Guidelines for Canadian Drinking Water Quality

Sixth Edition

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1. Introduction

Canadian Drinking Water Standards and Objectives, published in 1968, was the first comprehensive Canadian compilation of recommended limits for substances and conditions that affect the quality of drinking water. The *Guidelines for Canadian Drinking Water Quality*, published in 1978, superseded the 1968 document. In developing the 1978 guidelines, the criteria on which the 1968 standards had been based were critically re-examined, and the levels previously recommended were retained, modified or eliminated accordingly. Some water quality parameters that had not been considered in 1968 were also reviewed, and several additional limits were established.

After the publication of the 1978 guidelines, it became apparent that the guidelines would need to be revised again in light of new information that had become available. As well, it was obvious that the number of parameters included in the 1978 guidelines would need to be expanded, mainly as a result of growing concern over trace levels of synthetic organic chemicals in drinking water supplies.

In 1986, the Federal-Provincial Subcommittee on Drinking Water was established by the Federal-Provincial Advisory Committee on Environmental and Occupational Health (now known as the Federal-Provincial Committee on Environmental and Occupational Health) to revise and update the Canadian drinking water guidelines on a continuing basis. The 1987 and later editions of the *Guidelines for Canadian Drinking Water Quality* were prepared following a thorough review of the scientific, technical and medical literature on new parameters and on parameters whose guidelines required revision.

This booklet is the sixth edition of the *Guidelines for Canadian Drinking Water Quality* and includes the guidelines reported to the Conference of Deputy Ministers of Health as of March 1995. In the period since the fifth edition was published (1993), no evidence has been presented that would warrant changing the values proposed in that edition. These values have, therefore, been adopted and are presented in this edition as confirmed guidelines.

The guidelines and recommendations listed herein are intended to apply to all drinking water supplies, public and private. However, they should not be regarded as legally enforceable standards unless promulgated as such by the appropriate provincial, territorial or federal agency. Judicious use of the guidelines will result in the provision of drinking water that is

both wholesome and protective of public health. The approaches used in the derivation of the guidelines, as well as the supporting documentation for each parameter, are published separately by Health Canada.

Guidelines for some of the parameters included herein are more restrictive than those in the previous edition. It is recognized that not all drinking water systems will be able to meet these more restrictive guidelines immediately and that priority given to meeting these new limits may be based on factors such as cost and the degree to which the drinking water systems exceed the guideline values. However, it is recommended that all public and private drinking water supplies aim to reduce concentrations of these substances to below the specified values as soon as practicable.

The guidelines defined herein should not be regarded as implying that the quality of the drinking water may be degraded to the specified levels. Indeed, a continuous effort should be made to ensure that drinking water is of the highest possible quality.

2. Explanation of Terms

2.1 No-Observed-Adverse-Effect Level (NOAEL), No-Observed-Effect Level (NOEL), Lowest-Observed-Adverse-Effect Level (LOAEL) and Lowest-Observed-Effect Level (LOEL)

The no-observed-adverse-effect level (NOAEL) is the highest dose in a toxicity study that does not result in any observed adverse effect (an adverse effect significantly alters the health of the target animal for a sustained period of time or reduces survival). The no-observed-effect level (NOEL) is the highest dose in a toxicity study that results in no observed effects.

The lowest-observed-adverse-effect level (LOAEL) is the lowest dose in a toxicity study that results in an observed adverse effect (usually one dosage level above the NOAEL). The lowest-observed-effect level (LOEL) is the lowest dose in a toxicity study that results in an observed, but not adverse, effect (usually one dosage level above the NOEL). For example, the dose that induces a transient increase in organ weight without accompanying biochemical or histopathological effects would generally be considered a LOEL.

2.2 Tolerable Daily Intake (TDI), Acceptable Daily Intake (ADI) and Negligible Daily Intake (NDI)

A tolerable daily intake (TDI) is the amount of a substance that can be consumed from all sources each day by an adult, even for a lifetime, without any significant increased risk to health, based on current knowledge. The term TDI is now used instead of acceptable daily intake (ADI) – except for pesticides that have been previously evaluated by the Food Directorate of Health Canada (formerly Health and Welfare Canada) or by the World Health Organization in conjunction with the Food and Agriculture Organization – as TDI signifies permissibility rather than acceptability.

When insufficient toxicological data are available to derive an ADI or a TDI from all sources with reasonable certainty, a provisional value is recommended that takes into account the available health-related data. For pesticides evaluated by the Food Directorate of Health Canada, this provisional value was formerly called the negligible daily intake (NDI).

2.3 Maximum Acceptable Concentration (MAC)

Maximum acceptable concentrations (MACs) have been established for certain substances that are known or suspected to cause adverse effects on health. Each MAC has been derived to safeguard health assuming lifelong consumption of drinking water containing the substance at that concentration. The use of drinking water for all usual domestic purposes, including personal hygiene, has been considered in the derivation of the guidelines wherever possible. However, water of higher quality may be required for some special purposes, including renal dialysis.

Drinking water that continually contains a substance at a level greater than its MAC will contribute significantly to consumers' exposure to the substance and may, in some instances, induce deleterious effects on health. However, short-term excursions above the MAC do not necessarily mean that the water constitutes an undue risk to health. The amount by which, and the period for which, the MAC can be exceeded without posing a health risk must be assessed by taking into account the toxicity of the substance involved. When the MAC for a substance is exceeded, however, the minimum action required is immediate resampling. If the MAC continues to be exceeded, the local authority responsible for drinking water supplies should be consulted concerning appropriate corrective action.

2.4 Interim Maximum Acceptable Concentration (IMAC)

For those substances for which there are insufficient toxicological data to derive a MAC with reasonable certainty, interim values are recommended, taking into account the available health-related data, but employing a larger safety factor to compensate for the additional uncertainties involved. Interim maximum acceptable concentrations (IMACs) are also established for those substances for which estimated lifetime risks of cancer associated with the guideline (the lowest concentration in drinking water that is practically achievable using available analytical or treatment methods) are greater than those deemed to be essentially negligible. Because of their nature, IMACs will be reviewed periodically as new toxicological data and new methods of quantitation and treatment become available.

2.5 Aesthetic Objective (AO)

Aesthetic objectives (AOs) apply to certain substances or characteristics of drinking water that can affect its acceptance by consumers or interfere with practices for supplying good-quality water. For certain parameters, both AOs and health-related guidelines (e.g., MACs) have been derived. Where only AOs are specified, these values are below those considered to constitute a health hazard. However, if a concentration in drinking water is well above an AO, there is a possibility of a health hazard.

2.6 Practical Quantitation Limit (PQL)

The practical quantitation limit (PQL) is the concentration of a substance that can be measured in a laboratory within reasonable limits of precision and accuracy.

2.7 Other Abbreviations

Other abbreviations used in this report are as follows:

bw	body weight
FAO	Food and Agriculture Organization of the United Nations
U.S. EPA	United States Environmental Protection Agency
WHO	World Health Organization

3. Microbiological Characteristics

3.1 Derivation of Microbiological Guidelines

Microbiological guidelines are needed to control the presence of pathogenic or disease-causing micro-organisms. Pathogenic micro-organisms that occur in polluted surface water include protozoa, bacteria and enteric viruses; protozoa are not commonly found in groundwater. The most common disease attributable to waterborne pathogenic micro-organisms is gastrointestinal illness or diarrhoea. Although gastrointestinal illness is generally considered to be non-life threatening in normal healthy adults, mortality can occur in sensitive subpopulations, such as infants, the elderly and immunosuppressed individuals. As it is not practical or technically feasible to monitor for all pathogens in drinking water, the microbiological guidelines are based on indicator organisms and effective treatment.

3.2 Coliform, Coliform Background and Heterotrophic Plate Counts

All drinking water supplies should be analysed routinely for coliform bacteria and the general bacterial population.

The presence of excess total coliforms, as stated below, in drinking water indicates that treatment is inadequate or that the distribution system is experiencing regrowth or infiltration. Total coliforms are not necessarily an indication of the presence of faecal contamination. Faecal coliforms in drinking water may, however, indicate the presence of faecal contamination. The presence of *Escherichia coli*, one species in the faecal coliform group, is a definite indicator of the presence of faeces. Other species in the faecal coliform group (e.g., *Klebsiella pneumoniae*, *Enterobacter cloacae*) are not restricted to faeces but occur naturally on vegetation and in soils.

The general bacterial population can be estimated from either back-ground colony counts on total coliform membrane filters or heterotrophic plate counts (HPC), as outlined in the 16th edition of *Standard Methods for the Examination of Water and Wastewater*; according to this reference, incubation of HPC at 35°C for at least 48 hours is preferred. Excessive

concentrations of the general bacterial population may hinder the recovery of coliforms and thereby prevent the detection of a potential threat to public health.

The MAC for coliforms in drinking water is zero organisms detectable per 100 mL. Because coliforms are not uniformly distributed in water and are subject to considerable variation in enumeration, drinking water that fulfils the following conditions is considered to be in compliance with the coliform MAC:

1. No sample should contain more than 10 total coliform organisms per 100 mL, none of which should be faecal coliforms;
2. No consecutive sample from the same site should show the presence of coliform organisms; and
3. For community drinking water distribution systems:
   a) not more than one sample from a set of samples taken from the community on a given day should show the presence of coliform organisms; and
   b) not more than 10% of the samples based on a minimum of 10 samples should show the presence of coliform organisms.

If any of the above criteria are exceeded, corrective action should be taken immediately, in consultation with the local authority responsible for drinking water supplies. The most common immediate actions in response to the presence of total and faecal coliforms include resampling to confirm positive results and verifying the disinfectant dosage and system residual. If resampling confirms contamination of the water supply, additional actions may include increasing disinfectant dosage, flushing water mains, disease surveillance, using an alternative source of water and advising consumers to boil their drinking water. The confirmed presence of *E. coli* in drinking water should trigger an immediate "boil water" advisory.

If up to 10 total coliform organisms per 100 mL are detected from a single sample, or if the sample contains either more than 500 HPC colonies per millilitre or more than 200 background colonies on a total coliform membrane filter (i.e., overgrowth), the water should be resampled. If the presence of coliforms is reconfirmed, the cause should be determined if possible, and corrective action taken as appropriate. If there is a recurrence of unacceptable background or heterotrophic plate counts, the system should be inspected to determine the cause. If remedial action is deemed necessary, special sampling should continue until consecutive samples comply with the guidelines.

3.3 Viruses and Protozoa

Guidelines for viruses and protozoa are not proposed at this time, but relevant information is currently being reviewed (see Table 5). It is desirable, however, that no viruses or protozoa (e.g., *Giardia*) be detected. A water treatment system that provides effective filtration and disinfection and maintains an adequate disinfectant residual should produce water of an acceptable quality in this regard. Where possible, source protection should also be exercised.

3.4 Sampling

The frequency of sampling depends upon the quality of the source water, the number of water sources, the past frequency of unsatisfactory samples, the adequacy of treatment and capacity of the treatment plant, the size and complexity of the distribution system, the practice of disinfection and the size of the population served. The following is offered as a guide:

Population Served	Number of Samples per Month
up to 5 000	4
5 000 to 90 000	1 per 1 000 population
more than 90 000	90 + (1 per 10 000 population)

If a community supply has a history of producing water of high bacteriological quality, it may be possible to reduce the number of samples analysed.

3.5 Disinfection

Disinfection is the one step in water treatment specifically designed to destroy pathogenic organisms and thereby prevent waterborne diseases, which are the most significant health risk associated with drinking water. Alone, disinfection is not always sufficient to produce a supply of adequately treated water. Other treatments may be necessary, depending upon the water source, to ensure the effectiveness of the disinfection process and to satisfy other criteria for good-quality drinking water. The disinfecting agents most commonly used in water treatment today are chlorine and its compounds.

3.6 Turbidity

A summary paragraph on turbidity, which discusses guidelines for turbidity in drinking water, may be found in Section 4.6.

4. Chemical and Physical Parameters

4.1 Derivation of Chemical Guidelines

4.1.1 Approaches to Derivation of MACs

Different approaches are adopted for the derivation of guidelines for compounds considered to be carcinogenic and probably carcinogenic, compounds considered to be possibly carcinogenic and those considered to be probably not carcinogenic or for which data were inadequate for evaluation.

4.1.1.1 Chemicals That Are Not Considered Carcinogenic

For chemicals classified as "probably not carcinogenic to humans" or for which data on carcinogenicity were "inadequate for evaluation," the TDI (formerly called the ADI) is derived, where possible, by division of the lowest NOAEL for a response considered to be biologically significant by an uncertainty factor. Ideally, the NOAEL is derived from a lifetime ingestion study or from studies in the most sensitive subpopulation; data from acute or short-term studies are not normally used.

The uncertainty factor is derived on a case-by-case basis; in general, a factor of 1 to 10 may be used to account for one or more of the following elements of uncertainty: intraspecies variation, interspecies variation, nature and severity of effect, adequacy of study and use of LOAEL versus use of NOAEL. An additional factor of 1 to 5 is incorporated where there is information that indicates a potential for interaction with other chemicals. If the chemical is an essential nutrient at low concentrations, the dietary requirement is also taken into consideration in derivation of the uncertainty factor.

Derivation of the MAC from the TDI is generally based on an average daily intake of 1.5 L of drinking water by a 70-kg adult.[1] However, where appropriate, the MAC is derived based on intake in the most sensitive subpopulation (e.g., children). Human exposure from sources other than drinking water (e.g., air, food) is taken into account by apportioning a percentage of the TDI to drinking water. Where data concerning the proportion of total intake normally ingested in drinking water are unavailable, a 20% allocation of total daily intake to drinking water is made, which is believed to be sufficient to account for intake by any additional routes (e.g., inhalation, dermal exposure).

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1. MACs established for parameters in the *Guidelines for Canadian Drinking Water Quality – 1978* were derived assuming an average daily intake of 2 L of drinking water.

MACs must be achievable by available treatment methods and measurable by existing analytical techniques. Where a MAC is less than levels considered to be reliably measurable or achievable, an IMAC is established, and improvement in methods of quantitation and/or treatment is recommended.

4.1.1.2 Chemicals That Are Carcinogenic

As it is generally assumed that there is a probability of harm at any level of exposure to carcinogenic chemicals, carcinogens should ideally be absent from drinking water. However, the risks associated with exposure to low levels of these chemicals in drinking water may be sufficiently small so as to be essentially negligible compared with other commonly encountered risks.

Quantitative risks associated with exposure to low levels of potential carcinogens are estimated by extrapolation of the dose-response relationship observed at high doses in experimental studies (usually in animal species) to the low-dose range. Although the methods used involve uncertainties, they are based on conservative assumptions and tend to overestimate rather than underestimate risks.

For chemicals classified as "carcinogenic to humans" or "probably carcinogenic to humans," lifetime cancer risks are estimated using the robust linear extrapolation model, applied to the tumour types considered to be most appropriate from a biological perspective. Where justified, a surface area to body weight correction is applied to account for differences in metabolic rates between animals and humans.

For many carcinogenic compounds, available treatment technology is inadequate to completely eliminate exposure from drinking water. In addition, available analytical methods may be inadequate for reliable determination at extremely low levels. Therefore, MACs are set as close to zero as reasonably practicable, based on consideration of the following factors:

(1) The MAC must be achievable by available water treatment methods at reasonable cost.
(2) Wherever possible, the upper 95% confidence limit for the lifetime cancer risk associated with the MAC is less than 10^{-5} to 10^{-6}, a range that is generally considered to be "essentially negligible." In cases where intake from sources other than drinking water is significant, the upper 95% confidence limit for the lifetime cancer risk associated with the MAC is less than or equal to 10^{-6}.
(3) The MAC must also be reliably measurable by available analytical methods.

Where estimated lifetime cancer risks associated with the MAC are greater than those judged to be essentially negligible (i.e., 10^{-5} to 10^{-6}), an IMAC is established, and improvement in methods of quantitation and/or treatment is recommended.

4.1.1.3 Chemicals That Are Possibly Carcinogenic

For compounds that are "possibly carcinogenic to humans," the MAC is based upon a TDI, determined as described for "Chemicals That Are Not Considered Carcinogenic." However, an additional factor of 1 to 10 is incorporated in the uncertainty factor to account for the limited evidence of carcinogenicity. Where there are sufficient data, a quantitative estimate of tumour incidence may be considered in derivation of the MAC.

4.1.1.4 Pesticides

A number of pesticides considered to be "probably not carcinogenic to humans" or for which data on carcinogenicity are "inadequate for evaluation" have been considered by the Food Directorate, Health Protection Branch, Health Canada, in order to establish maximum tolerable residue levels in foods, as part of their registration under the Pest Control Products Act. Wherever possible, ADIs or NDIs established by the Food Directorate have been used in the derivation of MACs or IMACs, respectively, for pesticides.

The WHO, in conjunction with the FAO, also conducts evaluations to derive ADIs or, where data are insufficient, provisional daily intakes for pesticide residues in foods. For pesticides that are considered to be "probably not carcinogenic to humans" or for which data on carcinogenicity are "inadequate for evaluation" and that have been evaluated by the WHO/FAO, MACs or IMACs are based upon WHO/FAO ADIs or provisional daily intakes, respectively.

4.1.2 Approach to Derivation of AOs

In those cases where thresholds for organoleptic properties were less than the MAC, an AO was derived, based on information on taste and odour thresholds reported in the literature.

4.2 New, Revised and Reaffirmed Guidelines

New, revised and reaffirmed guidelines for chemical and physical parameters are presented in Table 1.

Table 1
New, Revised and Reaffirmed Guidelines for
Chemical and Physical Parameters

Parameter	Guideline (mg/L)	Previous Guideline (mg/L)
atrazine + metabolites	IMAC 0.005	IMAC 0.06
chloramines	MAC 3.0	None
cyanide	MAC 0.2	MAC 0.2
dichloroethylene, 1,1-	MAC 0.014	None
iron	AO ≤0.3	AO ≤0.3
sulphide (as H_2S)	AO ≤0.05	AO ≤0.05
tetrachloroethylene	MAC 0.03	None
trihalomethanes (total)	IMAC 0.1	MAC 0.35
vinyl chloride	MAC 0.002	None

4.3 Summary of Guidelines

Guidelines for all chemical and physical parameters, including all new, revised and reaffirmed guidelines, are listed in Table 2.

