropicrin formation)
- cleanliness of the distribution system.

The WHO state:

The use of chemical disinfectants in water treatment usually results in the formation of chemical by-products. However, the risks to health from these by-products are extremely small in comparison with the risks associated with inadequate disinfection, and it is important that disinfection efficacy not be compromised in attempting to control such by-products.

Ngā mihi,

Denise Tully

Technical Manager/Drinking Water Assessor

Community & Public Health

Attachment 3: Chlorination of Drinking-water – Health and Practical Considerations by Scott Rostron from the Ministry of Health

- Chlorine was introduced widely as a water disinfectant early in the 20th century and still remains the most common drinking disinfectant used around the world, including New Zealand, and this widespread use has been a major factor in reducing illness and deaths due to waterborne diseases.
- A major advantage of chlorination is that it produces a residual disinfectant that is moderately persistent. This residual can offer protection for water in distribution system pipework.
- Chlorine can routinely inactivate bacteria and viruses but not protozoa.
- The Drinking-water Standards for New Zealand set a maximum acceptable level for chlorine in drinking water at 5mg/L .
- This value is based on health considerations and is the same as the WHO guideline value.
- WHO indicate that the guideline value is conservative, as no adverse effect level was identified in the critical study.
- It is highly improbable that any disinfected drinking-water supply in New Zealand will contain this 5mg/L level of chlorine.
- For effective bacterial disinfection the Drinking-water Standards for New Zealand set a free available chlorine equivalent of 0.2mg/L.
- Typical levels in disinfected drinking water supplies are around 0.2mg/L to 1.0mg/L.
- Most people are able to taste or smell chlorine in drinking water at concentrations well below the 5mg/L health guideline level.
- Based on these aesthetic considerations, the concentration in drinking water should not exceed 0.6 – 1.0 mg/L, but microbiological quality must not be compromised.
- Long-term animal toxicity studies have shown no specific effects from the ingestion of chlorine. Chlorine, hypochlorous acid and hypochlorite did not act as carcinogens or tumour initiators.
- In humans and experimental animals exposed to chlorine in drinking-water, no specific adverse treatment related effects have been observed.
- Assessment of the mutagenicity of chlorine is complicated by the reactivity of chlorine. The International Agency for Research on Cancer (IARC) has concluded that hypochlorites are not classifiable as to their carcinogenicity to humans.
- Chlorine, in reaction with natural organic matter present in source water, can form a wide range of disinfection by products. Factors that influence the formation of

disinfection by products included the chlorine dose, the concentration and types of natural organic matter that are present, temperature, pH and detention time.

- A number of studies have suggested an association between chlorination by-products and various cancers. This association has been consistent in relation to cancers of the bladder and rectum, but there are insufficient data to determine concentrations at which chlorination by-products might cause increased risk to human health.
- While every effort should be taken to minimise the formation and concentration of chemical disinfection by-products, this should never be done in a manner that compromises disinfection as poor microbiological quality represents a greater and more immediate risk to human health than short term exposure to disinfection by products.
- Chlorine can be applied as a gas, liquid or solid. The storage, handling and transport of chlorine is strictly controlled under relevant legislation, standards and industry codes of practice. This includes consideration of work safe practices.
- Chlorination has common and long standing use in New Zealand with well established availability and reliability of dosing and monitoring equipment.

Attachment 4: Abstracts from two published papers by Dr Steve Hrudey

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EVALUATING EVIDENCE FOR ASSOCIATION OF HUMAN BLADDER CANCER WITH DRINKING-WATER CHLORINATION DISINFECTION BY-PRODUCTS

Steve E. Hrudey[1], Lorraine C. Backer[2], Andrew R. Humpage[3], Stuart W. Krasner[4], Dominique S. Michaud[5], Lee E. Moore[6], Philip C. Singer[7], Benjamin D. Stanford[8]

