# Assessment Report - Inorganic Chloramine

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The Ministers of Environment and Health have released for final publication the assessment report for the priority substance inorganic chloramine. Notice concerning the assessment of this substance and a summary of its assessment report was published in the Canada Gazette, Part 1 June 23, 2001. The synopsis of the report is provided below.

A draft of this Assessment Report was made available for a 60-day public comment period (July 8, 2000 - September 6, 2000). Following consideration of the comments received, the Assessment Report was revised as appropriate. A summary of the comments and their responses may also be accessed from this page.

**For paper copies of the Full Assessment Report, please contact the Inquiry Centre at Environment Canada:**

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**Synopsis**

Inorganic chloramines consist of three chemicals that are formed when chlorine and ammonia are combined in water: monochloramine ($NH_2Cl$), dichloramine ($NHCl_2$) and trichloramine ($NCl_3$). Inorganic chloramines, free chlorine and organic chloramines are chemically related and are easily converted into each other; thus, they are not found in isolation. Chloramines and free chlorine are released to the Canadian environment by municipal and industrial sources. They are used to disinfect drinking water and wastewaters and to control biological fouling in cooling water systems and at the intakes and outlets of utilities and industries (e.g., for zebra mussel control). When chlorination of fresh water or effluent occurs in the presence of ammonia, monochloramine usually forms; dichloramine may also form to a lesser degree, depending on the characteristics of the raw water or influent (e.g., pH, molar ratio of hypochlorous acid to ammonia, temperature) and the chlorine contact time. Conditions favouring the formation of trichloramine are rare. Organic chloramines are also produced if certain organic nitrogen compounds, including amino acids and nitrogen heterocyclic aromatics, are present.

This risk assessment focused on inorganic chloramines, but also acknowledged the combined presence of free residual chlorine (FRC) and organic chloramines. Risk assessments of organic chloramines and FRC were beyond the scope of this assessment.

In 1996, approximately 6.9 million Canadians were serviced by chloraminated drinking water. An estimated 250 000 kg of total residual chlorine (TRC) were released to Canadian surface waters and soils from potable water sources in 1996. In 1996, approximately 173 municipal wastewater treatment plants (WWTPs) chlorinated effluent and did not dechlorinate before discharge. These facilities released approximately 1.3 million kilograms of TRC to surface waters. In 1996, there were at least 43 industrial facilities chlorinating effluents or cooling waters or chlorinating to control biological fouling and not dechlorinating prior to discharge. Facilities involved in the control of biofouling released approximately 142 000 kg of TRC to surface waters. Cooling and other industrial sources released a total of approximately 91 000 kg of TRC to the Canadian environment in 1996. Many municipal and industrial facilities dechlorinate their effluents, and hence, do not release measurable concentrations of chloramines and free chlorine to the environment.

Inorganic chloramines are not persistent, but they are more persistent than FRC compounds. In surface waters, the available data suggest that inorganic chloramines have half-lives ranging from 1 minute to 23 days, depending on the conditions. Inorganic chloramine concentrations in the environment have been measured only in surface waters, and usually near the point of entry, because of their limited persistence. Since they are released to surface waters and have limited persistence, the assessment focused on an evaluation of risk to sensitive aquatic life near point sources. Acute and subacute effects were assessed in receptor organisms. The potential risks to microorganisms and soil processes were also acknowledged. Based on the available evidence, adverse effects on soil microorganisms and associated soil processes from inorganic chloramines were considered unlikely.

The aquatic toxicity of inorganic chloramines is dependent on biological species, chloramine compounds, presence of FRC and organic chloramines, temperature, exposure duration and life stage of the biological species. A critical review of environmental toxicity data for inorganic chloramines was conducted. Using a meta-analysis approach, a lower-boundary concentration line that bounded the acute toxicity data for all species was developed, sensitive species were identified and data gaps were outlined. To fill the data gaps, toxicity tests on freshwater fish (juvenile chinook salmon, *Oncorhynchus tshawytscha*), freshwater invertebrates (*Ceriodaphnia dubia* and *Daphnia magna*) and marine invertebrates (*Amphiporeia virginiana* and *Eohaustorius washingtonianus*) were undertaken, and time-to-lethality (e.g., LT100, LT50, LT20, LT0) reference lines were determined. Further analyses produced a reference line (the lowest reference concentration for 50% lethality) showing that the incipient lethality to 50% (i.e., LC50) of *C. dubia* occurred at times equal to or greater than 1073 minutes and a monochloramine concentration of 0.018 mg/L. Using application factors, the lower-boundary reference line was shifted to reflect 0% mortality for *C. dubia*. The line was also lowered to account for the species identified in the literature as being more sensitive to inorganic chloramines than *C. dubia*. Using this approach, an incipient Estimated No-Effects Value (ENEV) of 0.0056 mg/L for freshwater organisms was derived for the conservative-level assessment. The same reference line for acute toxicity was adopted to determine a suitable lower boundary line for marine invertebrates due to insufficient acute toxicity data with which to perform reliable modelling with marine and estuarine invertebrates. For the conservative-level assessment, an incipient ENEV of 0.0028 mg/L for marine and estuarine environments was derived by using application factors to reflect 0% mortality and to account for more sensitive species.