Table 2
Summary of Guidelines for Chemical and Physical Parameters[1]

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
aldicarb + metabolites	0.009		
aldrin + dieldrin	0.0007		
arsenic		0.025	
atrazine + metabolites		0.005	
azinphos-methyl	0.02		
barium	1.0		

Table 2 (cont'd)

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
bendiocarb	0.04		
benzene	0.005		
benzo[a]pyrene	0.000 01		
boron		5	
bromoxynil		0.005	
cadmium	0.005		
carbaryl	0.09		
carbofuran	0.09		
carbon tetrachloride	0.005		
chloramines	3.0		
chloride			≤250
chlorpyrifos	0.09		
chromium	0.05		
colour			≤15 TCU[2]
copper[3]			≤1.0
cyanazine		0.01	
cyanide	0.2		
diazinon	0.02		
dicamba	0.12		
dichlorobenzene, 1,2-	0.20		≤0.003
dichlorobenzene, 1,4-	0.005		≤0.001
dichloroethane, 1,2-		0.005	
dichloroethylene, 1,1-	0.014		
dichloromethane	0.05		
dichlorophenol, 2,4-	0.9		≤0.0003
dichlorophenoxyacetic acid, 2,4- (2,4-D)		0.1	

Table 2 (cont'd)

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
diclofop-methyl	0.009		
dimethoate		0.02	
dinoseb	0.01		
diquat	0.07		
diuron	0.15		
ethylbenzene			≤0.0024
fluoride	1.5		
glyphosate		0.28	
iron			≤0.3
lead[3]	0.010		
malathion	0.19		
manganese			≤0.05
mercury	0.001		
methoxychlor	0.9		
metolachlor		0.05	
metribuzin	0.08		
monochlorobenzene	0.08		≤0.03
nitrate	45[4]		
nitrilotriacetic acid (NTA)	0.4		
odour			Inoffensive
paraquat (as dichloride)		0.01[5]	
parathion	0.05		
pentachlorophenol	0.06		≤0.030
pH			6.5-8.5[6]
phorate	0.002		
picloram		0.19	
selenium	0.01		

Table 2 (cont'd)

Parameter	MAC (mg/L)	IMAC (mg/L)	AO (mg/L)
simazine		0.01	
sodium			≤200
sulphate			≤500
sulphide (as H_2S)			≤0.05
taste			Inoffensive
temperature			≤15°C
terbufos		0.001	
tetracholoroethylene	0.03		
tetrachlorophenol, 2,3,4,6-	0.1		≤0.001
toluene			≤0.024
total dissolved solids (TDS)			≤500
trichloroethylene	0.05		
trichlorophenol, 2,4,6-	0.005		≤0.002
trifluralin		0.045	
trihalomethanes (total)		0.1	
turbidity	1 NTU[7]		≤5 NTU[3,7]
uranium	0.1		
vinyl chloride	0.002		
xylenes (total)			≤0.3
zinc[3]			≤5.0

Notes:
1. Summary paragraphs for all the parameters in this table may be found in Section 4.6.
2. TCU = true colour unit.
3. At the point of consumption.
4. Equivalent to 10 mg/L as nitrate-nitrogen.
5. Equivalent to 0.007 mg/L for paraquat ion.
6. No units.
7. NTU = nephelometric turbidity unit.

4.4 Parameters without Guidelines

Since 1978, a number of parameters have been identified as not requiring a numerical guideline. Table 3 lists these parameters. The reasons for parameters having no numerical guideline include the following:

- currently available data indicate no health risk or aesthetic problem (e.g., calcium);
- data indicate the compound, which may be harmful, is not registered for use in Canada (e.g., 2,4,5-TP) or is not likely to occur in drinking water at levels that present a health risk (e.g., silver); or
- the parameter is composed of several compounds for which individual guidelines may be required (e.g., pesticides [total]).

Table 3
Parameters without Guidelines[1]

Parameter	Parameter
ammonia*	pesticides (total)
asbestos*	phenols
calcium*	phthalic acid esters (PAE)
chlordane (total isomers)	polycyclic aromatic hydrocarbons (PAH)[2]
DDT	radon[3]
endrin	resin acids
gasoline and its organic constituents*	silver*
hardness*	tannin
heptachlor + heptachlor epoxide	temephos
lignin	total organic carbon
lindane	toxaphene
magnesium*	triallate
methyl-parathion	trichlorophenoxyacetic acid, 2,4,5- (2,4,5-T)
mirex	trichlorophenoxypropionic acid, 2,4,5- (2,4,5-TP)

Notes:
1. Summary paragraphs for parameters marked with an asterisk may be found in Section 4.6.
2. Other than benzo[a]pyrene.
3. A summary paragraph for radon may be found in Section 5.5.

4.5 Sampling

4.5.1 Fluoride

Where fluoridation is practised, at least one sample of treated water per day should be collected and analysed to ascertain whether fluoride concentrations comply with the MAC. Where fluoridation is not practised, the general sampling schedule described for health-related parameters (see Section 4.5.2) should be followed.

4.5.2 Parameters Related to Health

In general, drinking water should be sampled semi-annually for all chemical substances for which MACs or IMACs have been set. If particular substances are consistently absent from a water supply system, the frequency of sampling for these substances may be reduced, subject to approval by the control agency. In addition, where water supplies are obtained from sources that are not likely to be contaminated by industrial and agricultural wastes, a full analysis may be required only to aid in the selection of new sources and occasionally thereafter.

If there is reason to suspect the presence of certain substances in a water supply, these substances should be sampled more frequently to ensure that their concentrations are below the acceptable limits. Also, where public water supplies are derived from frequently polluted raw water sources, the sampling frequency for chemical analyses should be increased from once every six months to once every three months or as determined by the control agency.

In the case of private water supplies, it is desirable to ascertain the levels of all health-related parameters when a new well or spring is brought into use. A good knowledge of local conditions, however, may make such a thorough examination unnecessary. The advice of the appropriate control agency should be obtained.

Concentrations of certain substances (e.g., pesticides) vary seasonally. Samples to be analysed for these substances should be collected at periods of the year when contamination of the water supply is likely to be greatest and representative of the water consumed. The local authority responsible for drinking water supplies should be consulted on any sampling program or evaluation of analytical results.

4.5.3 Parameters Related to Aesthetic Considerations

The sampling frequency for parameters affecting the appearance and palatability of water supplies will depend for the most part on local conditions and consumer complaints. Analysis for these substances is most useful when the suitability of a new source of drinking water is being considered.

Monitoring of non-health-related parameters may also provide information that will assist treatment plant personnel in establishing processes for optimum water treatment. The requirement for and frequency of sampling should be decided by the appropriate control agency.

4.6 Summary Paragraphs

Aldicarb + metabolites

Aldicarb is a broad-spectrum, systemic carbamate insecticide used to control a variety of insects, mites and nematodes on several crops, including citrus fruits, beans, grain, peanuts, potatoes, soybeans, sugar beets and tobacco. It is very persistent in groundwater, degrading with a half-life that ranges from a few weeks to as long as several years under typical conditions. Two major degradation products, aldicarb sulphoxide and aldicarb sulphone, are found in a 1:1 ratio in groundwater. Aldicarb has been detected in private and municipal drinking water supplies across Canada, usually at concentrations below 30 μg/L.

Aldicarb is an acetylcholinesterase inhibitor; clinical symptoms of aldicarb intoxication include dizziness, weakness, diarrhoea, nausea, vomiting, abdominal pain, blurred vision, headache and dyspnoea. Epidemiological studies are inconclusive with respect to the association between chronic aldicarb ingestion and both immunotoxicity and delayed neuropathy.

Aldicarb does not increase tumour incidence in carcinogenicity bioassays in rats and mice and has therefore been classified as probably not carcinogenic to humans. The only toxic effect observed consistently in studies conducted to date is the rapidly reversible inhibition of acetylcholinesterase activity, the biological significance of which is difficult to assess. The ADI for aldicarb is determined by dividing the NOAEL for red blood cell cholinesterase inhibition, obtained from a study in which human volunteers were administered single oral doses of aldicarb in orange juice, by an uncertainty factor that takes into consideration the variability observed in the human population.

The MAC for aldicarb in drinking water, derived from the ADI, is *0.009 mg/L*. This guideline is considered to be applicable to the total of aldicarb and its toxic metabolites, aldicarb sulphoxide and aldicarb sulphone.

Aldrin + dieldrin

Aldrin and dieldrin are organochlorine insecticides. Aldrin is rapidly converted to dieldrin under most environmental and biological conditions. Dieldrin is a highly persistent compound, with low mobility in soil. Both insecticides have been detected in Canadian drinking water and surface water.

Aldrin and dieldrin are highly toxic to experimental animals; target organs are the central nervous system and liver. Cases of poisoning in humans are also known. Chronic feeding with aldrin or dieldrin has led to hepatocellular carcinoma in mice. The ADI for aldrin and dieldrin is derived by dividing a NOAEL for hepatomegaly and dose-related histological changes in the liver in rats by an uncertainty factor that takes into account concern for the oncogenicity observed in mice.

The MAC for aldrin + dieldrin in drinking water is *0.0007 mg/L*.

Ammonia

Ammonia is a colourless gas that is used in the manufacture of chemical products such as fertilizers, explosives, nitric acid and plastics and in refrigeration plants and petroleum refineries. It is present in most waters as a result of the biological degradation of nitrogenous organic matter, although it may also reach groundwater and surface waters from industrial waste discharges. Ammonia and ammonium compounds may also be added to water in order to lower trihalomethane production.

Concentrations of ammonia and ammonia compounds in water are generally below 0.1 mg/L (as nitrogen). Ammonia in drinking water may increase the chlorine demand, which may lead to a "break-point" chlorination phenomenon.

Ammonia is produced in the body and is efficiently processed by enzymes in healthy individuals. Ammonia in drinking water should be considered as a potential source of nitrates. Although ingestion of large doses of ammonium chloride by human adults results in headache, nausea, diarrhoea and a failure in glucose tolerance, there seems to be little risk to humans from the ingestion of ammonia in drinking water at the levels normally encountered. It is therefore not considered necessary to establish a MAC for ammonia in drinking water.

Arsenic

Arsenic is a metalloid with four oxidation states. It is widely distributed throughout the earth's crust and is present in trace amounts in all living matter. Arsenicals are used commercially and industrially – for example, as alloying agents, in the processing of glass and pigment, in the hide tanning process and as pesticides, feed additives and pharmaceuticals.

Arsenic is introduced into water through the dissolution of minerals and ores, from industrial effluents and via atmospheric deposition. Natural sources, such as the dissolution of arsenic-containing bedrock, often contribute significantly to the arsenic content of drinking water and groundwater. Pentavalent arsenic is most common in surface waters, whereas the trivalent species is the predominant form in groundwater.

The concentration of arsenic in drinking water in areas without natural sources is usually less than 5 *μ*g/L. It is difficult to compare the intake of arsenic from food directly with that from drinking water, as the form and biological availability of arsenic in these two sources vary. It has been estimated that about 25% of the intake of arsenic from food is inorganic and 75% is organic.

Symptoms of acute arsenic intoxication associated with the ingestion of well water contaminated with arsenic include abdominal pain, vomiting and pain to the extremities and muscles. Later symptoms may include papular erythematous rash, Mee's lines of fingernails and progressive deterioration in motor and sensory responses. Signs of chronic arsenicalism, including dermal lesions, peripheral neuropathy, skin cancer, peripheral vascular disease and possibly cancers of other organs, have been observed in populations ingesting arsenic-contaminated drinking water in countries around the world.

Arsenic is classified as being carcinogenic to humans. An IMAC was established on the basis of the following considerations: (1) manganese dioxide-coated filters, which are commonly used by smaller communities for iron and/or manganese removal, appear capable, based on limited data, of reducing arsenic concentrations to 25 *μ*g/L or less; (2) based on the incidence of skin cancer in men in Taiwan, the estimated lifetime cancer risk associated with ingestion of water containing arsenic at 25 *μ*g/L is greater than the range that is considered generally to be "essentially negligible"; hence, the MAC is designated as interim; and (3) the PQL is 5 *μ*g/L.

The IMAC for arsenic in drinking water is *0.025 mg/L*. It should be noted that the IMAC may overestimate the actual risk in North American populations owing to concomitant exposure to other compounds in the water in Taiwan and possible dietary deficiencies of the Taiwanese population. Moreover, there are dose-dependent variations in the metabolism of arsenic that could not be taken into consideration in the quantitative risk assessment. Also, only a small proportion of arsenic-induced skin cancers (1 to 14%) are fatal. However, there is also recent evidence that cancers of internal organs have been associated with the ingestion of arsenic-contaminated water. The IMAC will be reviewed periodically in light of developments in treatment technology and additional data on health risks associated with exposure to arsenic in drinking water.

Asbestos

Six commercially important serpentine and amphibole minerals are generally characterized as asbestos. Chrysotile is the only member of the serpentine group and the form of asbestos that is mined in Canada. The amphiboles that are used most widely are amosite and crocidolite.

The chemical nature and crystalline structure of asbestos impart a number of desirable characteristics that make the mineral useful for a large number of applications, particularly in construction materials, such as asbestos-cement (A/C) sheet and pipe, electrical and thermal insulation and friction products, such as brake linings.

Asbestos is ubiquitous in the environment as a result of its extensive industrial use and the dissemination of fibres from natural sources. It is introduced into water by the dissolution of asbestos-containing minerals and ores and from industrial effluents, atmospheric pollution and, in some cases, A/C pipe in distribution systems.

The health hazards associated with the inhalation of asbestos in the occupational environment have long been recognized and include asbestosis, bronchial carcinoma, malignant mesothelioma of the pleura and peritoneum and possibly cancers of the gastrointestinal tract and larynx. In contrast, there has been little evidence of the carcinogenicity of ingested asbestos in toxicological and epidemiological studies conducted to date.

Exposure to high concentrations of asbestos in drinking water is unlikely, as standard water treatment processes effectively remove asbestos fibres from drinking water supplies. As well, there is no consistent, convincing evidence that ingested asbestos is hazardous to health. It is considered unnecessary, therefore, to establish a MAC for asbestos in drinking water.

Atrazine + metabolites

Atrazine is a chloro-N-dialkyl-substituted triazine herbicide. It is used extensively in Canada as a pre- and post-emergence weed control agent, primarily for corn but also for rapeseed, and for total vegetation control in non-cropland and industrial areas.

Atrazine has low soil adsorption and soil-water distribution coefficients, and it has been ranked highest of 83 pesticides in Agriculture Canada's priority scheme for potential groundwater contaminants. In areas where atrazine is used extensively, it (or its dealkylated metabolites) is one of the most frequently detected pesticides in surface and well water.

Although several analytical epidemiology studies provide some suggestive evidence for an association between exposure to triazine herbicides (largely atrazine) and increased risk of ovarian cancer or

lymphomas, the evidence is considered inadequate because of the limited number of studies conducted to date and the methodological limitations of the available studies. Oral administration of atrazine has resulted in mammary, uterine and haematopoietic system tumours in two strains of rats, although no tumours were observed in an adequate long-term study in mice. The tumours of the reproductive system, which were observed in both human and animal studies, are known to be associated with hormonal factors that act as tumour promoters.

The weight of evidence indicates that atrazine is not genotoxic, although the evidence is mixed for the few *in vivo* studies that are available. Atrazine has been classified as being possibly carcinogenic to humans.

The provisional ADI for atrazine is derived on the basis of division of a NOAEL obtained in a two-generation rat reproduction study, based on reductions in body weight of offspring in the F_2 generation, by an uncertainty factor that takes into account evidence that atrazine might act as a non-genotoxic carcinogen or as a promoter in rats through interferences in hormonal regulation. This NOAEL is supported by a NOEL obtained in a one-year dog study, based on cardiac toxicity, and by a NOAEL from a two-year feeding/oncogenicity study in rats, based on dose-related increases in mammary neoplasms in females.

The IMAC for atrazine in drinking water, derived from the provisional ADI, is *0.005 mg/L*. This guideline is applicable to the sum of atrazine and its N-dealkylated metabolites. It will remain an interim guideline until the full re-evaluation of the compound, currently in progress within the Health Protection Branch of Health Canada, is completed.

Azinphos-methyl

Azinphos-methyl is an organophosphorus insecticide and acaricide used for the control of a variety of pests for many fruit, vegetable, grain and forage crops.

Effects on cholinesterase activity have been observed in rats and dogs fed diets containing azinphos-methyl for up to two years. No definite conclusions can be drawn concerning the carcinogenicity of azinphos-methyl; however, it has not been found to be teratogenic in mammals, and it did not induce adverse reproductive effects in rats except at very high dose levels.

The ADI for azinphos-methyl has been derived by the FAO and WHO by dividing the NOAEL for effects on cholinesterase activity, obtained from two-year studies in rats and dogs, by an uncertainty factor.

The MAC for azinphos-methyl in drinking water, derived from the ADI, is *0.02 mg/L*.

Barium

Barium is not found free in nature, but it occurs in a number of compounds, most commonly barite (barium sulphate) and, to a lesser extent, witherite (barium carbonate). Barium compounds have a wide variety of industrial applications, being used in the plastics, rubber, electronics, textiles and oil and gas industries, among others.

Food appears to be the primary source of barium for the non-occupationally exposed Canadian population. However, in cases where barium levels in drinking water are high (0.6 mg/L, the maximum level observed in a survey of Canadian distributed water supplies), drinking water may contribute significantly (approximately 50%) to barium intake.

Barium is not considered to be an essential element for human nutrition. Soluble barium salts are highly acutely toxic, causing strong vasoconstriction, peristalsis, convulsions and paralysis.

Significant increases in mean systolic blood pressure have been observed in a 16-month study (12 to 16 mmHg) and an eight-month study (4 to 7 mmHg) in which rats ingested drinking water containing barium. No effects were found in another rat study following exposure for 20 weeks.

It has been suggested that small increases in mean systolic blood pressure in humans similar to those observed in rats could result in significant increases in clinical cases of coronary heart disease. However, in the most sensitive epidemiological study conducted to date, there were no significant differences in blood pressure or the prevalence of cardiovascular disease between populations drinking water containing 7.3 and 0.1 mg/L barium.

There has been no evidence of the carcinogenicity of barium in extremely limited lifetime bioassays of rats and mice exposed to barium in drinking water, and there are therefore inadequate data for its evaluation as a carcinogen.

The MAC is derived by division of a NOAEL, obtained from the sensitive epidemiological study of the effects on blood pressure and the prevalence of cardiovascular disease, by an uncertainty factor to account for intraspecies variation. This value is not substantially different from that derived on the basis of the results of toxicological studies in animals, using a NOAEL for effects on blood pressure in rats and an uncertainty factor; therefore, the MAC that was included in the 1978 Guidelines has been retained.

The MAC for barium in drinking water is *1.0 mg/L.*

Bendiocarb

Bendiocarb is a carbamate insecticide used in the control of a variety of insects in residences, public health areas, food storage and handling

premises and industrial facilities. It is also used in agriculture as a seed treatment and to control soil and foliar pests.

No data have been identified regarding levels of bendiocarb in Canadian drinking water, surface water or foods.

In a study in which rats were fed diets containing bendiocarb for two years, effects at the highest dose included significant changes in total white blood cells, serum cholesterol levels and brain cholinesterase levels. There was also a significant dose-dependent increase in the incidence of opacities in the lenses of males in the two highest dose groups.

Bendiocarb has not been found to be mutagenic, and results from several carcinogenicity bioassays have been negative or inconclusive.

The ADI of bendiocarb has been derived by the FAO and WHO by division of the NOAEL for several haematological and biochemical parameters and lens opacities in the two-year rat study by an uncertainty factor.

The MAC for bendiocarb in drinking water, derived on the basis of this ADI, is *0.04 mg/L.*

Benzene

Benzene is produced in Canada for use mainly in the manufacture of other organic chemicals. It is present in gasoline at concentrations of approximately 1 to 2%, and vehicular emissions constitute the main source of benzene in the environment. Benzene is introduced into water from industrial effluents and atmospheric pollution.

There is a fairly extensive data base available on the health effects associated with the inhalation of benzene by humans. Acute exposure to high levels affects primarily the central nervous system, whereas at lower concentrations benzene is toxic to the haematopoietic system. Haemato-logical effects have also been observed in an investigation of the effects of long-term ingestion of benzene in rats and mice.

Benzene is a documented human carcinogen. Because epidemiological data are insufficient to serve as a basis for quantitative estimation of cancer risks associated with exposure to low levels of benzene, cancer risks have been estimated on the basis of the results of a carcinogenesis bioassay in mice and rats. The MAC is established on the basis of the following considerations: (1) the PQL is 0.005 mg/L; (2) the estimated lifetime risk associated with the ingestion of drinking water containing 0.005 mg/L (based on the occurrence of leukaemia and lymphomas in female mice and of carcinomas in the mouths of male rats) is within a range that is considered to be "essentially negligible"; and (3) concentrations of benzene below 0.001 mg/L can be achieved using currently available treatment technologies.