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Exposure to chlorination disinfection by-products (CxDBPs) is prevalent in populations using chlorination-based methods to disinfect public water supplies. Multifaceted research has been directed for decades to identify, characterize, and understand the toxicology of these compounds, control and minimize their formation, and conduct epidemiologic studies related to exposure. Urinary bladder cancer has been the health risk most consistently associated with CxDBPs in epidemiologic studies. An international workshop was held to (1) discuss the qualitative strengths and limitations that inform the association between bladder cancer and CxDBPs in the context of possible causation, (2) identify knowledge gaps for this topic in relation to chlorine/chloramine-based disinfection practice(s) in the United States, and (3) assess the evidence for informing risk management. Epidemiological evidence linking exposures to CxDBPs in drinking water to human bladder cancer risk provides insight into causality. However, because of imprecise, inaccurate, or incomplete estimation of CxDBPs levels in epidemiologic studies, translation from hazard identification directly to risk management and regulatory policy for CxDBPs can be challenging. Quantitative risk estimates derived from toxicological risk assessment for CxDBPs currently cannot be reconciled with those from epidemiologic studies, notwithstanding the complexities involved, making regulatory interpretation difficult. Evidence presented here has both strengths and limitations that require additional studies to resolve and improve the understanding of exposure response relationships. Replication of epidemiologic findings in independent populations with further elaboration of exposure assessment is needed to strengthen the knowledge base needed to better inform effective regulatory approaches.

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40 years on: what do we know about drinking water disinfection by-products (DBPs) and human health?

Steve E. Hrudey and John Fawell

ABSTRACT

2014 marks the 40th anniversary of the seminal discovery by Johannes Rook, in 1974, that trihalomethanes (THMs) were formed by the chlorination of natural organic matter (NOM) in drinking water. Since this discovery, which revolutionized how we viewed drinking water safety and quality, hundreds of other classes of disinfection by-products (DBPs) have been discovered. The finding in 1976 by the US National Cancer Institute that chloroform, the dominant THM, was a rodent carcinogen spurred a large number of epidemiology and toxicology studies into chlorinated drinking water. In 1985, this cancer finding was shown to be wrong. We should now be asking: What do we know about the human health impacts of DBPs in drinking water? Bladder cancer has been the most consistent finding from epidemiologic studies in North America and Europe and the possibility that chlorinated drinking water contributes an increased risk of bladder cancer remains a viable hypothesis. Despite some recent improvements in exposure assessments to focus on inhalation and dermal exposures rather than ingestion, no causal agent with sufficient carcinogenic potency has been identified, nor has a mechanistic model been validated. Consequently, a sensible precautionary approach to managing DBPs remains the only viable option based on four decades of evidence.

Key words | causation, chloroform, precaution, rationale, risk trade-off, trihalomethanes, uncertainty

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LIST OF ABBREVIATIONS

BDCM	bromodichloromethane
CH	choral hydrate
CxDBP	chlorination disinfection by-product
DBAN	dibromoacetonitrile
DBCM	dibromochloromethane
DBP	disinfection by-product
DCAA	dichloroacetic acid
DCAN	dichloroacetonitrile
HAA5	sum of five haloacetic acids, MCAA, DCAA, TCAA, monobromoacetic acid (MBAA) and dibromoacetic acid (DBAA)
MCAA	monochloroacetic acid
NDMA	*N*-nitrosodimethylamine
NOM	natural organic matter
TBM	tribromomethane, bromoform
TCAA	trichloroacetic acid
TCP	trichlorophenol
THM	trihalomethane
THM4	sum of chloroform, BDCM, DBCM and TBM

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Attachment 5: Cancer Myths by the Western Australia Cancer Council, provided by the Drinking Water Assessor

Cancer Council Western Australia

CancerMyths

Chlorine and Cancer

Origin of the misconception

Chlorine (Cl) is a dangerous chemical. Inhalation of chlorine gas or drinking highly concentrated sources of chlorine (such as household bleach) can lead to vomiting, coma, and even death.[1] For this reason, many people fear that the chlorine in swimming pools and drinking water can be harmful for health, and cause cancer. This has been spread further by water filter manufacturers and makers of 'chlorine-free' pools, who may assert that chlorine can cause cancer.

