Chloride

An aesthetic objective of $\leq 250 \text{ mg/L}$ has been established for chloride in drinking water. At concentrations above the aesthetic objective, chloride imparts undesirable tastes to water and to beverages prepared from water and may cause corrosion in the distribution system.

General

Chloride is widely distributed in nature, generally as the sodium (NaCl) and potassium (KCl) salts; it constitutes approximately 0.05% of the lithosphere. By far the greatest amount of chloride found in the environment is in the oceans.

Underground salt deposits have been found in all Canadian provinces except British Columbia. Bedded deposits occur in southwestern Ontario, Saskatchewan and Alberta; dome deposits are found in Nova Scotia, New Brunswick, Ontario, Manitoba, Saskatchewan and Alberta.

Sodium chloride is widely used in the production of industrial chemicals such as caustic soda (sodium hydroxide), chlorine, soda ash (sodium carbonate), sodium chlorite, sodium bicarbonate and sodium hypochlorite. In 1984, it was estimated that 4 078 000 t of sodium chloride were used by the chemicals industry. Sodium chloride and, to a lesser extent, calcium chloride ($\text{CaCl}_2$) are used for snow and ice control in Canada; 45% of all salt consumed in Canada is used for this purpose, compared with 25% in the United States and 14% in western Europe. In 1984, it was estimated that 3 560 800 t of sodium chloride were applied to Canadian roads.

Potassium chloride is used in the production of fertilizers.

Occurrence

The presence of chloride in drinking water sources can be attributed to the dissolution of salt deposits, salting of highways to control ice and snow, effluents from chemical industries, oil well operations, sewage, irrigation drainage, refuse leachates, volcanic emanations, sea spray and seawater intrusion in coastal areas. Each of these sources may result in local contamination of surface water and groundwater. The chloride ion is highly mobile and is eventually transported into closed basins or to the oceans.

Chloride is generally present at low concentrations in natural surface waters in Canada; concentrations are normally less than 10 mg/L and often less than 1 mg/L. The mean chloride concentration in 109 lakes in the Experimental Lakes Area (ELA) of northwestern Ontario was 0.8 mg/L in 1973; a chloride concentration of 0.9 mg/L was measured in a small acidic lake near Sudbury, Ontario, in the same year. The Great Lakes and waters in the St. Lawrence lowlands have somewhat higher concentrations of chloride (20 mg/L), largely because of industrial activities in the area. The concentration of dissolved chloride in Canadian waters over the period 1980 to 1984 usually fell in the range <0.1 to 861 mg/L, but concentrations as high as 24 500 mg/L have been recorded in Bench Mark Creek in Alberta.

Drinking water data for several Canadian provinces indicate that chloride concentrations are generally low, often less than 10 mg/L. Of 127 stations in Saskatchewan that analysed for chloride in 1975, only one recorded a chloride concentration greater than 50 mg/L; no station recorded a concentration greater than 250 mg/L. The same results were found for 56 stations in Nova Scotia that recorded chloride concentrations in drinking water during 1975. In Alberta, 51 out of 492 stations recorded chloride concentrations greater than 50 mg/L in 1976; 15 stations recorded concentrations greater than 250 mg/L. In a 1987 analysis of 60 samples of treated water from the Lemieux Island water treatment plant in Ottawa, Ontario, the average chloride concentration was 5.5 mg/L (range 4.0 to 9.5 mg/L). The average concentration of chloride in U.S. public water supplies is about 11.5 mg/L; in European water supplies, it is 52 mg/L. Higher concentrations of chloride are most often present in drinking water derived from groundwater sources; this could be due to naturally high concentrations or to contamination. An estimated 25 to 50% of applied road salt enters groundwater.

Only limited data are available on chloride concentrations in air in Canada. A survey carried out in Edmonton over three one-month periods found the geometric means and ranges (in parentheses) of the
chloride concentrations in air to be as follows:
November 1978, 1.97 µg/m³ (0.3 to 9.0 µg/m³);
March/April 1979, 0.82 µg/m³ (0.1 to 3.4 µg/m³); and
July/August 1979, 0.64 µg/m³ (0.1 to 2.8 µg/m³). For
the total period of observation, the mean chloride
concentration was 1.2 µg/m³.\(^{24}\) The chloride concen-
tration in air above Lake Michigan was estimated to be
0.5 µg/m³.\(^{25}\)

The chloride content of foods varies over a wide
range; edible plants generally have concentrations below
0.5 mg/g, whereas meat and fish have concentrations up
to 1.0 and 1.5 mg/g, respectively.\(^{26}\)

**Canadian Exposure**

Estimation of the daily intake of chloride in food is
complicated by the widespread use of salt as a
condiment. Approximately 600 mg of chloride per day
are ingested in a salt-free diet.\(^{27,28}\) However, because
of the addition of salt to food, the daily intake of
chloride averages 6 g and may range as high as 12 g.\(^{29}\)

If one assumes that daily water consumption is
1.5 L and that the average concentration of chloride in
Canadian drinking water is 10 mg/L, the average daily
intake of chloride from drinking water can be calculated
to be approximately 15 mg per person. The intake from
water therefore constitutes only about 0.25% of the
average intake from food.