The MAC for benzene in drinking water is *0.005 mg/L.*

Benzo[a]pyrene

Benzo[a]pyrene, or BaP, is a member of a class of compounds known as the polycyclic aromatic hydrocarbons, or PAHs. It is not manufactured and has no industrial uses. It is ubiquitously distributed throughout the environment as a result of its formation during the combustion of organic matter, including fossil fuels. Food is the greatest contributor (99%) to ingested BaP, with drinking water accounting for only 0.1 to 0.3% of the total BaP ingested.

BaP is carcinogenic in a variety of species and by a number of routes. No human health effects have been unequivocally associated with exposure to BaP *per se*. Acute, subchronic and chronic studies in animals to examine effects other than carcinogenesis are not plentiful because of the prevailing concern about the role of the compound as a proximal carcinogen.

BaP has been classified as being probably carcinogenic to humans, and cancer risks have been estimated on the basis of a study in which mice fed BaP in the diet exhibited an increased incidence of stomach tumours. Its MAC is established on the basis of the following considerations: (1) the PQL is 0.000 01 mg/L; (2) the estimated lifetime risk associated with the ingestion of drinking water containing BaP at a concentration of 0.000 01 mg/L (based on an increased incidence of stomach tumours) is within a range that is considered to be "essentially negligible"; and (3) conventional water treatment processes are capable of reducing BaP concentrations to less than 0.000 001 mg/L.

The MAC for BaP in drinking water is *0.000 01 mg/L.* BaP is the only PAH for which there is sufficient toxicological evidence to allow the setting of a guideline.

Boron

Boron is ubiquitous in the environment, occurring naturally in over 80 minerals and in the earth's crust. Boron compounds, particularly boric acid and sodium borate or borax, are used, for example, in the preparation of disinfectants, in the manufacture of borosilicate glass, as anti-oxidants for soldering, as insecticides and as cleaning compounds.

The predominant form of boron in water is boric acid. Levels in well water have been reported to be more variable and often higher than those in surface waters, most likely owing to erosion from natural sources. Food is the principal source of boron intake for Canadians.

Although boron has been considered to be non-essential for animals, recent studies suggest that boron might indeed be an essential element. Symptoms of acute boron poisoning include nausea, vomiting, diarrhoea,

headache, skin rashes and evidence of central nervous system stimulation followed by depression. Children, the elderly and individuals with kidney problems are most susceptible to the acute toxic effects of boron.

There was no evidence of carcinogenicity in adequate bioassays in two species (rats and mice), so boron has been classified as being probably not carcinogenic to humans. Available data from several studies in mice, dogs and two strains of rats indicate that exposure to boron causes testicular atrophy and spermatogenic arrest in males, resulting in infertility.

The ADI for boron is derived by division of the lowest reported NOAEL for adverse testicular effects, obtained in a 38-week study in dogs, by an uncertainty factor that takes into account the limitations of the critical study (i.e., the small number of experimental animals exposed for a small proportion of their life span). Using this ADI, a recommended value for boron in drinking water, based solely on health considerations, may be derived. This value is similar to that derived from a study in which boron was administered for the greatest proportion of the life span of the test animals (i.e., two years in rats).

However, practicable treatment technology and analytical methods must be taken into consideration in the establishment of a MAC. As available practicable treatment technology is inadequate to reduce boron concentrations in Canadian drinking water supplies to less than 5 mg/L, an IMAC of *5 mg/L* has been established. This IMAC will be reviewed periodically in light of new data.

Bromoxynil

Bromoxynil and its octanoate ester are phenolic benzonitrile-based herbicides employed for the control of broad-leaved weeds in grain crops. Bromoxynil was ranked high with respect to potential for groundwater contamination in an Agriculture Canada survey. Traces of bromoxynil have been found in municipal and private water supplies.

Bromoxynil esters are metabolized rapidly in animals to the phenol bromoxynil, which is considered to be the active species. Bromoxynil has a moderately high acute toxicity and acts by uncoupling oxidative phosphorylation. Its principal toxic action is on the liver. Bromoxynil has been considered to be non-tumorigenic, with negative results in two acceptable long-term studies in the mouse and rat. Increases in liver and kidney weights, thyroid enlargement and swollen thymus were noted at higher doses in mice, and reduced liver/body weight ratios were found in the rat study.

The Food Directorate of Health Canada has established an NDI for bromoxynil on the basis of division of the NOAEL, obtained from an unpublished two-year rat feeding/oncogenicity study, by an uncertainty

factor. There are insufficient data on long-term toxicity of bromoxynil or its esters to non-rodents to establish an ADI.

The IMAC for bromoxynil in drinking water, derived from the NDI, is *0.005 mg/L.*

Cadmium

Cadmium is not considered to be an essential element in human nutrition. Symptoms associated with the ingestion of small amounts of cadmium include vomiting and gastrointestinal cramps; chronic ingestion is believed to be associated with Itai-Itai, a syndrome characterized by softening of the bone and renal disease. A relationship between chronic ingestion of cadmium and hypertension has also been suggested. There is no evidence that cadmium is carcinogenic by ingestion.

Food is the main source of cadmium intake for humans that are not occupationally exposed. Consumption of drinking water obtained from unpolluted sources contributes only a small percentage to the total dietary intake of cadmium, although cadmium that is present as an impurity in galvanized pipes, a constituent of solders used in fitting water heaters and coolers or incorporated into stabilizers in black polyethylene pipes may contaminate water supplies during their distribution.

A joint FAO/WHO expert committee has recommended that the provisional tolerable weekly intake (PTWI) of cadmium be between 0.4 and 0.5 mg. Because it is difficult to reduce cadmium intake from food, the intake from water should be as low as possible.

A MAC of *0.005 mg/L* for cadmium in drinking water has been established on the basis of health considerations. Daily consumption of water containing cadmium at the MAC would result in the ingestion of about 12% of the PTWI.

Calcium

Calcium is an abundant natural element, entering the freshwater system through the weathering of rocks, especially limestone, and from the soil through seepage, leaching and runoff. Calcium oxide (lime) is used extensively in mortar, stucco and plaster in the building industry, in pulp and paper production, sugar refining, petroleum refining and tanning and as a wastewater treatment chemical.

Surface water generally contains lower concentrations of calcium than groundwater. Raw water supplies that receive lime treatment show significant increases in the amount of calcium in the treated water. Food is the main contributor of calcium to the Canadian diet.

Calcium is one of the principal cations associated with hardness in drinking water. The hardness of water can range from less than 75 mg/L as calcium carbonate (considered a soft water) to more than 300 mg/L (considered a very hard water). Undesirable effects due to the presence of calcium in drinking water may result from its contribution to hardness. These effects are dealt with in the "Hardness" review.

Efficient homeostatic mechanisms control calcium metabolism, so that adverse effects are observed only following the intake of extremely large quantities of calcium. High dietary calcium levels may adversely affect the bioavailability of other minerals in the diet. On the other hand, dietary calcium may slow the development of osteoporosis, prevent colon cancer and act as an anti-hypertensive agent. Hard drinking water has also been associated with a lower incidence of cardiovascular disease.

There is no evidence of adverse health effects specifically attributable to calcium in drinking water. Insufficient data are available to establish an AO for calcium in drinking water. A guideline for calcium has therefore not been specified.

Carbaryl
Carbaryl is a carbamate insecticide used for the control of a variety of pests on fruit, vegetables, cotton and other crops. It was detected only once in samples taken from municipal and private water supplies from across Canada and from three Ontario river basins.

The acute toxicity of carbaryl is due to its ability to inhibit cholinesterase activity. However, it is rapidly metabolized following absorption, so that its acute oral toxicity is low and its toxic effects are rapidly reversible. Carbaryl does not appear to be tumorigenic, and results from mutagenicity testing are largely negative.

The ADI of carbaryl in drinking water has been established by the FAO and WHO based on the NOAEL in human volunteers (for an increase in the ratio of the concentration in urine of amino acid nitrogen to that of creatinine) and in rats (for cloudy swelling of the kidney tubules and central hepatic cords).

The MAC for carbaryl in drinking water, derived from the ADI, is *0.09 mg/L.*

Carbofuran

Carbofuran is a carbamate insecticide and nematocide used for the control of a variety of soil-dwelling and foliar-feeding pests on many fruit and vegetable crops. It has been detected only once in samples from Canadian municipal and private water supplies and Ontario river basins.

Carbofuran is a cholinesterase inhibitor. Cholinesterase levels were depressed in human volunteers, rats, mice and beagle dogs administered oral carbofuran doses. Growth was also significantly depressed in rats fed carbofuran in the diet for two years. Carbofuran was not carcinogenic or tumorigenic in two-year studies in rats and mice. Several negative results and one positive result for mutagenicity have been obtained.

The ADI of carbofuran has been derived by the FAO and WHO by dividing the NOAEL for cholinesterase inhibition and growth suppression in a two-year study in rats by an uncertainty factor.

The MAC for carbofuran in drinking water, based on the ADI, is *0.09 mg/L.*

Carbon tetrachloride

Carbon tetrachloride is used primarily as an intermediate in the manufacture of other chlorinated hydrocarbons. Its intake from air is much greater than that from food or drinking water.

Chronic exposure to low doses of carbon tetrachloride leads to liver and kidney damage in humans. Carbon tetrachloride has been found to cause liver tumours in both sexes of rats and mice, but evidence for carcinogenicity in humans is inadequate. Carbon tetrachloride is therefore classified as being probably carcinogenic to humans.

The MAC for carbon tetrachloride was established on the basis of the following considerations: (1) the PQL is 0.005 mg/L; (2) the estimated lifetime risk (based on liver tumours in male mice and male rats) associated with the ingestion of drinking water containing carbon tetrachloride at a concentration of 0.005 mg/L is within a range that is considered to be "essentially negligible"; and (3) concentrations of carbon tetrachloride in drinking water below 0.001 mg/L can be achieved by currently available treatment technologies.

The MAC for carbon tetrachloride in drinking water is *0.005 mg/L.*

Chloramines

Monochloramine may be a by-product of drinking water chlorination, or it may be added to maintain residual disinfection activity in potable water distribution systems. Other advantages of the use of monochloramine as a secondary disinfectant in the treatment of drinking water include reduction of the formation of trihalomethanes and other by-products associated with

chlorine use, possible control of bacterial biofilm regrowth in the distribution systems and, in some circumstances, reduction of taste and odour problems associated with chlorination of drinking water supplies.

Monochloramine has been weakly mutagenic in several *in vitro* studies; however, there has been no evidence of clastogenic activity in *in vivo* studies conducted to date. No treatment-related developmental or reproductive effects have been observed in rats exposed to monochloramine in drinking water in limited studies. Although some possible immunologic effects have been reported, the biological significance of these effects is not clear.

Available epidemiological studies are inadequate for the assessment of the carcinogenicity of monochloramine in humans. There has, however, been some equivocal evidence of neoplastic responses in rats following chronic exposure to monochloramine in drinking water. The evidence for the carcinogenicity of monochloramine is considered to be limited, and the compound has been classified as possibly carcinogenic to humans (inadequate evidence in humans, some evidence in animals).

A TDI for monochloramine was derived from a NOEL based on decreased mean body weights in male rats, observed in a chronic study in which monochloramine was administered in drinking water, taking into consideration inter- and intraspecies variation, and a MAC was calculated from this TDI. However, the reduction in body weight gains may have been related to a decrease in water consumption, owing to a taste aversion to monochloramine in the drinking water. As well, because of possible carcinogenic and immunotoxicity effects, methaemoglobinaemia and haemolysis in dialysis patients, increases in plasma apoliprotein B levels in humans, and other observed effects, a conservative approach was used in derivation of the guideline.

A MAC of *3.0 mg/L* for total chloramines was established on the basis of the following considerations: (1) because of the questionable significance of the toxicity end-point, the guideline was established at the lowest practicable level of 3.0 mg/L – the PQL for chloramines is approximately 0.1-0.2 mg/L, well below the proposed MAC; however, many small municipalities do not have the capacity to measure individual chloramines or total chloramines down to the sub-milligram level, and 3.0 mg/L is a realistic PQL in these cases; (2) this level is considered to be close to the MAC calculated from the NOEL for monochloramine, in view of the uncertainties associated with this calculation; moreover, although monochloramine normally represents a large fraction of the total chloramines, the specification for measurement of total chloramines ensures that monochloramine will be less than the maximum; and (3) natural ammonia may be found at higher concentrations in groundwater

and surface water during the colder winter months and therefore may present a potential plant operational control problem if the guideline is lower than 3.0 mg/L; under conditions of high ammonia, the production of chloramines may increase.

It should be emphasized that this MAC is based on the risk evaluation for monochloramine only, as monochloramine is usually the predominant chloramine and as information on dichloramine and trichloramine toxicity is insufficient to establish guidelines for these two compounds.

Chloride

The presence of chloride in natural waters can be attributed to a variety of sources, including the dissolution of salt deposits, salting of roads for ice control and effluents from chemical industries. Chloride is generally present at low concentrations in natural surface waters in Canada, although higher concentrations may be found in drinking water derived from groundwater sources as a result of naturally high levels of chloride in soils in some areas or contamination by road salt.

Chloride is the most abundant anion in the human body. Chloride levels in the body are well regulated through a complex interrelated system involving both the nervous and hormonal systems. Even after intake of large quantities of chloride in food and water, the chloride balance is maintained, mainly by the excretion of excess chloride in the urine. No evidence has been found suggesting that ingestion of chloride is harmful to humans.

Chloride in water supplies is objectionable because it imparts undesirable tastes to water and beverages prepared from water. The AO for chloride in drinking water is ≤ *250 mg/L*. Levels of chloride in Canadian drinking water supplies are generally much lower than this concentration.

Chlorophenols

There are 19 chlorophenol congeners, many of which are used in Canada in pesticide products or as wood preservatives. Data are available to establish MACs for only four of the chlorophenols.

Available data are inadequate to classify 2,4-dichlorophenol (2,4-DCP), 2,3,4,6-tetrachlorophenol (2,3,4,6-TeCP) and pentachlorophenol (PCP) with respect to their potential carcinogenicity. For these compounds, the ADIs were derived on the basis of division of the NOAELs by uncertainty factors that take into account study limitations. The NOAELs were derived from studies that showed effects on liver in mice in a subchronic (six months) feeding study (2,4-DCP); effects on embryotoxicity (delayed ossification of skull bones) in rats in a short-term study (2,3,4,6-TeCP); and effects on such parameters as body weight gain and enzyme activity in a limited chronic study in mice (PCP).

2,4,6-Trichlorophenol (2,4,6-TCP) is classified as being probably carcinogenic to humans; it has been shown to be carcinogenic to male rats and mice of both sexes, although there is inadequate evidence of carcinogenicity in humans. Its MAC was established based on the following considerations: (1) the PQL is 0.008 μg/L; (2) the concentrations of 2,4,6-TCP in Canadian drinking water supplies are generally considerably less than 0.005 mg/L, and it is likely that concentrations below 0.001 mg/L can be achieved using currently available treatment technologies; and (3) the estimated lifetime cancer risk (based on leukaemias in male rats) associated with the ingestion of drinking water containing 2,4,6-TCP at a concentration of 0.005 mg/L is within a range that is considered to be "essentially negligible."

The AOs for the four chlorophenols are based on the threshold odour values for these compounds.

MACs and AOs for the four chlorophenols in drinking water are as follows:

	MAC	**AO**
2,4-dichlorophenol	*0.9 mg/L*	*≤0.0003 mg/L*
2,4,6-trichlorophenol	*0.005 mg/L*	*≤0.002 mg/L*
2,3,4,6-tetrachlorophenol	*0.1 mg/L*	*≤0.001 mg/L*
pentachlorophenol	*0.06 mg/L*	*≤0.030 mg/L*

Chlorpyrifos

Chlorpyrifos is an organophosphorus insecticide used for the control of mosquitoes, flies, various crop pests in soil and on foliage, household pests and aquatic larvae. It is also used on sheep and cattle for the control of ectoparasites.

Chlorpyrifos is tightly absorbed by soil and is not expected to leach significantly. It has not been detected in surveys of municipal and private drinking water supplies and surface water in Canada, even in areas in which it had been used extensively.

Chlorpyrifos is a cholinesterase inhibitor. Studies have found cholinesterase activity to be inhibited in beagle dogs and rats but not in rhesus monkeys or human volunteers.

The ADI for chlorpyrifos has been derived by the FAO and the WHO on the basis of division of the NOAEL (obtained from two-year studies on the inhibition of enzyme activities in the dog and rat and short-term studies with human volunteers) by an uncertainty factor.

The MAC for chlorpyrifos in drinking water, derived from the ADI, is *0.09 mg/L.*

Chromium

Trivalent chromium, the most common natural state of chromium, is essential in humans and animals for efficient lipid, glucose and protein metabolism. It is considered to be non-toxic; however, if it is present in raw water, it may be oxidized to hexavalent chromium during chlorination.

Hexavalent chromium is not considered to be an essential element, and the toxic effects of chromium in humans are attributed primarily to this hexavalent form. Chromium has been linked with cancer following occupational exposures to the element, although a recent report states that there are inadequate data to conclude that chromium is carcinogenic via ingestion. The main toxic effects observed in animals following ingestion of the element are on the liver, kidney and gastrointestinal tract.

A MAC of *0.05 mg/L* for chromium in drinking water has been established on the basis of health considerations. At the MAC, hexavalent chromium has not had any known harmful effects on the health of humans or animals. Available data are insufficient to determine whether higher concentrations would also be safe.

Concentrations of total chromium in drinking water are normally well below the MAC. Although chromium salts impart odour and taste to water, the concentration at which this occurs is considerably higher than the MAC.

Colour

Colour in drinking water may be due to the presence of coloured organic substances, metals such as iron, manganese and copper or highly coloured industrial wastes. Although the presence of colour in drinking water is not directly linked to health, experience has shown that consumers may turn to alternative, possibly unsafe, sources when their drinking water contains aesthetically displeasing levels of colour.

The AO for colour in drinking water is *≤15 true colour units (TCU)*. The provision of treated water at or below the AO will encourage rapid notification by consumers should problems leading to the formation of colour arise in the distribution system.

Copper

Copper occurs in nature as the metal and in minerals. It has a variety of uses, including extensive use in plumbing, especially for domestic water systems, in the production of electrical wire, in the manufacture of alloys and in pesticide formulations for the treatment of wood and water supplies for drinking water and recreational use.

Copper and its compounds are widely distributed in nature, and copper is found frequently in surface water and in some groundwater. Distributed water contains considerably more copper than the original water supply

because of the dissolution of copper from copper piping. It has been estimated that drinking water contributes approximately 11% of an adult's total daily intake of copper, with the rest coming from food.

Copper is an essential element in human metabolism, being required in many enzymatic reactions and for the normal utilization of iron. The recommended daily intake for adults is about 2 mg. Copper deficiency results in a variety of clinical disorders, including nutritional anaemia in infants. Although copper intake has resulted in adverse health effects, this occurs only at extremely high doses.

Copper in public water supplies enhances corrosion of aluminum and zinc and imparts an undesirable bitter taste to water. Staining of laundry and plumbing fixtures occurs at copper concentrations above 1.0 mg/L.

The AO for copper in drinking water is set at *≤1.0 mg/L*. This level is below the taste threshold for copper in water, is protective of health and contributes to minimum nutritional requirements.

Cyanazine
Cyanazine is a triazine herbicide used for pre- and post-emergence weed control for corn, rapeseed and mixed grains. It adsorbs to soil but is considered to have strong leaching potential. It has been detected in municipal and private water supplies and surface water samples in Canada.

No information on the toxicity of cyanazine in humans was identified in the literature. A short-term study in which rats were fed daily doses of cyanazine found reduced kidney weight in males and increased liver weight in females. Cyanazine was not considered to be carcinogenic in mice or oncogenic in rats, but these studies were considered inadequate by the U.S. EPA. Teratological effects, including alterations in skeletal ossification sites in the foetus, were observed when pregnant rats were administered cyanazine on days 6 through 15 of gestation.