Current evidence

Since 1849, when Dr John Snow first suggested that disease could be transmitted through drinking water, many methods have been used to ensure clean and safe drinking water. Chlorination was first proposed in 1910 as a method for purifying water for troops in the field.

A consistent, safe supply of drinking water in the developed world is a major public health sanitation success. Millions of people still die from contaminated water in developing countries. Without clean water, most people would not live long enough to get cancer.

Chlorine dissolves in water to form hypochlorous acid (HOCl) that partially breaks down again to form the hypochlorite ion (OCl^-). Hypochlorous acid and the hypochlorite ion are toxic to potentially harmful microorganisms and disinfect drinking water.[2]

Chlorinated Drinking Water

The Australian Drinking Water Guidelines allow for up to 5 mg of chlorine per litre (mg/L) of drinking water. This is the same as the limit recommended by the World Health Organization (WHO). Concentrations found in Australian drinking water range from 0.1 mg/L to 4.0 mg/L, with a typical concentration of between 0.2 mg/L and 0.4 mg/L.[2] For comparison, the Western Australian Department of Health recommends maintaining chlorine in swimming pools over 2.0 to 3.0 mg/L depending on temperature.[3]

The Australian Drinking Water Guidelines report no adverse effects from the ingestion of chlorinated water. Long-term animal toxicity studies show that chlorine or its breakdown products do not act as carcinogens (cancer causing agents) or tumour initiators. According to the Australian Drinking Water Guidelines, there is very little risk from chlorine associated with drinking a lot of water. In one report, 150 people drank water with chlorine concentrations of 50 mg/L, during water mains disinfection, with no reported adverse health effects. Another study of military personnel, who often drink water with chlorine concentrations greater than 32 mg/L for extended periods, showed no adverse effects.[2]

The International Agency for the Research of Cancer (IARC) has evaluated the safety of chlorine in drinking water and concluded that there is *insufficient evidence for its carcinogenicity* (ability to cause cancer) in animals and humans. It has classified chlorine as neither a carcinogen nor a possible carcinogen.[4]

Cancer Council Western Australia 131120 www.cancerwa.asn.au

Chlorinated Swimming Pools

Swimming pools are chlorinated using hypochlorite salts (sodium hypochlorite or calcium hypochlorite). The safety of hypochlorite salts has also been evaluated by the IARC, which has concluded that there *is inadequate evidence for the carcinogenicity* of hypochlorite in animals. A similar conclusion could not be reached for humans because of the absence of human studies.[4]

Chlorination Disinfection By-Products

Trihalomethanes (chloroform) and haloacetic acids are formed when chlorine reacts with organic matter in the water. These are called water disinfection by-products (DBPs).[5]

A number of studies have suggested a weak association between DBPs and cancers of the bladder and rectum.[6, 7]

The IARC has concluded that chloroform is *possibly carcinogenic to humans*. This classification is based on research on animals that may or may not be relevant to human cancers[8]

The Australian Drinking Guidelines state that, "action to reduce the concentration of disinfection by-products is encouraged, but disinfection itself must not be compromised: the risk posed by disinfection by-products is considerably smaller than the risk posed by the presence of pathogenic microorganisms in water that has not been disinfected."[2]

Summary

There is no evidence for the myth that chlorine in drinking water or swimming pools can cause cancer. However, chlorine and chlorine gas can aggravate respiratory conditions and high concentrations of chlorine can lead to many health complications. There is limited evidence that DBPs in drinking water may be associated with a very small increased risk of cancer. The Australian Drinking Guidelines include guideline values for a number of DBPs to minimise their formation, but not so as to compromise disinfection because the presence of pathogens in water poses a much greater and more immediate risk to public health than exposure to DBPs.

Further reading

- Australian Drinking Water Guidelines
  National Health and Medical Research Council
  http://www.nhmrc.gov.au/guidelines/publications/eh52

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