If the average concentration of chloride in air in
Canada is assumed to be 1.2 µg/m³ and the daily
respiratory volume is 20 m³, then the daily intake of
chloride from air would be 0.024 mg.

Based on the above considerations, the total daily
intake of chloride is about 6 g and comes almost entirely
from food. Large deviations from this value are expected
because of individual variations in the quantities of salt
added to food during cooking and at the table.

**Analytical Methods and Treatment
Technology**

Several analytical techniques may be used for
chloride in water, including titration (e.g., potenti-
ometric titration with silver nitrate), colorimetry
(e.g., thiocyanate colorimetry), chloride ion selective
electrode and ion chromatography.\(^{26}\) Limits of
detection range from 50 µg/L for colorimetry to 5 mg/L
for titration.

Because chloride is very soluble in water, it is not
easily removed, and conventional water treatment
processes are generally ineffective.\(^{21}\) A removal of
87% has been reported using a point-of-use treatment
device employing granular activated carbon adsorption
and reverse osmosis.\(^{22}\) Chloride concentrations in
water may increase during the treatment process if
chlorine is used for disinfection purposes or if aluminum
or iron chlorides are used for flocculation purposes.\(^{23}\)

**Health Considerations**

**Essentiality**

Chloride is an essential element and is the main
extracellular anion in the body. It is a highly mobile ion
that easily crosses cell membranes and is involved in
maintaining proper osmotic pressure, water balance and
acid–base balance.

Until recently, it had been assumed that the
physiological role of the chloride ion was simply that of
a passive counterion. Over the past few years, however,
several studies have suggested that the chloride ion may
play a more active and independent role in renal
function,\(^{33,34}\) neurophysiology\(^{35}\) and nutrition.\(^{36}\)

**Absorption, Distribution and Excretion**

Absorption of chloride from the diet is considered
to be essentially complete. Balance studies in young
men have shown that 92% of the ingested chloride is
excreted in the urine.\(^{37}\)

The amount of chloride in the intestinal contents
declines as the contents move along the gastrointestinal
tract. Typically, 540 mg of chloride enter the duodenum
each day.\(^{38}\) Chloride is absorbed in the jejunum by
“solvent drag” and in the ileum and colon by active
chloride transport coupled to bicarbonate
secretion.\(^{39}\) Both of these processes are linked to
sodium-based co-transport mechanisms that create the
necessary osmotic and electrochemical gradients.

It has been estimated that the human body contains
0.15% chloride,\(^{40}\) or 105 g/70 kg bw. Most of this
chloride is extracellular, as shown by serum levels of 98
to 106 meq/L, compared with the approximate 1 meq/L
for tissue cells.\(^{41}\) Stomach secretions are high in
chloride, with concentrations between 45 and 155
meq/L in gastric residues. All body chloride is
considered to belong to an exchangeable pool.\(^{42}\)

Body chloride concentrations are regulated by
excretions, primarily via the kidneys. Both chloride and
sodium are regulated by aldosterone.\(^{43}\) The urinary
excretion of chloride for adults is about 4.4 g/d, with a
range of 2.2 to 13 g/d; the amount excreted is closely
related to the amount of salt in the diet. Chloride loss in
the faeces is low, with 14 to 110 mg excreted daily by
this route. Significant additional daily losses of chloride
occur in perspiration.\(^{47}\)

**Toxic Effects**

A role for chloride in sodium-sensitive hypertension
has been proposed.\(^{44,45}\) Evidence seems to indicate
that both sodium and chloride are required for a hyper-
tensive effect.\(^{42}\) Chloride by itself does not appear to
cause hypertension in rats,\(^{46}\) although red blood cells
from human hypertensives show altered chloride
handling.\(^{47}\) The role of sodium in hypertension is
under investigation (see sodium review); however, there
is no evidence that high chloride concentrations would be any more toxic than high sodium concentrations.

Other Considerations

The taste threshold for chloride is dependent on the associated cation and is generally in the range of 200 to 300 mg/L. Chloride concentrations detected by taste in drinking water by panels of 18 or more people were 210, 310 and 222 mg/L from the respective sodium, potassium and calcium salts. The taste of coffee was affected when brewed with water containing chloride concentrations of 400, 450 and 530 mg/L from sodium, potassium and calcium chloride, respectively. Chloride concentrations above 250 mg/L in drinking water may cause corrosion in the distribution system. The chloride ion’s ability to form soluble salts with many metal ions prevents the formation of films that could prevent the further corrosion of metal surfaces.

Rationale

1. Chloride concentrations in the body are well regulated through a complex interrelated system involving both nervous and hormonal systems. Even after intake of large quantities of chloride through food and water, the chloride balance is maintained, mainly by the excretion of excess chloride via the urine. Therefore, a maximum acceptable concentration has not been set for chloride in drinking water.

2. Taste thresholds for chloride from sodium chloride, potassium chloride and calcium chloride in drinking water are 210, 310 and 222 mg/L, respectively; the taste of coffee is affected when brewed with water containing chloride concentrations of 400, 450 and 530 mg/L from the same salts. Chloride concentrations above 250 mg/L in drinking water may cause corrosion in the distribution system.

3. The aesthetic objective for chloride in drinking water is therefore ≤250 mg/L. Chloride concentrations in Canadian drinking water supplies are generally much lower than 250 mg/L.

References