An NDI for cyanazine was established by the Food Directorate of Health Canada on the basis of division of the NOAEL, in terms of decreased kidney and increased liver weights in a 13-week study in rats, by an uncertainty factor.

The IMAC for cyanazine in drinking water, derived from the NDI, is *0.01 mg/L.*

Cyanide
Cyanides are employed in many industrial processes, including chemical manufacturing and metal extraction from low-grade ores, and industrial effluents are the main sources of cyanide contamination of water.

Canadian drinking water contains very low levels of cyanide. Food and drinking water are the main sources of cyanide exposure for individuals who are not occupationally exposed to the chemical.

Cyanide is an extremely toxic and fast-acting poison. However, because it can be detoxified (through conversion to the relatively non-toxic thiocyanate ion) to a certain extent in the human body, cyanide poisoning generally results from acute exposure to high doses, not from chronic ingestion of low doses.

The MAC for free cyanide in drinking water, based on health effects, is *0.2 mg/L*. Levels in Canadian drinking water are usually considerably less than this, and chlorination or ozonation would further lower the concentration of free cyanide and yield much less toxic products.

Diazinon

Diazinon is an organophosphorus insecticide used for the control of soil and household insect pests, as well as sucking and chewing insects and mites on a wide variety of crops. It is also used as an animal ectoparasiticide.

Diazinon is not very persistent in soil, owing to rapid chemical and biological degradation, and it is not considered to leach significantly into water. It is hydrolysed slowly in water. Diazinon has been detected only rarely in surveys of municipal and private water supplies.

Diazinon is a cholinesterase inhibitor. It has not been found to be carcinogenic in studies using mice and rats.

The ADI for diazinon has been derived by the FAO and WHO on the basis of division of the NOAEL for cholinesterase inhibition, obtained from studies in dogs and in human volunteers, by an uncertainty factor. The MAC is derived from the ADI assuming that 20% of daily intake comes from drinking water, although actual intake from water appears to be much less.

The MAC for diazinon in drinking water is *0.02 mg/L*.

Dicamba

Dicamba is a broad-spectrum chlorobenzoic acid herbicide used in large quantities for general weed control on grain crops, pastures and non-crop areas. It is not strongly adsorbed onto soil particles and is readily leached to groundwater. It has occasionally been detected in municipal and private water supplies and in surface waters.

Dicamba has a fairly low acute toxicity. Its principal toxic action is on the liver, with vacuolization, necrosis, fatty deposits and liver weight changes noted at high doses in rats and dogs. A two-year study with dogs administered technical dicamba in the diet found a decrease in body weight in males at the two highest doses. No compound-related increases in tumour

incidence were observed in the dog study or in a two-year rat study, although these studies were inadequate to allow evaluation of the carcinogenicity of dicamba.

The Food Directorate of Health Canada has established an ADI for dicamba on the basis of division of the NOAEL, obtained from the two-year feeding study in dogs, by an uncertainty factor.

The MAC for dicamba in drinking water, derived from the ADI, is *0.12 mg/L.*

Dichlorobenzenes

There are three dichlorobenzene (DCB) isomers. Although they are not manufactured in Canada, several thousand tonnes of the 1,2- and 1,4-isomers are imported each year for use in degreasing and paint removal formulations, as chemical intermediates, in moth crystals and in urinal or space deodorants.

Available data are considered inadequate to classify 1,2-DCB with respect to its potential carcinogenicity. Its MAC is derived from an ADI calculated by dividing a LOAEL, based on subchronic toxicity studies that showed biochemical changes (increases in serum cholesterol, protein and glucose levels) in rats, by an uncertainty factor that takes into consideration the subchronic nature of the study and the use of a LOAEL instead of a NOAEL.

1,4-DCB is classified as being probably carcinogenic to humans. Its MAC is established on the basis of the following considerations: (1) the PQL is 0.005 mg/L; (2) the estimated lifetime risks associated with the ingestion of drinking water containing 1,4-DCB at a concentration of 0.005 mg/L (based on tumours in the liver and the adrenal gland in male mice) are within a range that is considered to be "essentially negligible"; and (3) it is likely that concentrations below 0.001 mg/L can be achieved in Canadian drinking water supplies using currently available treatment technologies.

There are no data available to serve as a basis for establishing a MAC for 1,3-DCB in drinking water.

The AOs for 1,2- and 1,4-DCB are based on their threshold odour values.

The following MACs and AOs have been established for 1,2-and 1,4-DCB in drinking water:

	MAC	AO
1,2-DCB	*0.20 mg/L*	*≤0.003 mg/L*
1,4-DCB	*0.005 mg/L*	*≤0.001 mg/L*

In cases where total DCBs are measured and concentrations exceed the most stringent value (0.005 mg/L), the concentrations of the individual isomers should be established.

1,2-Dichloroethane

1,2-Dichloroethane has been reported to be one of the most widely used chemicals in the world. Almost all of the domestic 1,2-dichloroethane is used as a chemical intermediate in the preparation of vinyl chloride. About 1% is used as a solvent and as a lead scavenger in leaded gasoline formulations.

1,2-Dichloroethane enters the environment through atmospheric emissions, waste effluents to waterways and land disposal of liquid and solid wastes. Because of its high volatility, 1,2-dichloroethane that is released to land and water can be expected to be transferred predominantly to the atmosphere.

Acute and chronic occupational exposures to inhaled 1,2-dichloroethane lead to such symptoms as nausea, headache, vomiting and loss of consciousness. In subchronic studies, severe effects, including hepato-toxicity and death, were observed in rats and guinea pigs exposed to 1,2-dichloroethane vapour at high concentrations.

1,2-Dichloroethane is considered to be probably carcinogenic to humans, on the basis that it has been shown to be carcinogenic in both sexes of two animal species. An IMAC for 1,2-dichloroethane is established on the basis of the following considerations: (1) the PQL is 0.005 mg/L; (2) the estimated lifetime cancer risk associated with the ingestion of drinking water containing 0.005 mg/L (based on haemangiosarcomas in male rats) is 8×10^{-6} (the MAC is considered interim because intake in drinking water is approximately 9% of the total intake, and the estimated total risk from all sources therefore will exceed 1×10^{-5}, which is above a range considered "essentially negligible"); and (3) it is possible to achieve concentrations of 1,2-dichloroethane below 0.001 mg/L using currently available treatment technologies.

The IMAC for 1,2-dichloroethane in drinking water is *0.005 mg/L*.

1,1-Dichloroethylene

1,1-Dichloroethylene (1,1-DCE) is not produced in Canada. Its polymer, polyvinylidene chloride (PVDC), which is imported from the United States, is used primarily in the food packaging industry as cast and extruded film and as a barrier coating for paper, cellulose, polypropylene and other plastics.

Although 1,1-DCE has been detected only infrequently in drinking water in Canada, the leaching into groundwater of the common contaminants tetrachloroethylene and 1,1,1-trichloroethane, of which 1,1-DCE is a known degradation product, is a potential source of 1,1-DCE contamination. In general, the concentrations of 1,1-DCE found in both ambient and indoor air would result in a higher intake of 1,1-DCE from air than from either food (leached from food packaging materials) or drinking water, and probably less than 10% of total 1,1-DCE intake is normally ingested in drinking water.

The evidence for the carcinogenicity of 1,1-DCE is considered to be limited, and the compound has been classified as being possibly carcinogenic to humans. As no adequate studies by the oral route that resulted in adverse effects have been identified, the ADI is derived on the basis of division of a LOEL, based on mid-zonal fatty changes in the liver observed in female rats, by an uncertainty factor that takes into account the limited evidence of carcinogenicity by the inhalation route and the use of a LOEL instead of a NOAEL.

The MAC for 1,1-DCE in drinking water, derived from the ADI, is *0.014 mg/L.*

Dichloromethane

Dichloromethane is a volatile liquid that is used extensively as an industrial solvent, for paint stripping, as a degreasing agent and as an aerosol propellant. It is not manufactured in Canada but is imported from the United States. About 85% of the dichloromethane produced in the United States has been estimated to be lost to the environment (and hence lost from the drinking water supply) via sewage treatment.

Acute inhalation exposures of animals to dichloromethane indicate that the central nervous system is its primary target. Chronic exposures to high concentrations result in hepatic and renal effects. Human health effects induced by inhalation exposures have included neurotoxicity and increased carboxyhaemoglobin levels. Chronic exposures did not produce any demonstrable irreversible effects.

The evidence for the carcinogenicity of dichloromethane is inadequate in humans, but evidence from animal studies (both sexes of two species) is sufficient to classify it as being probably carcinogenic to humans. Its MAC is established on the basis of the following considerations: (1) the PQL is 0.005 mg/L; (2) concentrations in Canadian drinking water supplies are generally considerably less than 0.05 mg/L, and it is likely that concentrations below 0.001 mg/L can be achieved using currently available treatment technologies; and (3) the estimated lifetime risk associated with the ingestion of drinking water containing 0.05 mg/L dichloromethane

(based on the occurrence of liver adenomas and carcinomas in female mice) is within a range that is considered to be "essentially negligible."

The MAC for dichloromethane in drinking water is *0.05 mg/L.*

2,4-Dichlorophenol – See *Chlorophenols*

2,4-Dichlorophenoxyacetic acid (2,4-D)

2,4-Dichlorophenoxyacetic acid, commonly referred to as 2,4-D, is a systemic chlorophenoxy herbicide used widely in Canada in the control of broadleaf weeds in cereal cropland and on industrial property, lawns, turf, pastures and non-cropland. It is also used to control aquatic weeds. 2,4-D may enter the aquatic environment through effluents and spills arising from its manufacture and transport and through direct application as a weed control agent. 2,4-D has been detected in samples of raw and treated drinking water from municipal and private supplies across Canada at concentrations below 30 μg/L.

Most epidemiological studies on 2,4-D have dealt with multiple exposures to various chlorophenoxy herbicides, other pesticides and other organic compounds, and, until recently, most dealt with populations exposed in the 1950s and 1960s, when some chlorophenoxy herbicides were contaminated with polychlorinated dioxins and furans. A series of population-based case-referent studies conducted in Sweden in the late 1970s and early 1980s found strong associations between soft-tissue sarcomas (STS) and multiple lymphomas, including Hodgkin's disease (HD) and non-Hodgkin's lymphoma (NHL), and the use of chlorophenoxy herbicides by agricultural or forestry workers. Several case-control studies conducted since then have been suggestive of a causal association between farming, chlorophenoxy herbicide use and NHL, but their results are not consistent with results from other studies, particularly occupational cohort studies. The association with STS, commonly attributed to dioxins, is at best weak and inconsistent.

Analytical epidemiology and animal studies conducted on 2,4-D and related chlorophenoxy compounds have not provided conclusive evidence for their carcinogenicity, although a slight dose-related increase in brain tumours was noted in male rats in the highest dose group in one chronic bioassay. Currently available evidence suggests that 2,4-D is non-genotoxic. 2,4-D has therefore been classified as possibly carcinogenic to humans.

A provisional ADI for 2,4-D is derived on the basis of division of a NOAEL for tubular cell pigmentation in the kidney, observed in a two-year dietary toxicity/oncogenicity study in rats, by an appropriate uncertainty factor. The IMAC derived from this provisional ADI is only slightly lower than the previous guideline of *0.1 mg/L* for 2,4-D in drinking water, which

has therefore been retained in view of the small difference between the old and the new values. However, the guideline has changed from a MAC to an IMAC until new studies that clarify the status of 2,4-D with respect to carcinogenicity are available and a re-evaluation is completed.

Diclofop-methyl

Diclofop-methyl is a chlorophenoxy derivative used for the control of annual grasses in grain and vegetable crops. It is not considered to be a groundwater contaminant. It was not detected in municipal drinking water supplies in Manitoba and Alberta and has only occasionally been detected in private farm wells and surface waters.

The acute toxicity of diclofop-methyl is relatively low. Its principal toxic action was on the liver in a 15-month study in dogs (increased liver weights, increased enzyme levels and centrilobular fatty deposits at higher doses), a two-year study in rats (elevations in liver enzymes) and a two-year mouse feeding/oncogenicity study (elevated liver enzyme levels and liver pathology). There was no evidence of tumorigenicity in the two-year rat study, although the two-year mouse study found a statistically significant increase in hepatocellular benign tumours in male mice along with some malignant tumours at the highest dose.

Based on evaluations by the Food Directorate of Health Canada, an ADI for diclofop-methyl is derived by dividing the NOAEL for liver enlargement and liver enzyme changes in two-year feeding studies in rats and mice by an uncertainty factor assigned by the Food Directorate.

The MAC for diclofop-methyl in drinking water, derived from the ADI, is *0.009 mg/L*.

Dimethoate

Dimethoate is an organophosphorus insecticide and acaricide used for the control of houseflies, as well as a wide range of insects and mites on a variety of fruit, vegetable, field and forestry crops. Dimethoate released to the environment does not adsorb onto the soil and is subject to considerable leaching. It is degraded in the environment to another more toxic pesticide, omethoate. Dimethoate has only once been detected, at trace levels, in samples from municipal and private drinking water supplies and surface water from across Canada.

Dimethoate is a cholinesterase inhibitor. Cholinesterase levels have been observed to decrease in human volunteers administered oral doses of dimethoate for periods of 14 to 57 days and in dogs and rats administered dimethoate in the diet. Available studies are inadequate to allow

classification of dimethoate with regard to its potential carcinogenicity. Dimethoate has been found to be mutagenic in a number of *in vivo* and *in vitro* short-term tests.

In 1984, the FAO and WHO withdrew their estimate of an ADI for dimethoate because of its incomplete data base. Until further experimental studies are completed, a temporary ADI has been established by the WHO by division of the NOAEL from studies on cholinesterase inhibition in human volunteers by an uncertainty factor.

The IMAC for dimethoate in drinking water, derived from the temporary ADI, is *0.02 mg/L.*

Dinoseb

Dinoseb is a selective non-systemic herbicide and desiccant with moderate use in Canada. It is effective in the control of many broadleaf weeds in such crops as cereals and peas and is also used for pre-emergence control of annual weeds in beans, peas and potatoes and for control of runners and suckers in raspberries and strawberries.

Dinoseb is considered by Agriculture Canada to have a high potential for leaching based on its soil half-life and its soil organic carbon partition coefficient (K_{oc}). It has been detected in samples taken from municipal and private water supplies across Canada.

Dinoseb is very toxic to humans and is believed to act by uncoupling oxidative phosphorylation. Symptoms of acute poisoning include vomiting, pain and swelling of the eyes, headache, loss of weight and shortness of breath. Although there is no strong evidence for the carcinogenicity of dinoseb, available data are inadequate for assessment of its carcinogenicity, and an adequate dietary oncogenicity study is required. There is also no strong evidence of the mutagenic potential of dinoseb in studies conducted to date.

The principal toxic effects of dinoseb that are of concern are its teratogenic and foetotoxic effects at doses below those that cause maternal toxicity and its potential as a cataract-inducing agent. In a rat reproduction study in which dinoseb was administered by gavage, skeletal anomalies were observed at the higher doses. This finding was supported by an oral teratology study in rabbits in which neural tube defects were observed, a dermal teratology study in rabbits and a 100-week dietary study in mice in which cataracts occurred.

The ADI of dinoseb has been derived by division of the NOAEL, derived from the rat reproduction study in which skeletal anomalies were observed, by an uncertainty factor that takes into account its teratogenicity, considered to be a serious effect, and limitations in the toxicity data base.

Because of dinoseb's significant foetotoxic effects and the probability that it will be withdrawn from the market, it was decided that a MAC should be set rather than an IMAC.

The MAC for dinoseb in drinking water, derived from the ADI, is *0.01 mg/L.*

Diquat

Diquat is a bipyridyl herbicide generally marketed as a dibromide salt or a dichloride monohydrate. It is used as a pre-harvest desiccant for various seed crops, for potato haulm destruction and for the control of aquatic weeds.

The double positive charge on the diquat cation causes it to be adsorbed tightly to the negatively charged clay minerals in the soil. As a result, diquat is unlikely to leach to groundwater. Diquat applied to aquatic systems disappears from the water in one to four weeks through adsorption to plants and sediments. No information on the concentrations of diquat in Canadian drinking water or surface waters has been identified.

Diquat poisoning in humans may cause damage to the lining of the gastrointestinal tract, brain, liver, kidneys and lungs. Chronic ingestion of diquat has induced the formation of cataracts in rats and dogs, an effect that has never been reported in humans following exposure. No carcinogenic or tumorigenic potential was reported for diquat in long-term feeding studies in rats and dogs.

The ADI for diquat (measured as the cation) has been derived by the FAO and WHO on the basis of division of the NOAEL, in terms of cataract formation in rats, by an uncertainty factor.

The MAC for diquat (measured as the cation) in drinking water, derived from the ADI, is *0.07 mg/L.*

Diuron

Diuron is a substituted urea-based herbicide used principally for the control of vegetation in non-crop areas, including irrigation and drainage ditches. It is considered to have high potential for leaching from soil and subsequent groundwater contamination. It has not often been included in Canadian water monitoring surveys.

In animals, the principal toxic effects of chronic ingestion of diuron are weight loss and abnormalities in blood, liver and spleen. Studies to date have been inadequate for an assessment of the carcinogenicity of diuron.

The Food Directorate of Health Canada has derived an ADI for diuron based on division of the NOAEL, obtained from a two-year dog study in which such effects as body weight loss and increased liver weight were observed at higher doses, by an uncertainty factor assigned by the Food Directorate.

The MAC for diuron in drinking water, derived from the ADI, is *0.15 mg/L.*

Ethylbenzene – See **Toluene, ethylbenzene and the xylenes**

Fluoride

Fluoride occurs naturally in minerals and soils, and fluorides are widely used by Canadian industry in the manufacture of, for example, aluminum, phosphate fertilizers and bricks. The fluoride concentration in natural waters varies widely, as it depends on such factors as the source of the water and the geological formations present. Food and drinking water are the main sources of fluoride for most Canadians.

Trace amounts of fluoride may be essential for human nutrition. The presence of small quantities of fluoride in drinking water leads to a substantial reduction of dental caries, particularly among children. The ingestion of excessive quantities of fluoride can result in dental fluorosis, a condition characterized by mottling of tooth enamel.

The optimum concentration of fluoride in drinking water for the reduction of dental caries is 1.0 mg/L in most Canadian communities. The appearance of dental fluorosis may be objectionable at fluoride concentrations above 1.5 mg/L.

The MAC for fluoride in drinking water is *1.5 mg/L.* Surface waters usually contain fluoride at concentrations below 1 mg/L.

The guideline for fluoride is currently being reviewed for possible revision owing to new data (see Table 5).

Gasoline and its organic constituents

Gasoline is a complex mixture of hydrocarbons and such substances as anti-knock agents, anti-rust additives, pre-ignition additives, upper cylinder lubricants and dyes. The most important use of gasoline is as a fuel in internal combustion engines.

Gasoline is not likely to be found in drinking water except as the result of a spill or a leaking storage tank. Exposure to gasoline *per se* is unlikely to occur, as most people would not drink water if it had the taste or smell of gasoline. Such rejection of the water would take place at concentrations well below those at which there might be harmful effects.

Because of the complexity of gasoline and its variable composition, it is not appropriate to review data on the health effects of exposure to gasoline in drinking water. Therefore, gasoline has not been classified on the basis of potential health effects. Some of the constituents of interest from a health point of view (e.g., benzene, toluene, ethylbenzene, the xylenes, lead and 1,2-dichloroethane) are dealt with separately.

Glyphosate

Glyphosate is a systemic herbicide used in high volume for non-selective weed control on rights-of-way, in forestry plantations, in site preparation for crop plantings and as a foliage desiccant for selected crops (e.g., wheat, barley, legumes, forage crops). Glyphosate is usually formulated as the isopropylamine salt (Roundup).

Glyphosate undergoes microbial degradation to the metabolite aminomethylphosphonic acid (AMPA). Owing to their physicochemical properties, glyphosate and AMPA are not expected in surface waters except after direct application or soil erosion due to precipitation. Glyphosate is strongly adsorbed to soils and is not expected to migrate to groundwater supplies after application.

In chronic toxicity studies, effects at high glyphosate doses include liver and kidney necrosis (male mice), increased liver weights (male rats), decreased body weight gain (male and female mice, male and female rats) and reduced body weights (female rats). Unequivocal evidence for tumorigenicity has not been found. Glyphosate was not mutagenic in a battery of *in vitro* and *in vivo* short-term tests. No teratogenic effects were observed in rabbit and rat studies, and no adverse reproductive effects were noted in a two-litter, three-generation rat study.

The Food Directorate of Health Canada established an NDI for glyphosate in drinking water on the basis of division of a NOAEL for reduced body weight gain in a two-year rat feeding/oncogenicity study by an uncertainty factor that takes into consideration inter- and intraspecies variation.

The IMAC for glyphosate in drinking water, derived from the NDI, is *0.28 mg/L.*

Hardness

Water hardness is caused by dissolved polyvalent metallic ions, principally calcium and magnesium, and is expressed as the equivalent quantity of calcium carbonate. Incrustation and excessive soap consumption are the main concerns with hardness. On heating, hard waters have a tendency to form scale deposits. Soft water, on the other hand, may result in corrosion of water pipes.

Depending on the interaction of other factors such as pH and alkalinity, hardness levels between 80 and 100 mg/L (as calcium carbonate) are considered to provide an acceptable balance between corrosion and incrustation. Water supplies with a hardness greater than 200 mg/L are considered poor but have been tolerated by consumers; those in excess of 500 mg/L are unacceptable for most domestic purposes. Because water softening by sodium ion exchange may introduce undesirably high quantities of sodium into drinking water, it is recommended that, where such a process is employed, a separate unsoftened supply be retained for drinking and culinary purposes.

Although hardness may have significant aesthetic effects, public acceptance of hardness varies considerably according to local conditions. There is also some epidemiological evidence that suggests that hardness may be inversely related to the incidence of cardiovascular disease. Therefore, a MAC for hardness in drinking water has not been established.

Iron

Iron is the fourth most abundant element in the earth's crust. In Canada, iron ore is used mainly for processing into steel products. Few data are available on levels of iron in Canadian surface waters or drinking water, and it is not known what effect local contamination of surface water or groundwater has on the concentration of iron in finished waters.

Iron is an essential element in human nutrition; however, intake of iron from a typical Canadian diet is more than sufficient to meet the minimum daily requirement. Toxic effects have resulted from the ingestion of large quantities of iron, but there is no evidence to indicate that concentrations of iron commonly present in food or drinking water constitute any hazard to human health.

At concentrations above 0.3 mg/L, iron can stain laundry and plumbing fixtures and cause undesirable tastes in beverages. The precipitation of excessive iron imparts an objectionable reddish-brown colour to the water. Iron may also promote the growth of certain micro-organisms, leading to the deposition of a slimy coat in piping.

The AO for iron in drinking water is ≤*0.3 mg/L*. Generally, only a small percentage of the population will be able to taste iron in drinking water at concentrations below 0.3 mg/L.

Lead

Lead is the most common of the heavy elements and is widely distributed throughout the environment. It is used in the production of lead acid storage batteries, tetraethyl lead (a gasoline additive), pigments, chemicals and solder. From a drinking water perspective, the almost

universal use of lead compounds in plumbing fittings and as solder in water distribution systems is important. Older distribution systems and plumbing may also be made from lead pipe.

Lead is present in tap water as a result of dissolution from natural sources or from household plumbing systems containing lead in pipes, solder or service connections to homes. The relative contribution of drinking water to average daily intake is estimated to be approximately 10% for children and 11% for adults. Soils and household dust are significant sources of lead exposure for small children.

Lead is a cumulative general poison, with foetuses, infants, young children and pregnant women being most susceptible to adverse health effects. Lead can severely affect the central nervous system. Acute intoxication leads to restlessness, irritability, poor attention span, headaches and loss of memory. Signs of chronic lead toxicity include fatigue, sleeplessness, irritability, headaches, gastrointestinal symptoms and renal disease. Lead also interferes with the activity of several of the major enzymes involved in the biosynthesis of haem.

Several epidemiological studies have examined the effects of lead exposure on the intellectual abilities and behaviour of young children. Interpretation of these epidemiological data is difficult, and results are inconsistent. However, research on young primates supports the view that lead causes significant behavioural impairment.

Lead has been classified as being possibly carcinogenic to humans. The ADI for compounds classified in this way is derived on the basis of division of the NOAEL or LOAEL in humans or in animals, taking into account the equivocal evidence of carcinogenicity. For lead, there is also evidence from human studies that adverse effects other than cancer may occur at very low levels, and that a guideline derived for these effects would be protective for the risk of carcinogenic effects.

The WHO established a provisional tolerable weekly intake (PTWI) for lead for children of 25 μg/kg bw, equivalent to an ADI of approximately 3.5 μg/kg bw per day. This PTWI was established on the premise that lead is a cumulative poison and that there should be no increase in the body burden of lead from any source, thus avoiding the possibility of adverse biochemical and neurobehavioural effects in infants and young children. It was based on metabolic studies in infants showing that a mean daily lead intake of 3 to 4 μg/kg bw was a NOAEL and was not associated with an increase in blood lead levels or in the body burden of lead, whereas a daily intake of 5 μg/kg bw or more resulted in lead retention. An unusually small uncertainty factor (less than 2) reflected the conservatism of the end-point, the quality of the metabolic data and use of one of the most susceptible groups in the population.

The MAC for lead in drinking water is derived from the ADI, taking into account the average body weight of a two-year-old child, the proportion of total daily intake allocated to drinking water (intake of lead from sources other than water has decreased substantially over the last few years because of the phase-down of the use of lead-soldered cans in the food industry and the phase-out of lead additives in gasoline) and the average daily water consumption for a two-year-old child. The MAC calculated in this manner is approximately 0.008 mg/L.

The PQL for routine analysis of lead in drinking water is 1 to 10 μg/L, depending on the presence of other compounds in the water supply. Because the MAC should be measurable and achievable at reasonable cost, the MAC selected for lead in drinking water is *0.010 mg/L*, based on this limit.

Because the MAC for lead is based on chronic effects, it is intended to apply to average concentrations in water consumed for extended periods; short-term consumption of water containing lead at concentrations above the MAC does not necessarily pose undue risk to health.

In order to minimize exposure to lead introduced into drinking water from plumbing systems, it is also recommended that only the cold water supply be used, after an appropriate period of flushing to rid the system of standing water, for analytical sampling, drinking, beverage preparation and cooking.

Magnesium

Magnesium is an essential element in human metabolism, and magnesium deficiencies are associated with cardiovascular, neuromuscular and renal disorders. Magnesium is one of the major contributors to water hardness, and numerous studies have linked magnesium content in drinking water with a decrease in cardiovascular disease.

Undesirable effects from the ingestion of magnesium in drinking water may result indirectly from the laxative effect of magnesium in association with the sulphate ion. As well, magnesium may contribute undesirable tastes to drinking water, but the taste threshold is well above the magnesium concentrations encountered in most Canadian drinking waters.

There is no evidence of adverse health effects specifically attributable to magnesium in drinking water. Therefore, a MAC for magnesium in drinking water has not been specified.

Malathion

Malathion is an organophosphorus insecticide and acaricide used for the control of a variety of insects and mites on a wide range of agricultural and horticultural crops, as well as for the control of mosquitoes, flies, household insects, animal ectoparasites and human head and body lice.

Malathion binds moderately to soil and is biodegraded and hydrolysed significantly; it is not expected to leach to groundwater. Biodegradation is important in the removal of malathion from natural waters. Malathion was not detected in municipal and private water supplies in Canada and has only rarely been found in surface water samples.

Malathion is of low acute toxicity in humans. Its principal toxic action is inhibition of acetylcholinesterase, which is only slowly reversible. No evidence of carcinogenicity has been found for malathion or its metabolite, malaoxon.

The ADI for malathion has been derived by the FAO and WHO on the basis of division of the NOAEL, obtained from studies on the reduction of cholinesterase activity in human volunteers, by an uncertainty factor. The MAC is derived from the ADI assuming that 20% of daily intake comes from drinking water (actual daily intake is estimated to be 0.06% of the ADI).

The MAC for malathion in drinking water is *0.19 mg/L.*

Manganese

Manganese occurs in over 100 common salts and mineral complexes that are widely distributed in rocks, in soils and on the floors of lakes and oceans. Manganese is generally present in natural surface waters at concentrations below 0.05 mg/L. It is more prevalent in groundwater supplies owing to the reducing conditions that exist underground. High manganese concentrations are also found in some lakes and reservoirs as a result of acidic conditions.

Manganese is an essential element in humans and animals. It is regarded as one of the least toxic elements; toxicity in humans is usually the result of chronic inhalation of high concentrations of manganese in dust from industrial sources.

At levels exceeding 0.15 mg/L, manganese stains plumbing fixtures and laundry and causes undesirable tastes in beverages. As with iron, its presence in water may lead to the accumulation of microbial growths in the distribution system that could give rise to taste, odour and turbidity problems in the distributed water. Even at concentrations as low as 0.02 mg/L, manganese will form coatings on piping that may slough off as black precipitates; however, it is difficult to remove manganese from water to achieve concentrations below 0.05 mg/L.

The AO for manganese in drinking water is *≤0.05 mg/L.* Manganese at this level is not considered to represent a threat to health, and drinking water with much higher concentrations has been safely consumed. However, deposition and staining problems may still occur under some conditions in water supplies that meet this limit.

The manganese guideline is currently being reviewed for possible revision to a health-based guideline (see Table 5).

Mercury

Mercury is a toxic element and serves no beneficial physiological function in humans. The presence of mercury in water has become a source of concern because of the finding that organic mercury is bioconcentrated by fish. Elevated mercury levels have been found in all freshwater fish taken from areas with suspected mercury contamination as a result of industrial and agricultural applications, and these frequently render the fish unacceptable for human consumption.

The two major responses to mercury poisoning involve neurological and renal disturbances, characteristic of poisoning by organic and inorganic mercury compounds, respectively. Although no evidence for genetic, teratogenic or carcinogenic effects has yet been described for inorganic mercury, organic mercury has been shown to be embryotoxic and teratogenic in laboratory animals, and alkyl mercury readily crosses the placenta and concentrates in human foetal tissues.

Epidemiological data suggest that the onset of irreversible neurological symptoms as a result of ingestion of methyl mercury is associated with a daily intake of 0.3 mg. Application of a safety factor of 10 gives a tolerable daily intake of 0.03 mg of mercury as methyl mercury.

A MAC of *0.001 mg/L* for mercury in drinking water has therefore been established on the basis of health considerations. Daily consumption of water containing total mercury at the MAC would contribute approximately 5% of the tolerable intake. The MAC therefore provides a considerable margin of safety. Mercury levels in both surface water and tap water are generally well below the MAC.

Methoxychlor

Methoxychlor is an organochlorine insecticide used in the control of livestock parasites and a variety of pests on ornamentals, fruits and vegetables. It has been detected only once, in trace amounts, in samples of municipal and private water supplies from various provinces, and it has not been detected in surface water samples from across Canada.

In human volunteers administered oral doses of methoxychlor for eight weeks, there were no adverse effects on health, clinical chemistry or the morphology of the blood, bone marrow, liver, small intestine or testes. Rats fed methoxychlor in the diet for two years had reduced growth but experienced no other adverse effects. There is no evidence that methoxychlor is carcinogenic in animals, and studies to date indicate that it is not mutagenic.

The ADI of methoxychlor has been established by the FAO and WHO by division of the NOAEL for growth retardation in rats by an uncertainty factor.

The MAC for methoxychlor in drinking water, derived from the ADI, is *0.9 mg/L.*

Metolachlor

Metolachlor is a chloracetanilide herbicide used in Canada primarily for the control of grasses in corn, beans, soybeans and other crops, and it is often applied in combination with broadleaf herbicides. It does not accumulate in soil following repeated annual applications, as it biodegrades with a half-life of about six to 10 weeks. Metolachlor has been detected in surface water samples from Ontario river basins and in samples from municipal and private water supplies across Canada.

Other than isolated reports of skin allergies, no information on the toxicity of metolachlor to humans has been identified.

The NDI for metolachlor has been determined by the Food Directorate of Health Canada by division of a NOAEL for such treatment-related effects as reduced body weight, reduced food consumption, testicular atrophy and increased incidence of hepatic lesions, obtained in a two-year feeding study in rats, by an uncertainty factor.

The IMAC for metolachlor in drinking water, derived from the NDI, is *0.05 mg/L.*

Metribuzin

Metribuzin is a triazine herbicide used for pre- and post-emergent weed control for a variety of agricultural crops. It has been detected in municipal and private water supplies across Canada and in surface water samples in Ontario.

No reports on the effects of exposure of humans to metribuzin have been identified in the literature. In a two-year feeding study in beagle dogs, food consumption and body weight gain were reduced in the highest dose group, and thyroid, liver, spleen and kidney weights were increased relative to body weights. Treatment-related effects on the liver were also observed at the second highest dose. A carcinogenicity study in mice found no significant increase in any specific type of tumour at any dose level.

The ADI for metribuzin was derived by the Food Directorate of Health Canada on the basis of division of the NOAEL, obtained from the two-year study in dogs, by an uncertainty factor.

The MAC for metribuzin in drinking water, derived from the ADI, is *0.08 mg/L.*

Monochlorobenzene

Monochlorobenzene (MCB) is used mainly as a solvent for adhesives. Because MCB is very volatile, its intake from air is probably much greater than that from food or drinking water.

MCB has been found to be toxic in subchronic gavage studies conducted in rats and mice. Effects included reduced survival, reduction in body weight gain and increases in liver and kidney lesions. In another study, an increased incidence of neoplastic nodules in the liver was observed in male rats, but no evidence of carcinogenicity was found in female rats or mice of either sex. MCB has therefore been classified as being possibly carcinogenic to humans.

The ADI is derived from the NOAEL obtained in the subchronic toxicity studies, using an uncertainty factor that takes into account the subchronic nature of the studies and the equivocal evidence of carcinogenicity.

The MAC for MCB in drinking water, derived from the ADI, is *0.08 mg/L.*

The AO for MCB in drinking water is ≤*0.03 mg/L*, based on its threshold odour value.

Nitrate/nitrite

Nitrate and nitrite are naturally occurring ions that are ubiquitous in the environment. Nitrates are used widely as inorganic fertilizers, whereas nitrites are used mainly as food preservatives, especially in cured meats.

Because of the relative stability of the nitrate ion, most nitrogenous materials in environmental media tend to be converted to nitrates. Sources of nitrates in water (particularly groundwater) include decaying plant or animal material, agricultural fertilizers, manure and domestic sewage. Nitrites may be produced from excess ammonia in drinking water distribution systems that use chloramines as a disinfectant.

Because nitrate salts are very soluble, nitrate is highly mobile in soil and migrates readily to the water table when present in excess of the amount utilized by plants as an essential nutrient. Under anaerobic conditions, nitrate may be degraded to nitrite or denitrified. Biological activity in the soil is very important in determining the ultimate fate of nitrate.

Nitrate levels in Canadian municipal water supplies are generally less than 5 mg/L. Nitrate levels in well water are often higher than those in surface water supplies. For adults, food is generally the main source of ingested nitrate and nitrite unless drinking water concentrations are above average. For bottle-fed infants, water used in the preparation of infant formula is generally the main source of nitrates.

Although an association between the ingestion of nitrate/nitrite in drinking water and gastric cancer has been observed in some descriptive and analytical epidemiological studies conducted to date, no firm conclusions concerning causality can be drawn because of the limitations of the available data. There is, however, some concern about an increased risk of cancer in humans because of the fact that nitrites derived from nitrates may react with certain foods *in vivo* to form carcinogenic N-nitroso compounds. Nitrate has not been found to be carcinogenic in chronic animal studies; the results of similar investigations with nitrite have been equivocal. Nitrate/nitrite have, therefore, been classified as being possibly carcinogenic to humans, although the weight of evidence is weak.

The critical effect associated with the ingestion of nitrate/nitrite in drinking water is methaemoglobinaemia, the development of which requires the presence of nitrite. The most sensitive subpopulation is infants less than three months of age.

On the basis of the available data, a MAC for nitrate in drinking water of *45 mg/L*, expressed as nitrate, is reaffirmed/recommended. (This is equal to 10 mg/L as nitrate-nitrogen.) This value has been derived based on the NOAEL for infantile methaemoglobinaemia of 45 mg/L observed in a North American population.

The application of an uncertainty factor to this NOAEL is not deemed necessary, for a number of reasons, including the fact that the NOAEL applies to the most sensitive subgroup of the population and therefore will be protective of the general population and the fact that most infants exhibit no signs of toxicity until the LOAEL (approximately twice the NOAEL) is reached.

Although the guideline is based on effects in the most sensitive subgroup, it is considered prudent to minimize exposure of the entire population to nitrate owing to suggestive evidence of an association in several populations between gastric cancer and moderate levels of nitrate in drinking water. The guideline is therefore intended to apply to both children and adults.

Nitrite is directly toxic and is converted endogenously from nitrate. A relative potency for nitrite and nitrate of 10 to 1 (on a molar basis) with respect to methaemoglobinaemia formation has been suggested, and an uncertainty factor of 10 should be applied to the NOAEL for nitrate to derive a guideline for nitrite. A maximum of *3.2 mg nitrite/L* is therefore recommended in cases where nitrite and nitrate are determined separately.

Nitrilotriacetic acid (NTA)

Nitrilotriacetic acid (NTA) is an important chelating agent, with many industrial applications. Because of its ability to chelate calcium and magnesium ions, the trisodium salt is used in laundry detergents as a "builder" to replace phosphates, the use of which has been restricted in Canada. NTA is also used extensively in the treatment of boiler water to prevent accumulation of mineral scale.

NTA is present in the environment primarily as a result of its release in sewage. It biodegrades readily and is broken down by photochemical and chemical reactions under certain conditions. It is present in drinking water primarily in the form of metal complexes, rather than as the free acid. NTA is not regularly monitored in Canadian drinking water supplies because its analysis requires non-routine methods, but it was detected in raw and treated drinking water samples in a national survey.

NTA is poorly absorbed in humans and does not appear to be metabolized in mammalian systems. It has not been found to be teratogenic or genotoxic in studies conducted to date, but it has induced urinary tract tumours in rats and mice at high doses. The induction of tumours is considered to be due to cytotoxicity resulting from the chelation of divalent cations such as zinc and calcium in the urinary tract, which leads to the development of hyperplasia and neoplasia. In general, neoplasms occur following ingestion of NTA at concentrations greater than those that cause nephrotoxicity.

Because NTA induces tumours only at doses higher than those that are nephrotoxic, it is classified as being possibly carcinogenic to humans. Its ADI is derived by division of the NOAEL for nephrotoxic effects, obtained in a two-year study in rats in which an increased incidence of nephritis and nephrosis was observed, by an uncertainty factor that takes into account the carcinogenic potential of NTA at high doses.

There are few data available on concentrations of NTA in food; however, drinking water is expected to be the primary source of intake. The MAC for NTA in drinking water, derived from the ADI by assuming that 80% of the daily intake comes from drinking water, is *0.4 mg/L.*

Because of the rapid degradation of NTA in the environment and the non-routine nature of currently available analytical methods for this compound, it is not necessary to monitor NTA on a regular basis in drinking water supplies unless there is sufficient reason to suspect its presence in the source supply at levels approaching the MAC.

Odour

Although odour in drinking water can often be attributed to a specific chemical, it is usually impractical and often impossible to isolate and identify the odour-producing chemical. Furthermore, separate limits have been established for those substances that commonly cause unpleasant odours and tastes in drinking water.

Odour is rarely indicative of the presence of harmful chemical substances. It may, however, indicate an undesirably high level of biological activity in the drinking water source, contamination of the water supply or treatment and distribution inadequacies.

Because odour cannot be objectively measured, a MAC for drinking water has not been specified. However, the provision of water that has no offensive odour is desirable.

Paraquat

Paraquat is a bipyridyl contact herbicide most commonly marketed as paraquat dichloride. It is used to control aquatic weeds and weeds in seed crops and orchards, as a crop desiccant and defoliant on cotton and potato vines and as a harvest aid for soybeans.

No information was identified regarding levels of paraquat in Canadian surface or drinking water. As it is rapidly and completely bound to clay particles in the soil, paraquat is unlikely to contaminate drinking water supplies as a result of its application to crops. However, paraquat may remain in water for several days following its use for aquatic weed control.

Acute paraquat poisoning in humans may cause respiratory distress, which may lead to death, and effects on the nervous system and kidneys. Decreased food intake, decreased body, spleen and testes weights and respiratory distress were among the effects observed in a study in which dogs were fed diets containing paraquat dichloride for more than two years. In a two-year study in which rats were administered paraquat dichloride in the diet, degenerative effects on the kidney were observed.

No signs of tumorigenicity have been observed in studies conducted to date, and results of mutagenicity tests are usually negative.

The FAO and WHO have established a temporary ADI for paraquat dichloride based on unvalidated toxicological data from studies in rats and dogs.

The IMAC for paraquat (as the dichloride) in drinking water, derived from the temporary ADI, is *0.01 mg/L*. This is equivalent to an IMAC of *0.007 mg/L* for paraquat ion in drinking water.

Parathion

Parathion is an organophosphorus insecticide and acaricide used to control soil-dwelling pests and a wide range of insects and mites on a variety of agricultural crops. Parathion released to the environment adsorbs to soil and does not leach significantly. It disappears from surface water in about a week. Parathion has not been detected in samples of municipal and private drinking water supplies from across Canada or in surface water samples in Ontario.

Parathion is a cholinesterase inhibitor. Plasma cholinesterase levels were reduced in human volunteers, rats and dogs administered oral doses of parathion. There is inadequate evidence to evaluate the carcinogenicity of parathion in animals, and most studies to date suggest that parathion is not mutagenic.

The ADI of parathion has been derived by the FAO and WHO by division of a NOAEL, derived from studies in rats, dogs and human volunteers, by an uncertainty factor.

The MAC for parathion in drinking water, derived from the ADI, is *0.05 mg/L.*

Pentachlorophenol – See *Chlorophenols*

pH

One of the main objectives in controlling pH is to produce water that minimizes corrosion or incrustation. These processes, which can cause considerable damage to the water supply system, result from complex interactions between pH and other parameters, such as dissolved solids, dissolved gases, hardness, alkalinity and temperature. Elevated levels of certain undesirable chemical substances may result from the corrosion of specific types of pipe. Corrosion effects may become significant below pH 6.5, and the frequency of incrustation and scaling problems may be increased above pH 8.5. There is also a progressive decrease in the efficiency of chlorine disinfection processes with increasing pH levels.

An acceptable range for drinking water pH is from *6.5 to 8.5.*

Phorate

Phorate is an organophosphorus insecticide and acaricide used for the control of sucking and biting insects, mites and certain nematodes on root and feed crops, cotton, brassicas and coffee. In various Ontario surveys, phorate has not been detected in samples of municipal and private drinking water supplies, stream water from agricultural watersheds or water from river basins.

Phorate is reported to be one of the more toxic cholinesterase-inhibiting organophosphorus insecticides. Depressions in the level of cholinesterase activity have been observed in occupationally exposed workers (plasma cholinesterase), in dogs administered phorate in encapsulated corn oil for 15 weeks (plasma and red cell cholinesterase) and in rats fed diets containing phorate for two years (plasma and brain cholinesterase). Phorate has not been found to be carcinogenic or mutagenic.

The ADI of phorate has been established by the FAO and WHO based on NOAELs in dogs and rats for cholinesterase inhibition.

The MAC for phorate in drinking water, derived on the basis of this ADI, is *0.002 mg/L.*

Picloram

Picloram is a chloropicolinic acid-derived herbicide used for the control of woody plants and broadleaf weeds on rights-of-way, rangelands, pastures and non-crop areas and, to a smaller extent, for the control of weeds in barley crops in the Prairie provinces. It is persistent and highly mobile in soils, and it is considered to have high potential as a groundwater contaminant. Despite this, picloram has been detected infrequently in surface water and groundwater in four provinces in Canada.

The principal target organ for the toxicity of picloram is the liver; effects on the kidney occur at higher doses. Rats administered picloram in the diet for two years exhibited increased liver and kidney weights, slight histopathological changes in liver and kidney and some changes in clinical chemistry parameters at the two highest doses. Tests for carcinogenicity were negative in this rat bioassay and in a less well conducted study on the mouse.

An NDI for picloram was established by the Food Directorate of Health Canada by dividing the NOAEL from the two-year rat feeding/oncogenicity study by an uncertainty factor that takes into account the deficiencies in the data base (e.g., no long-term studies on a non-rodent species).

The IMAC for picloram in drinking water, derived from the NDI, is *0.19 mg/L.*

Selenium

Selenium appears to be an essential element in human nutrition. Selenium deficiency in the diet has been associated with Keshan disease, a heart muscle disorder, and some epidemiological data suggest a connection between low selenium intakes or blood levels and an increased risk of cardiovascular disease.

Ingestion of large amounts of selenium has been correlated with a variety of clinical disorders in humans, including jaundice, chronic gastrointestinal disease, dermatitis, nail changes and fatigue. Available data provide no conclusive evidence that selenium is carcinogenic in humans; in fact, selenium may have anti-carcinogenic properties. Selenium may also have teratogenic properties in humans.

Food is the main source of intake of selenium for humans who are not occupationally exposed, and toxic effects are most often associated with its intake in food. A safe and adequate range of selenium intake of 0.05 to 0.2 mg per person per day has been recommended for adults, with correspondingly lower ranges for infants and children.

A MAC of *0.01 mg/L* for selenium in drinking water has been established on the basis of health considerations. Drinking water containing selenium at the MAC would be the source of between 10 and 25% of total selenium intake. Therefore, the MAC is considered to provide a reasonable margin of safety from adverse effects of selenium.

Silver

Silver is a non-essential element and normally occurs in human tissues in only trace amounts. In Canada, photography and coin production are the major uses of silver.

Food is the main source of silver for persons not occupationally exposed to the element. Drinking water contributes negligibly to a person's intake of silver, except when silver is used as an anti-microbial agent in water treatment devices.

Ingestion of very large doses of silver has been associated with a number of severe acute effects in humans, including argyria, a condition characterized by a blue-grey discoloration of the skin, eyes and mucous membranes, and death. However, daily intake of silver from food and water is considerably below the level at which adverse health effects would occur.

It is therefore not considered necessary to specify a MAC for silver in drinking water.

Simazine

Simazine is a triazine soil sterilant and pre-emergence herbicide used in the control of broadleaf and grassy weeds for a wide variety of crops. It is also used in aquatic weed control.

Biological processes are important in the removal of simazine from soil and water. The herbicide has a high leaching potential, although it is lower than that of other triazine herbicides. Simazine has been detected in surface water samples in Ontario and in municipal and private drinking water supplies across Canada.

No reports on the toxicity of simazine ingested by humans have been identified, although skin contact has caused dermatitis. Dogs fed diets containing simazine for two years exhibited slightly lower body weights, marginally higher levels of serum alkaline phosphatase and serum glutamic-oxaloacetic transaminase and slight hyperplasia of the thyroid at the highest dose only.

Studies with mice are inadequate for an assessment of the carcinogenicity of simazine. Simazine does not show any mutagenic potential, and no teratogenic effects were noted in rat studies at levels below those that produced maternal toxicity.

The Food Directorate of Health Canada has derived an NDI for simazine on the basis of division of the NOAEL, obtained from the two-year study in dogs, by an uncertainty factor.

The IMAC for simazine in drinking water, derived from the NDI, is *0.01 mg/L.*

Sodium

Sodium is the most abundant cation in the extracellular fluid. It is important in regulating acid-base equilibrium, maintaining the osmotic pressure of body fluid and preserving the normal irritability of muscle and permeability of cells. The minimum daily requirement for sodium is approximately 50 mg for the average adult.

Because the body has very effective methods to control levels of sodium, sodium is not an acutely toxic element in the normal range of environmental or dietary concentrations. At extremely high doses, however, toxic effects include muscle twitching, cerebral and pulmonary oedema and death. The relationship between sodium intake and hypertension is unclear; although numerous studies have shown that reducing sodium intake lowers blood pressure in hypertensives, this does not imply that increased sodium intake causes hypertension in normotensive individuals.

The average intake of sodium from water is only a small fraction of that consumed in a normal diet (about 5 g/d). However, persons suffering from hypertension or congestive heart failure may require a sodium-restricted diet (about 500 mg/d), in which case the intake of sodium from drinking water could become significant. If it is assumed that sodium from drinking water should make up only 10% of the total sodium intake of persons on sodium-restricted diets, then concentrations in drinking water would have to be less than 20 mg/L. Reducing the sodium content in drinking water to this level would generally incur considerable expense using currently available technologies.

An excessive level of sodium is easily detected by taste. At a sodium concentration of 175 to 185 mg/L, the taste of drinking water is offensive.

There is therefore a built-in restriction on acceptable sodium levels in drinking water. The taste threshold can be altered by habituation and depends on the associated anion, the temperature of the water and individual salt-eating habits.

The AO for sodium in drinking water has been set at ≤ *200 mg/L.* It is recommended that sodium be included in routine monitoring programs, as sodium levels may be of interest to authorities who wish to prescribe sodium-restricted diets for their patients.

Sulphate

Sulphates, which occur naturally in numerous minerals, are used in the manufacture of chemicals, dyes and fertilizers, in the mining and pulping industries, in sewage treatment and in wood preservation. The sodium sulphate industry, based in southern Saskatchewan and Alberta where natural brine deposits occur, is the primary sulphate-producing activity in Canada.

Sulphates are discharged into the aquatic environment in wastes from industries that use sulphates and sulphuric acid (e.g., mining and smelting operations, kraft pulp and paper mills); atmospheric sulphur dioxide may also contribute to the sulphate content of surface waters. A wide range of sulphate concentrations has been found in Canadian municipal water supplies.

Sulphate is one of the least toxic anions. The major physiological effects resulting from the ingestion of large quantities of sulphate are catharsis and gastrointestinal irritation. These effects are enhanced when sulphate is consumed in combination with magnesium. Water containing magnesium sulphate at levels above 1000 mg/L acts as a purgative in human adults. Lower concentrations may affect new users and children. Ingestion of water containing magnesium sulphate at concentrations in excess of 600 mg/L can cause diarrhoea in children.

The presence of sulphate in drinking water can result in a noticeable taste. Taste threshold concentrations for various sulphate salts appear to be at or above 500 mg/L for the general population, although sensitive individuals may find the taste objectionable at lower sulphate concentrations.

The AO for sulphate in drinking water is ≤ *500 mg/L.* Because of the possibility of adverse physiological effects at higher concentrations, it is recommended that health authorities be notified of sources of drinking water that contain sulphate concentrations in excess of 500 mg/L.

Sulphide (as hydrogen sulphide)

The −2 reduction state of sulphur, a non-metal, is known as sulphide. Sulphides occur naturally in mineral ores, oil and coal deposits and are generated through anaerobic decomposition of sewage, algae, naturally deposited organic matter and the sulphur found in fertilizers. Sulphides are also present in industrial wastes from petroleum and petrochemical plants, gas works, paper mills, heavy water plants and tanneries.

Hydrogen sulphide and sulphides of the alkaline earth metals are soluble in water. Soluble sulphide salts dissociate into sulphide ions that react with the hydrogen ions in water to form the hydrosulphide ion or hydrogen sulphide. The relative concentrations of these species are a function of the pH, temperature, salinity and dissolved oxygen content of the water.

Although data on sulphide concentrations in drinking water have not been found, levels will usually be low because the sulphides are readily oxidized in well-aerated water. Under the aerobic conditions most often encountered in public water supplies, the ultimate product of sulphide oxidation is sulphate. The intermediates, sulphite and thiosulphate, may persist for long periods of time.

The ingestion of large doses of alkali sulphides has been reported to cause nausea, vomiting and epigastric pain. The low amounts of sulphide likely to be found in drinking water are not expected to produce toxic effects, as there is an intestinal enzymatic detoxification system to handle endogenously produced sulphide. Although the acute toxicity of inhaled hydrogen sulphide is well documented and includes effects on the respiratory, cardiac and nervous systems, no reports of toxic effects due to hydrogen sulphide present in drinking water have been found.

The presence of sulphide (as hydrogen sulphide) in drinking water results in disagreeable taste and odour; an AO of ≤0.05 mg/L (expressed as hydrogen sulphide) has therefore been established. The quantity of sulphide ingested from drinking water containing sulphide at the AO is well below the amount that the body can detoxify. Although ingestion of large quantities of sulphide has resulted in toxic effects in humans, it is unlikely that an individual would consume a harmful dose in drinking water because of the associated unpleasant taste and odour. The oxidation of sulphide to sulphate in well-aerated waters should ensure that sulphide concentrations in public water supplies are very low.

Taste

There is no method for the objective measurement of taste in drinking water, and there is considerable variation among consumers as to which tastes are acceptable. In addition, consumers frequently mistake odours for tastes. Taste and odour problems in drinking water supplies constitute the largest single class of consumer complaints. Changes in the taste of a potable water supply also serve as a warning signal of possible contamination of the raw water supply, treatment inadequacies or contamination of the water distribution network.

A numerical limit for taste in drinking water has not been established. The provision of water that has an inoffensive taste is desirable.

Temperature

Low water temperature tends to decrease the efficiency of water treatment processes and can thus have a deleterious effect on drinking water quality if compensating measures are not taken. On the other hand, temperatures above 15°C enhance the growth of nuisance organisms. As a result, taste, odour, colour and corrosion problems may be intensified. Maintenance of a water temperature of 15°C or less will also discourage the use of alternative water sources that, although cooler, may be injurious to health.

An AO of ≤*15°C* has been established for the temperature of drinking water.

Terbufos

Terbufos is an organophosphorus insecticide used to control soil-borne insects, primarily on corn, sugar beets and rutabagas. Monitoring for terbufos has been relatively infrequent; terbufos has not been detected in municipal water in Manitoba or surface water in Ontario.

The principal toxic effect of terbufos is acetylcholinesterase inhibition. Data base deficiencies include lack of mutagenicity and subchronic or chronic data on a non-rodent species.

The Food Directorate of Health Canada has established an NDI for terbufos on the basis of division of the NOAEL for cholinesterase inhibition in a 28-day dog study by an uncertainty factor to compensate for the short duration of the study and other deficiencies of the toxicology data base. The IMAC derived from the NDI is 0.0005 mg/L. However, as the IMAC must be measurable by available analytical methods, the PQL must also be taken into consideration in its derivation. An IMAC of *0.001 mg/L*, the quantitation limit, is therefore established for terbufos in drinking water.

The theoretical maximum dietary intake of terbufos, 0.0008 mg/kg bw per day, exceeds the NDI established by Health Canada, and intake of

drinking water at the IMAC will further exceed the NDI. It should be noted, however, that terbufos residues have not been detected in food. Every effort should be made to maintain terbufos concentrations in drinking water as low as possible.

Tetrachloroethylene

Tetrachloroethylene is used primarily in Canada as a solvent in the dry-cleaning and metal-cleaning industries. Most tetrachloroethylene is expected to enter the atmosphere, but the substance has also been found in groundwater, primarily after improper disposal or dumping of cleaning solvents. Tetrachloroethylene has been detected in some samples of drinking water across Canada, usually at concentrations below 1 μg/L. Available data indicate that the intake of tetrachloroethylene through ingestion in drinking water contributes on average approximately 1% of total intake; most (approximately 80%) of the total intake is from indoor air. However, when present at higher concentrations in drinking water, it can contribute significantly more to total intake, both directly and through increased dermal and inhalation exposure.

Increased mortality and morbidity due to various types of cancer have been observed in workers employed in the dry-cleaning and laundry industries; however, the available information is considered inadequate to assess the carcinogenicity of tetrachloroethylene in humans, owing to the lack of consistency of reported results and to possible confounding by concomitant exposure to other substances. On the basis of the observation of a small increase in the incidence of spontaneously occurring mononuclear cell leukaemias in male and female rats in a National Toxicology Program bioassay, tetrachloroethylene has been classified as being possibly carcinogenic to humans.

A TDI for tetrachloroethylene has been derived by dividing a NOEL for increased liver and kidney to body weight ratios, obtained from a 90-day study in which tetrachloroethylene was administered orally to rats in drinking water, by an uncertainty factor that takes into account inter- and intraspecies variation and the use of a subchronic study. An additional factor for the limited evidence of carcinogenicity was not incorporated, as mononuclear cell leukaemia in rats is not related to the critical effect on which the TDI is based. Moreover, the weight of evidence from a battery of genotoxicity tests indicates that this compound is not genotoxic.

The MAC for tetrachloroethylene in drinking water, derived from the TDI and taking into consideration both oral and dermal absorption from water, is *0.03 mg/L.*

2,3,4,6-Tetrachlorophenol – See *Chlorophenols*

Toluene – See *Toluene, ethylbenzene and the xylenes*

Toluene, ethylbenzene and the xylenes

Toluene, ethylbenzene and the xylenes (there are three possible xylene isomers) all belong to a group of organic compounds known as alkyl benzenes. The primary sources of these alkyl benzenes in the environment are the petroleum industry and, to a lesser extent, the coke industry. All are used extensively as solvents and as raw materials in the synthesis of a variety of chemicals, and all have been used as gasoline additives.

The alkyl benzenes are recognized primarily as atmospheric pollutants because of their high volatility, but small amounts may enter aquatic and terrestrial ecosystems (e.g., gasoline spills from leaking storage tanks).

Available information on the toxicology of toluene, ethylbenzene and the xylenes suggests that the exposures or doses related to the induction of central nervous system, respiratory or irritant effects exceed, by several orders of magnitude, the levels known to elicit organoleptic effects. Therefore, these substances have not been classified on the basis of potential health effects.

The AOs for toluene, ethylbenzene and the xylenes in drinking water are based on their threshold odour values and are as follows:

	AO
toluene	≤0.024 mg/L
ethylbenzene	*≤0.0024 mg/L*
xylenes (total)	≤0.3 mg/L

Total dissolved solids (TDS)

The term "total dissolved solids" (TDS) refers mainly to the inorganic substances that are dissolved in water. The effects of TDS on drinking water quality depend on the levels of its individual components; excessive hardness, taste, mineral deposition and corrosion are common properties of highly mineralized water.

The AO for TDS in drinking water is ≤*500 mg/L*. At low levels, TDS contributes to the palatability of water.

Trichloroethylene

Trichloroethylene is a highly volatile liquid used primarily in metal degreasing operations and in tetrachloroethylene production. Most trichloroethylene used for degreasing is believed to be emitted to the atmosphere. Trichloroethylene may, however, be introduced into surface water and groundwater in industrial effluents. It has been detected

frequently in natural water and drinking water in Canada. Probably less than 5% of total daily intake is normally ingested in drinking water, with the rest coming from air.

Acute exposure to high levels of trichloroethylene affects the central nervous system. Short-term exposure of humans to airborne trichloro-ethylene can lead to eye irritation, nausea, headache and unconsciousness, depending on the exposure concentration.

Available epidemiological data are inadequate for assessment of the carcinogenicity of trichloroethylene in humans. Increased incidences of several different tumour types in various strains of mice have been observed following both ingestion and inhalation of trichloroethylene, but often only at toxic dose levels. In rats, the only significant tumour increase observed to date in an acceptable study was an excess of benign Leydig cell tumours of the testis in an inhalation study. The evidence for carcinogenicity in rats is therefore considered to be limited, and the compound is classified as being possibly carcinogenic to humans.

The ADI has been derived by division of the NOAEL for such effects as liver enlargement and elevated protein and ketone levels in urine, obtained from the longest-term study (six months) using the most sensitive species (mice) with the most appropriate route (i.e., oral) and vehicle (i.e., drinking water) of administration, by an uncertainty factor that takes into account the short length of the study and the limited evidence of carcinogenicity.

The MAC for trichloroethylene in drinking water, derived from the ADI, assuming 5% of total daily intake comes from drinking water, is *0.05 mg/L*.

The guideline for trichloroethylene is currently being reviewed for possible revision owing to new data (see Table 5).

2,4,6-Trichlorophenol – See *Chlorophenols*

Trifluralin
Trifluralin is a dinitroaniline-based herbicide sold in large quantities for pre-emergence control of grassy and broadleaf weeds in cereal, grain and vegetable crops. Because of its limited solubility and strong soil adsorption, trifluralin is considered unlikely to leach into groundwater supplies. It has been detected in some Canadian municipal and private water supplies and has occasionally been found at trace levels in surface waters.

The acute oral toxicity of trifluralin is low. The primary effects of chronic ingestion of trifluralin include reduced body weights, increased liver weights and manifestations of renal toxicity, including glomerulo-nephritis and renal calculi. Results from six long-term dietary studies conducted on rats and mice are inconclusive with regard to its tumorige-

nicity and oncogenicity, although significant dose-related increases in benign and malignant tumours of the urinary transitional epithelium of the kidney and bladder of male rats were observed in one study.

Based on evaluation by the Food Directorate of Health Canada, an NDI has been established by dividing the NOAEL, obtained in a one-year feeding study in dogs in which increases in liver and spleen weights and changes in serum chemistry (lipid and protein fractions) were noted, by an uncertainty factor that takes into consideration limitations of the data base.

The IMAC for trifluralin in drinking water, derived from the NDI, is *0.045 mg/L.*

Because dose-related increases in tumours have been observed in one sex of one species of rodent after dietary administration of trifluralin in a single study, and because the structurally similar compound ethylfluralin is considered to be carcinogenic to animals, the potential lifetime cancer risks associated with exposure to trifluralin were estimated to ensure that the IMAC is protective. The lifetime risk from drinking water containing trifluralin at the IMAC is estimated to be within a range that is considered to be "essentially negligible."

The IMAC is based on a non-carcinogenic end-point and will remain an interim value until the results of further carcinogenicity bioassays that clarify the status of trifluralin as a possible tumorigen have been completed and evaluated.

Trihalomethanes

Trihalomethanes (THMs) are halogen-substituted single-carbon compounds. The THMs most commonly present in drinking water are chloroform, bromodichloromethane, chlorodibromomethane and bromoform.

THMs are formed in drinking water primarily as a result of chlorination and/or bromination of organic matter present naturally in raw water supplies. Chloroform is the THM detected most frequently and at highest concentrations in drinking water. Available data suggest that the principal sources of intake of THMs are drinking water and beverages produced with treated water. Because of chloroform's volatility, there is also potential for exposure in the home to airborne chloroform released from tap water.

Available data are consistent with the hypothesis that ingestion of chlorinated drinking water, if not THMs specifically, may be causally related to cancers of the bladder and colon (chloroform and other THMs account for up to 50% by weight of the total chlorination by-products in drinking water). Chloroform has been found to be carcinogenic in two

animal species in the most extensive bioassays conducted to date and has been classified as being probably carcinogenic to humans.

As chloroform is the THM present in greatest concentration in drinking water, any guideline developed for this compound will be protective with respect to the other THMs.

An IMAC of *0.1 mg/L* for total THMs, based on the risk associated with chloroform, was established, therefore, on the basis of the following considerations: (1) using optimum methods (i.e., improvement of specific conventional water treatment processes to remove organic compounds prior to disinfection and addition of such processes as carbon adsorption and pre-oxidation), total THM concentrations can be reduced to below 0.1 mg/L; (2) the estimated lifetime cancer risk associated with the ingestion of drinking water containing chloroform at a concentration of 0.1 mg/L (based on renal tubular cell adenomas or adenocarcinomas [combined] in rats administered chloroform in drinking water) is within a range that is considered to be "essentially negligible"; the MAC is designated as interim until such time as the risks from other disinfection by-products are ascertained; and (3) the PQL is 0.001 to 0.002 mg/L.

The IMAC is expressed as a running annual average based on quarterly samples. The frequency of sampling may be reduced where historical data indicate that maximum values will not exceed the IMAC. Samples should be representative of exposure; protocols should, therefore, specify inclusion of samples from the extremities of the distribution system.

It is not expected that all water systems will be able to meet the revised THMs guideline immediately. When water systems are expanded or upgraded, every effort should be made not only to meet the revised guideline, but also to reduce concentrations of THMs to as low a level as possible.

The preferred method of controlling disinfection by-products is precursor removal; however, any method of control employed ***must not*** compromise the effectiveness of water disinfection.

Turbidity

Turbidity in water is caused by suspended matter, such as clay, silt, finely divided organic and inorganic matter, soluble coloured organic compounds, plankton and other microscopic organisms. Turbidity measurements relate to the optical property of a water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. The current method of choice for turbidity measurement in Canada is the nephelometric method; the unit of turbidity measured using this method is the nephelometric turbidity unit (NTU).

Control of turbidity in public drinking water supplies is important for both health and aesthetic reasons. Excessive turbidity detracts from the appearance of treated water and has often been associated with unacceptable tastes and odours. Turbidity can serve as a source of nutrients for waterborne bacteria, viruses and protozoa, which can be embedded in or adhere to particles in the raw water or become trapped within floc formed during water treatment; turbidity can thus interfere with the enumeration of micro-organisms in finished water, as the micro-organisms may not be detectable or may be grossly underestimated by current detection methods. The adsorptive properties of suspended particles can also lead to a concentration of heavy metal ions and biocides in turbid waters. Turbidity can interfere with disinfection processes and the maintenance of a chlorine residual; depending on the composition of the turbidity-causing material, interference with disinfection can range from negligible to severe. Turbidity has also been related to trihalomethane formation in chlorinated water.

Viable coliform bacteria have been detected in waters with turbidities higher than 3 NTU, even in the presence of free chlorine residuals. Outbreaks of disease traced to chlorinated water supplies have been associated with high turbidity. The occurrence and persistence of micro-organisms within distribution systems have been correlated with turbidity and other factors.

The effect of turbidity on disinfection efficiency may be frequently related to the type and nature of the particulates. Surface water sources in particular may be susceptible to organic substances and undesired organisms that can impede disinfection or otherwise cause drinking water quality problems. Appropriate technology is available to treat and monitor turbidity to low levels. Therefore, the MAC for turbidity in water entering distribution systems has been set at *1 NTU*. Provision of treated water at or below this limit will minimize the introduction of unfavourable particulate and biological matter into the distribution system and thereby render better disinfection opportunity, effectiveness and maintenance. Special site-specific problems may require more rigorous attention for the production of low-turbidity water. Any sudden increase in the turbidity of the finished water indicates deteriorating quality of the raw water or loss of control in the water treatment processes.

Certain water supplies, such as groundwater, may contain non-organic-based turbidity, which may not seriously hinder disinfection. Therefore, a less stringent value for turbidity in water entering a distribution system may be permitted if it is demonstrated that the system has a history of acceptable microbiological quality and that a higher turbidity value will not compromise disinfection.

Turbidity in excess of 5 NTU becomes apparent and may be objected to by a majority of consumers. Therefore, an AO of ≤*5 NTU* has been set for water at the point of consumption.

Uranium[2]

Uranium is a naturally occurring element, consisting of a mixture of three radionuclides, all of which decay by alpha emission. Uranium is used primarily as fuel in nuclear energy plants. It may enter drinking water from naturally occurring deposits or as a result of human activity, such as mill tailings and phosphate fertilizers.

Nephritis is the primary chemically induced effect of uranium in animals and humans. Lesions are seen in the kidney at both glomerular and tubular levels. At sublethal levels, regeneration of the injured tubular epithelium begins two to three days after exposure. The chronic health effects of natural environmental exposure to uranium have received little attention, although persons exposed to variable amounts of natural uranium in their drinking water in Nova Scotia showed no overt renal disease or any other symptomatic complaints that could be attributed to uranium exposure.

Although the potential exists for radiological toxicity of orally administered natural uranium, this has not been observed in humans or animals, presumably because of the relatively low specific activity of this mixture of uranium radionuclides. Because the chemical data reviewed to date suggest a more stringent recommendation than that based upon available radiological criteria, it is recommended that assessment of uranium toxicity in drinking water be based upon chemical criteria.

As available data are inadequate to classify uranium with respect to its potential carcinogenicity, its ADI is derived on the basis of division of the NOAEL for the critical response (i.e., histopathological lesions in kidney tubules) in rabbits in an unpublished subchronic drinking water study by an uncertainty factor that takes into account the subchronic nature of the study as well as indications of the reversibility of subclinical lesions.

The MAC for uranium in drinking water, derived from the ADI, is *0.1 mg/L*. The derivation assumes that the proportion of total uranium intake normally ingested in drinking water is 90%. This is based on the consideration that the total daily intake of uranium from food and from drinking water containing uranium at the MAC (assuming 90% allocation to drinking water) is unlikely to exceed the ADI.

The guideline for uranium is currently being reviewed for possible revision owing to new data (see Table 5).

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2. Data on chemical, not radiological, toxicity are considered here. Information pertinent to the derivation of a guideline based on radiological effects is discussed separately in Section 5.

Vinyl chloride

Vinyl chloride is a synthetic chemical with no known natural sources. Most vinyl chloride produced in Canada is used to manufacture polyvinyl chloride (PVC), which is used primarily in electrical wire, insulation and cables, industrial and household equipment, medical supplies, food packaging materials, building and construction products and piping.

The presence of vinyl chloride in the aquatic environment is primarily a result of industrial discharges from chemical and latex manufacturing plants. Its occurrence in potable water is associated mainly with the use of PVC water pipes manufactured with incompletely polymerized vinyl chloride monomer. Vinyl chloride is also formed from trichloroethylene and perchloroethylene in groundwater.

Acute exposure to vinyl chloride by inhalation results in central nervous system depression. Chronic inhalation exposure to lower levels also results in a variety of adverse effects in humans, including degenerative bone changes, circulatory disturbances in the extremities, dermatitis and damage to liver, spleen and lungs. Sufficient evidence has accumulated in recent years to implicate vinyl chloride as a human and animal carcinogen. In particular, a causal relationship between exposure to vinyl chloride and the development of angiosarcoma of the liver is now commonly accepted. However, epidemiological data are insufficient to serve as a basis for quantitative estimation of cancer risks associated with exposure to low levels of vinyl chloride.

A MAC was established on the basis of the following considerations: (1) the PQL is 0.002 mg/L; (2) the estimated lifetime cancer risk associated with the ingestion of drinking water containing vinyl chloride at a concentration of 0.002 mg/L (based on hepatocellular angiosarcomas in female rats) is within a range that is considered to be "essentially negligible"; and (3) concentrations of vinyl chloride below 0.002 mg/L can be achieved by packed tower aeration, considered to be the best available treatment technology. Existing product standards, which specify the quality of PVC water pipes to limit the amount of free vinyl chloride monomer present, prevent any excessive leaching of vinyl chloride from the pipes.

The MAC for vinyl chloride in drinking water is *0.002 mg/L*.

Xylenes – See *Toluene, ethylbenzene and the xylenes*

Zinc

Zinc is an essential element for human nutrition. Intake of zinc from food is more than sufficient to satisfy the recommended daily requirement, which is generally in the range between 4 and 10 mg. Drinking water is not regarded as an important nutritional source of zinc.

Long-term ingestion of zinc in quantities considerably in excess of the daily requirement has not resulted in adverse effects. Furthermore, because of efficient homeostatic control mechanisms, the occurrence of chronic zinc toxicity is extremely unlikely. A MAC for zinc in drinking water has therefore not been set.

Although surface waters seldom contain zinc at concentrations above 0.1 mg/L, levels in tap water can be considerably higher because of the use of zinc in plumbing materials. Water containing zinc at concentrations in excess of 5.0 mg/L has an undesirable astringent taste and may be opalescent and develop a greasy film on boiling. The AO for zinc in drinking water is therefore ≤5.0 mg/L.

5. Radiological Characteristics

Humans are exposed to radiation from a variety of sources, both natural and human-made. The global average dose from natural sources, which contribute most of the radiation dose to humans, is estimated to be 2.4 mSv/year; this can be compared with an estimate of 2.6 mSv/year for Canada. The contribution of drinking water to total exposure is very small and is primarily the result of the presence of naturally occurring radionuclides in the uranium and thorium decay series.

5.1 Derivation of Radiological Guidelines

Guidelines for radionuclides in drinking water are derived differently from those for chemical carcinogens in drinking water. The derivation of radiological guidelines conforms to international radiation protection methodologies, as recommended by the International Commission on Radiological Protection (ICRP) and the WHO. Unlike chemical contaminants, which are treated individually in the setting of guidelines, the guideline dose for radionuclides applies to the total dose received from all radionuclides in the water supply. Owing to extensive human epidemiological data and well-documented dose-effect data, radiation risk estimates contain considerably fewer uncertainties than chemical risk estimates.

Exposure to ionizing radiation, whether natural or artificial, can cause two kinds of health effects as a result of changes to the atoms and molecules of the exposed tissue. Effects for which the severity of the damage caused is proportional to the dose and for which a threshold dose exists below which they do not occur are called *deterministic effects*. Under normal conditions, doses received from natural radioactivity and routine exposures from regulated practices are well below the threshold levels, and therefore deterministic effects are not relevant to these guidelines.

Effects for which the probability of occurrence, rather than severity, is proportional to dose are known as *stochastic effects*, and it is assumed that there is no threshold below which they do not occur. The main stochastic effect of concern from low-level radiation exposure is the induction of cancer following a variable latent period of up to several decades, although there is a small probability associated with hereditary effects. Stochastic effects are the most important consequence of environmental levels of radiation and are the basis of the current radiological guidelines.

The relationship between radiation exposure and the probability of causing a cancer depends on the type of radiation and the tissue or organ exposed. Because different types of radiation have different effectiveness at causing biological damage, and different organs and tissues in the body have different sensitivities to radiation, the ICRP has introduced a set of radiation and tissue weighting factors to provide a measure of equal effect. The sum of the weighted doses received by all organs and tissues in the body provides a measure of the total harm and is referred to as the *effective dose*. The effective dose is a broad indicator of the risk to human health for any type of radiation and any distribution of dose in the body.

Radionuclides taken into the body by inhalation or ingestion may persist for extended periods of time; in some cases, the resulting dose to the internal organs may extend over several months or years. Internal exposures are therefore measured in terms of the integrated, or committed, dose delivered to an organ or the whole body over a period of time. Standard periods of integration are 50 years for the adult population and 70 years for a lifetime exposure. This dose is termed the *committed effective dose*, which is measured in sieverts (Sv). It is this measure of extended internal exposure that is relevant to the establishment of drinking water guidelines.

The ICRP has recommended a lifetime risk coefficient for fatal cancer of 5% per 1 Sv, distributed among the various body organs, for low-level exposures to radiation. The ICRP has also recognized that not all cancers are fatal, and that this, in addition to the possibility of hereditary effects, should be considered in evaluating the total risk from radiation exposure. It has therefore estimated a lifetime risk coefficient for all fatal and weighted non-fatal cancers and hereditary disorders of 7.3% per 1 Sv. Based on these risk coefficients, the ICRP has recommended a limit on effective and committed effective dose of 1 mSv/year for any combination of external dose received and internal dose committed in one year, excluding natural background radiation and medical and therapeutic exposures.

5.2 Radiological Guidelines

In setting dose guidelines for radionuclides in drinking water, it is recognized that water consumption contributes only a portion of the total radiation dose and that some radionuclides present are natural in origin and therefore cannot be excluded. Consequently, MACs for radionuclides in drinking water have been derived based on a committed effective dose of 0.1 mSv from one year's consumption of drinking water, or one-tenth of the ICRP's recommendation on public exposure. This dose represents less than 5% of the average annual dose attributable to natural background radiation (i.e., 2.6 mSv).

The guideline reference dose is based on the total activity in a water sample, whether the radionuclides appear singly or in combination, and includes the dose due to natural radionuclides, in contrast to the ICRP guideline. The risk of fatal and weighted non-fatal conditions at a lifetime exposure of 0.1 mSv/year is between 10^{-5} and 10^{-6} per year, or about 6×10^{-4} over a lifetime. The guideline dose limit is based solely on health considerations and has not been adjusted to incorporate any limitations in the sampling and treatment capability of water supplies.

To facilitate the monitoring of radionuclides in water, the reference level of dose is expressed as an activity concentration, which can be derived for each radionuclide from published radiological data. The National Radiological Protection Board (NRPB) has calculated dose conversion factors (DCFs) for radionuclides based on metabolic and dosimetric models for adults and children. Each DCF provides an estimate of the 50-year or 70-year committed effective dose resulting from a single intake of 1 Bq of a given radionuclide.

The MACs of radionuclides in public water supplies are derived from adult DCFs, assuming a daily water intake of 2 L, or 730 L/year, and a maximum committed effective dose of 0.1 mSv, or 10% of the ICRP limit on public exposure:

$$\text{MAC (Bq/L)} = \frac{1 \times 10^{-4} \text{ (Sv/year)}}{730 \text{ (L/year)} \times \text{DCF (Sv/Bq)}}$$

Adult consumption of drinking water containing a single radionuclide at its MAC for one year would result in a committed effective dose of 0.1 mSv.

The MACs of many radionuclides with half-lives longer than one day and that could possibly enter public water supplies from natural sources or human activities are provided in Table 4. This list, however, does not preclude the presence of other radionuclides in water supplies.

Where two or more radionuclides that affect the same organ or tissue are found to be present in drinking water, the following relationship should be satisfied:

$$\frac{c_1}{\text{MAC}_1} + \frac{c_2}{\text{MAC}_2} + \cdots \frac{c_i}{\text{MAC}_i} \leq 1$$

where c_i and MAC_i are the observed and maximum acceptable concentrations, respectively, for each contributing radionuclide.

Table 4
Summary of Guidelines for
Radionuclides in Drinking Water

Radionuclide		Half-life ($t_{1/2}$)	DCF (Sv/Bq)	MAC (Bq/L)
Natural Radionuclides				
Beryllium-7	^{7}Be	53.3 days	3.3×10^{-11}	4000
Bismuth-210	^{210}Bi	5.01 days	2.1×10^{-9}	70
Lead-210	^{210}Pb	22.3 years	1.3×10^{-6}	0.1
Polonium-210	^{210}Po	138.4 days	6.2×10^{-7}	0.2
Radium-224	^{224}Ra	3.66 days	8.0×10^{-8}	2
Radium-226	^{226}Ra	1600 years	2.2×10^{-7}	0.6
Radium-228	^{228}Ra	5.76 years	2.7×10^{-7}	0.5
Thorium-228	^{228}Th	1.91 years	6.7×10^{-8}	2
Thorium-230	^{230}Th	7.54×10^{4} years	3.5×10^{-7}	0.4
Thorium-232	^{232}Th	1.40×10^{10} years	1.8×10^{-6}	0.1
Thorium-234	^{234}Th	24.1 days	5.7×10^{-9}	20
Uranium-234	^{234}U	2.45×10^{5} years	3.9×10^{-8}	4[1]
Uranium-235	^{235}U	7.04×10^{8} years	3.8×10^{-8}	4[1]
Uranium-238	^{238}U	4.47×10^{9} years	3.6×10^{-8}	4[1]
Artificial Radionuclides[2]				
Americium-241	^{241}Am	432 years	5.7×10^{-7}	0.2
Antimony-122	^{122}Sb	2.71 days	2.8×10^{-9}	50
Antimony-124	^{124}Sb	60.2 days	3.6×10^{-9}	40
Antimony-125	^{125}Sb	2.76 years	9.8×10^{-10}	100
Barium-140	^{140}Ba	12.8 days	3.7×10^{-9}	40
Bromine-82	^{82}Br	35.3 hours	4.8×10^{-10}	300
Calcium-45	^{45}Ca	165 days	8.9×10^{-10}	200
Calcium-47	^{47}Ca	4.54 days	2.2×10^{-9}	60
Carbon-14	^{14}C	5730 years	5.6×10^{-10}	200
Cerium-141	^{141}Ce	32.5 days	1.2×10^{-9}	100
Cerium-144	^{144}Ce	284.4 days	8.8×10^{-9}	20
Cesium-131	^{131}Cs	9.69 days	6.6×10^{-11}	2000
Cesium-134	^{134}Cs	2.07 years	1.9×10^{-8}	7
Cesium-136	^{136}Cs	13.1 days	3.0×10^{-9}	50

Table 4 (cont'd)

Radionuclide		Half-life ($t_{1/2}$)	DCF (Sv/Bq)	MAC (Bq/L)
Cesium-137	^{137}Cs	30.2 years	1.3×10^{-8}	10
Chromium-51	^{51}Cr	27.7 days	5.3×10^{-11}	3000
Cobalt-57	^{57}Co	271.8 days	3.5×10^{-9}	40
Cobalt-58	^{58}Co	70.9 days	6.8×10^{-9}	20
Cobalt-60	^{60}Co	5.27 years	9.2×10^{-8}	2
Gallium-67	^{67}Ga	78.3 hours	2.6×10^{-10}	500
Gold-198	^{198}Au	2.69 days	1.6×10^{-9}	90
Indium-111	^{111}In	2.81 days	3.9×10^{-10}	400
Iodine-125	^{125}I	59.9 days	1.5×10^{-8}	10
Iodine-129	^{129}I	1.60×10^{7} years	1.1×10^{-7}	1
Iodine-131	^{131}I	8.04 days	2.2×10^{-8}	6
Iron-55	^{55}Fe	2.68 years	4.0×10^{-10}	300
Iron-59	^{59}Fe	44.5 days	3.1×10^{-9}	40
Manganese-54	^{54}Mn	312.2 days	7.3×10^{-10}	200
Mercury-197	^{197}Hg	64.1 hours	3.3×10^{-10}	400
Mercury-203	^{203}Hg	46.6 days	1.8×10^{-9}	80
Molybdenum-99	^{99}Mo	65.9 hours	1.9×10^{-9}	70
Neptunium-239	^{239}Np	2.35 days	1.2×10^{-9}	100
Niobium-95	^{95}Nb	35.0 days	7.7×10^{-10}	200
Phosphorus-32	^{32}P	14.3 days	2.6×10^{-9}	50
Plutonium-238	^{238}Pu	87.7 years	5.1×10^{-7}	0.3
Plutonium-239	^{239}Pu	2.41×10^{4} years	5.6×10^{-7}	0.2
Plutonium-240	^{240}Pu	6560 years	5.6×10^{-7}	0.2
Plutonium-241	^{241}Pu	14.4 years	1.1×10^{-8}	10
Rhodium-105	^{105}Rh	35.4 hours	5.4×10^{-10}	300
Rubidium-81	^{81}Rb	4.58 hours	5.3×10^{-11}	3000
Rubidium-86	^{86}Rb	18.6 days	2.5×10^{-9}	50
Ruthenium-103	^{103}Ru	39.2 days	1.1×10^{-9}	100
Ruthenium-106	^{106}Ru	372.6 days	1.1×10^{-8}	10
Selenium-75	^{75}Se	119.8 days	2.1×10^{-9}	70
Silver-108m	^{108m}Ag	127 years	2.1×10^{-9}	70
Silver-110m	^{110m}Ag	249.8 days	3.0×10^{-9}	50
Silver-111	^{111}Ag	7.47 days	2.0×10^{-9}	70
Sodium-22	^{22}Na	2.61 years	3.0×10^{-9}	50
Strontium-85	^{85}Sr	64.8 days	5.3×10^{-10}	300

Table 4 (cont'd)

Radionuclide		Half-life (t$_{1/2}$)	DCF (Sv/Bq)	MAC (Bq/L)
Strontium-89	^{89}Sr	50.5 days	3.8×10^{-9}	40
Strontium-90	^{90}Sr	29 years	2.8×10^{-8}	5
Sulphur-35	^{35}S	87.2 days	3.0×10^{-10}	500
Technetium-99	^{99}Tc	2.13×10^{5} years	6.7×10^{-10}	200
Technetium-99m	^{99m}Tc	6.01 hours	2.1×10^{-11}	7000
Tellurium-129m	^{129m}Te	33.4 days	3.9×10^{-9}	40
Tellurium-131m	^{131m}Te	32.4 hours	3.4×10^{-9}	40
Tellurium-132	^{132}Te	78.2 hours	3.5×10^{-9}	40
Thallium-201	^{201}Tl	3.04 days	7.4×10^{-11}	2000
Tritium	^{3}H	12.3 years	1.8×10^{-11}	7000
Ytterbium-169	^{169}Yb	32.0 days	1.1×10^{-9}	100
Yttrium-90	^{90}Y	64 hours	4.2×10^{-9}	30
Yttrium-91	^{91}Y	58.5 days	4.0×10^{-9}	30
Zinc-65	^{65}Zn	243.8 days	3.8×10^{-9}	40
Zirconium-95	^{95}Zr	64.0 days	1.3×10^{-9}	100

Notes:
1. The activity concentration of natural uranium corresponding to the chemical guideline of 0.1 mg/L (see separate summary paragraph on uranium in Section 4.6) is about 2.6 Bq/L.
2. Tritium and ^{14}C are also produced naturally in the atmosphere in significant quantities.

5.3 Application of the Guidelines

The levels of radionuclides normally encountered in drinking water are far below the threshold for acute effects of radiation. In virtually every case, the limitation is governed by the chronic or cumulative exposure over a period of one year. The sampling and analyses for individual radionuclides should be carried out often enough to accurately characterize the annual exposure. If the source of the activity is known, or expected, to be changing rapidly with time, then the sampling frequency should reflect this factor. If there is no reason to suppose that the source varies with time, then sampling may be carried out seasonally, semi-annually or annually. If measured concentrations are consistent and well below the reference levels, this would be an argument for reducing the sampling frequency. On the other hand, the sampling frequency should be maintained, or even increased, if concentrations are approaching the reference levels.

Water samples may be initially screened for radioactivity using techniques for gross alpha and gross beta activity determinations, subject to the limitations of the method. Compliance with the guidelines may be inferred if the measurements for gross alpha and gross beta activity are less than 0.1 Bq/L and 1 Bq/L, respectively, as these are lower than the strictest MACs (^{210}Pb for alpha activity; ^{90}Sr for beta activity). If either screening level is exceeded, then the specific radionuclides should be identified and individual activity concentrations measured. When the additive formula is satisfied, no further action is required, and the water is acceptable for human consumption based on radiological considerations (although analyses for chemical or biological contamination may still be necessary). Where the sum exceeds unity for a single sample, the reference dose level would be exceeded only if exposure to the same measured concentration were continued for a full year. Hence, such a sample does not in itself imply that the water is unsuitable for consumption and should be regarded only as a level at which further investigation, including additional sampling, is needed.

Treatment of water supplies for radionuclides should be governed by the principle of keeping exposures as low as reasonably achievable, social and economic considerations being taken into account, and should be considered only in the event that alternative water supplies are unavailable. Releases of radionuclides to the environment are most effectively limited through regulatory control of the source if they originate from human practices, the exception being the globally dispersed radionuclides (e.g., ^{137}Cs and ^{90}Sr) from nuclear weapons tests and accidents. It is through the regulatory mechanism that remedial action should be taken in the event that these sources result in radionuclide levels that exceed the guidelines for

extended periods of time. These guidelines apply to the total exposure from drinking water supplies and are not intended to replace regulatory limits governing releases of radionuclides from human practices. Any facility contributing radionuclides to a drinking water source must meet the regulatory requirements as established by the Atomic Energy Control Board (AECB).

These recommendations apply to routine operational conditions of existing or new water supplies. They do not apply in the event of contamination during an emergency involving the release of radionuclides into the environment.

5.4 Summary Paragraphs for Selected Radionuclides

Some of the radionuclides of greatest concern from a health perspective in terms of the potential for normal or accidental release from nuclear industries into drinking water supplies are ^{137}Cs, ^{131}I, ^{226}Ra, ^{90}Sr and tritium (^{3}H). Brief summaries of these radionuclides are presented below. Uranium is one of the most important natural radionuclides that may be found in water supplies; however, concentrations of uranium in drinking water are limited by chemical toxicity rather than radiological toxicity. A summary paragraph on uranium can be found in Section 4.6.

Cesium-137

Cesium-137, an alkali metal, is one of the more important fission products owing to its relatively high yield and its ability to bioconcentrate in some food chains. It has a radioactive half-life of 30.17 years and is produced in nuclear explosions with a ^{137}Cs/^{90}Sr ratio of 1.6. Cesium-137 is released during normal reactor operations primarily in aqueous effluent. As in the case of ^{90}Sr, weapons fallout over land is the most important source as far as committed doses to humans are concerned. On land, ^{137}Cs is strongly affixed to soil, limiting both its downward mobility and its availability for root uptake in plants. Fixation by sediments in aquatic environments is similar to that in soil, reducing its concentration in the water column. Direct atmospheric deposition is the primary mode of contamination for vegetation.

Concentrations of ^{137}Cs measured in surface waters of the Great Lakes averaged about 0.5 mBq/L in 1992. No enhancement in concentration was observed in the vicinity of reactor installations.

Cesium-137 is bioconcentrated in a number of food chains, including the air-vegetation-livestock chain, the air-lichen-caribou chain and the fresh water-fish chain. The main contributions to dietary intake are grains, meat and milk. Cesium-137, which metabolically resembles potassium, is readily absorbed following ingestion and becomes uniformly distributed in soft

tissues, with minimal uptake by bone tissue. The biological half-life of ^{137}Cs is a function of age and sex, with representative retention rates of two days for 10% of the body burden and 110 days for the remaining 90%.

The MAC for ^{137}Cs in drinking water is *10 Bq/L.*

Iodine-131

Iodine-131 is found in the environment mainly as a result of nuclear explosions and releases from reactors and fuel reprocessing facilities. Releases of ^{131}I from reactors are widely variable. Being a volatile element, ^{131}I is readily released to the atmosphere in the event of an accident. As a result of its short half-life (eight days), ^{131}I is of concern only immediately following a significant release from a reactor.

Iodine-131 is very mobile in the environment. The most significant exposure route for humans is the air-vegetation-livestock-milk pathway. Following consumption, ^{131}I is rapidly taken up by the body and selectively irradiates the thyroid gland; the absorbed dose in the thyroid is about 1000 times that in other organs and tissues.

The MAC for ^{131}I in drinking water is *6 Bq/L.*

Radium-226

Radium-226 occurs naturally in soils as a decay product of the ^{238}U series. It decays with a half-life of 1600 years to form ^{222}Rn. Uptake in food is the major pathway into the body. The contribution of drinking water to total intake is small when supplies are drawn from surface waters, which typically display a narrow range of concentrations. Concentrations in groundwater sources, however, are highly variable and result mainly from the interaction between the groundwater aquifer and radium-bearing materials, such as rock, soil and ore deposits.

Radium-226 concentrations in water samples measured at various sites across Canada between 1981 and 1984 ranged from about 1 to 13 mBq/L. Radium levels in water samples from Port Hope (Ontario) and Regina (Saskatchewan) averaged less than 5 mBq/L in 1988. Levels recorded during the same period in Elliot Lake (Ontario) ranged from 8 to 18 mBq/L. In general, higher levels of ^{226}Ra can be expected in areas containing uranium mining and milling operations or where rock containing high concentrations of the natural radionuclides is in contact with water.

When ^{226}Ra is taken into the body, its metabolic behaviour is similar to that of calcium, and an appreciable fraction is deposited in bone. The remainder is distributed more or less equally in soft tissues. Following the decay of ^{226}Ra to ^{222}Rn in bone, approximately 70% of ^{222}Rn diffuses to the blood and is exhaled.

The MAC for ^{226}Ra in drinking water is *0.6 Bq/L.*

Strontium-90

Strontium-90 decays with a half-life of 29 years through ^{90}Y, which is also radioactive, to form stable ^{90}Zr. Strontium is produced during fission in nuclear explosions and nuclear power generation. The majority of ^{90}Sr in the environment has come from weapons fallout. Discharge rates from nuclear reactors are small, and measurements of local impact are indistinguishable from fallout ^{90}Sr.

Mean activities of ^{90}Sr in the Great Lakes during 1981 to 1982 ranged from 15 mBq/L in Lake Superior to 29 mBq/L in Lake Ontario. Average concentrations recorded in the Winnipeg, Ottawa and St. Lawrence rivers and in Lakes Huron and Ontario near the Bruce and Pickering generating stations ranged from 1 to 12 mBq/L in 1988. These levels are indistinguishable from background levels due to nuclear weapons fallout.

As an alkaline earth element, strontium is similar to calcium, barium and radium, following calcium through the food chain from the environment to humans. The deposition of ^{90}Sr on land and the transfer to humans by ingestion of contaminated food is the most important exposure pathway. Significant transfer occurs via the air-vegetation-livestock-milk pathway. Of less importance are the aquatic pathways, and contributions from drinking water are always less than 5% of the total ingestion intake. Upon ingestion, absorption of ^{90}Sr by the body is relatively high. Strontium is retained largely in the bone. The mean residence time in bone tissue ranges from 3.4 to 6.7 years.

The MAC for ^{90}Sr in drinking water is *5 Bq/L*.

Tritium

Tritium (^{3}H), with a half-life of 12.3 years, exists in the environment mainly as water, from which it enters the hydrological cycle and all components of the biosphere. It is produced naturally in the upper atmosphere and artificially in nuclear detonations and during nuclear reactor operations. Nuclear weapons tests conducted in the atmosphere since 1945 have produced quantities of tritium far exceeding the natural inventory. Tritium produced during nuclear power generation in the moderator and coolant of heavy water reactors and in the reactor fuel rods of all reactors is released in liquid and gaseous effluent as tritiated water.

Average tritium concentrations in surface waters across Canada are on the order of 5 to 10 Bq/L, owing primarily to residual fallout from atmospheric weapons tests conducted prior to 1963. Average levels in the Great Lakes ranged from 7 to 10 Bq/L during 1982 to 1984. An average concentration of about 6 Bq/L was recorded at locations throughout Ontario

in 1990. Activity concentrations in community water supplies near all Ontario nuclear reactors ranged from 12 to 35 Bq/L, slightly higher than background levels.

Transfer of tritium to humans from the environment takes place through inhalation, skin absorption and ingestion. Exposure to an atmosphere contaminated with tritiated water vapour results in total absorption of the inhaled activity and absorption of about 50% of the skin exposure. Ingested tritiated water is completely absorbed from the gastrointestinal tract. Absorbed tritiated water is rapidly distributed throughout the body via the blood. The majority of this amount is removed from the body with a biological half-life ranging from 2.4 to 18 days, representing the turnover of body water. The remainder is removed with a half-life of one month to one year, representing the turnover of tritium incorporated in organic compounds.

The MAC for tritium in drinking water is *7000 Bq/L*.

5.5 Radon

Radon-222 is a chemically inert gas formed through the radioactive decay of ^{226}Ra; both are members of the ^{238}U decay series. Radon has a half-life of 3.82 days. Its decay products form a series of short-lived radionuclides that decay within hours to ^{210}Pb; because of their short half-lives, the radon daughters rapidly approach radioactive equilibrium with their radon parent.

Radon is the major source of naturally occurring radiation exposure for humans. Exposure occurs via the ingestion of radon dissolved in water and the inhalation of airborne radon. Because of radon's volatility, water drawn from surface supplies does not generally contain appreciable levels of the radionuclide, usually on the order of 0.01 Bq/L. Groundwater generally contains higher levels, on the order of 10 to 75 Bq/L, although levels as high as 14 kBq/L have been measured in Canadian groundwater supplies.

The average radon level in outdoor air for continental locations in temperate latitudes is about 9 Bq/m^3; average levels in the Prairie provinces in the summer ranged from 10 to 60 Bq/m^3, depending on precipitation conditions. Indoor radon levels are typically much higher and more variable than outdoor levels. Radon entry into houses and other buildings is primarily from the soil or rock under the structures. Radon in tap water, building materials and natural gas can also contribute to indoor levels, particularly in confined spaces with low air change rates. An average indoor radon concentration of about 50 Bq/m^3 has been estimated for temperate regions of the world.

It is radon's progeny, not radon itself, that damage the bronchial epithelium following inhalation. Epidemiological data derived from underground miners of various metal ores have shown a relatively consistent relationship between lung cancer incidence and exposure to radon progeny. However, no experimental or epidemiological studies have linked ingested radon with health impacts in humans, and it has generally been concluded from animal studies that the risk from ingestion is insignificant compared with the risk from inhalation. As well, radon that has emanated from water supplies into air generally contributes only 1% or 2% to the mean indoor concentration. Thus, under normal conditions, the intake of radon in ambient and indoor air generally far surpasses the intake of radon from drinking water via both ingestion and inhalation routes. Even these normally occurring levels of radon and radon progeny in indoor and ambient air have not been linked with an increase in lung cancer death rate from inhalation exposure in available epidemiological studies.

It has therefore been concluded that there is no need to establish a MAC for radon in drinking water. However, anyone whose indoor air radon concentrations exceed acceptable levels (800 Bq/m^3 as an annual average concentration in the normal living area) should investigate the possibility that their groundwater also contains high levels of radon. Individuals who attempt to remove radon from their water supply using point-of-use devices containing activated carbon should be cautioned regarding the difficulties of disposing of the used radioactive carbon.

6. Parameters under Review or Scheduled for Review

Table 5 lists all of the microbiological, chemical, physical or radiological parameters that are under review or scheduled for review for possible revision or addition to the Guidelines for Canadian Drinking Water Quality.

Table 5
Parameters under Review or Scheduled for Review

Parameter	Parameter
aluminum	methyl-4-chlorophenoxyacetic acid, 2- (MCPA)
antimony	nickel
bromate	organotins
chlorates + chlorites + chlorine dioxide	protozoa
cyanobacterial toxins	total petroleum hydrocarbons (TPH)
dichlorophenoxypropionic acid, 2,4- (dichlorprop)	trichloroethylene
fluoride	viruses
formaldehyde	uranium
haloacetic acids	