A conservative-level assessment of drinking water releases found that even very small direct discharges (e.g., approximately 0.001 $m^3$/s) of chloramine-treated potable water could result in impacts if dilutions are less than 1:10 to 1:100. However, most flows of this nature are indirect and would be subject to chemical demand en route to the surface water; hence, small overland flows would not likely have an impact on aquatic organisms. Larger flows with discharges of greater than 0.01 $m^3$/s, such as from large distribution system leaks, main breaks, fire hose discharge, main flushing, street washing and some industrial and commercial activities, will have a greater possibility of producing impacts. A probabilistic risk assessment for drinking water releases was not conducted because it was not possible to attain the required data (e.g., comprehensive data would be required regarding numbers of major releases, volumes, chloramine concentrations and destinations of flow). In spite of this limitation, severely negative consequences to freshwater ecosystems have occurred in the Lower Mainland of British Columbia, where releases of chloramine-treated potable water due to water main breaks resulted in the mortality of many thousand salmonids and several thousand invertebrates.

Characteristics of chloramine discharges from over 110 WWTPs were screened using a conservative-level assessment. This assessment recommended discharge scenarios for a probabilistic risk assessment. Probabilistic risk assessments were conducted on two wastewater discharges (North Toronto WWTP discharge to the Don River, Toronto, Ontario; Ashbridges Bay WWTP discharge to Ashbridges Bay of Lake

Ontario, Toronto, Ontario) and a cooling water discharge (Clover bar Generating Station discharge to the North Saskatchewan River, Edmonton, Alberta). All discharges were to freshwater rivers and a lake. No marine discharges required probabilistic risk assessment, although there is a potential for negative impact from inorganic chloramine discharge to salt waters.

The probabilistic risk assessment focused on sensitive invertebrate and fish species commonly found in Canada. Sensitive receptors included the freshwater invertebrate, *C. dubia*, and a juvenile freshwater life stage of the anadromous fish, chinook salmon. The chinook salmon was chosen as a fish receptor in spite of the fact that it is not ubiquitous across Canada. However, it is related to other salmonid species, such as rainbow trout (*Oncoryhynchus mykiss*), which together have a widespread presence in Canadian waters. Except for coho salmon (*Oncorhynchus kisutch*), chinook salmon have a sensitivity to chloramines that is similar to or greater than that of other salmonids. Cladocerans (e.g., *C. dubia* and *D. magna*) are representative of other larger and smaller invertebrates that together act as food sources for many fish. They form a significant portion of the diet of many fishes, including salmonids, which are themselves an important food, economic and cultural resource for Canadians. To estimate probabilistic risk of chloramines to aquatic biota, each exposure distribution was compared with three incipient lethality endpoints: 50% mortality to *C. dubia* (0.018 mg/L); and 50% (0.112 mg/L) and 20% (0.077 mg/L) mortality to chinook salmon.

In the Don River, forecasted risks were most severe in January, with probabilities of >80% for 50% or greater mortality for *C. dubia* at 1900 m from the source. Lowest risk was forecasted for the month of August, with probabilities of up to 41% for 20% mortality 1900 m from the outfall. For Lake Ontario, there was a probability of >40% for 50% mortality to *C. dubia* in a narrow, semi-elliptical band that was 500 m in width and extended approximately 1000 m. In the North Saskatchewan River, it appeared that elevated risk (i.e., >40% probability of 50% or greater mortality to *C. dubia*) was contained in a plume stretching to a maximum 30 m in width and approximately 3000 m in length.

Since fish are less sensitive than invertebrates to chloramines, risk forecasts for chinook salmon were lower than those for *C. dubia*. Because fish have longer regeneration times, however, the lower probabilities of mortality may lead to longer population consequences for fish than for daphnids. On the other hand, fish are mobile and have the ability to detect and avoid chloramine. Avoidance of chloramine has been reported at 0.05 – 0.11 mg/L for coho salmon and rainbow trout. The avoidance effects may be offset by conditions in the effluent (e.g., elevated ammonia concentration and elevated water temperatures) that result in attraction. Data were not available to determine whether avoidance and/or attraction can affect the risk forecasts that were determined in this assessment.

**Based on the available data, it is concluded that inorganic chloramines are entering the environment in a quantity or concentration or under conditions that have or may have an immediate or long-term harmful effect on the environment or its biological diversity. However, it is concluded that inorganic chloramines are not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger to the environment on which life depends. Therefore, inorganic chloramines are considered to be "toxic "as defined in Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999).**

Risk management efforts should involve limiting the exposure in surface waters from the largest sources (i.e., municipal wastewater facilities, followed by potable and industrial sources). Reducing the exposure of aquatic biota may involve an examination of regional or location-specific characteristics that affect chloramine risk. These would include decay, dilution and the presence of aquatic biota with a sensitivity to inorganic chloramines.

Limiting exposure from unpredictable releases will prove most challenging. Reducing chloramine loading may be technologically feasible for point sources such as waste effluents or cooling waters, but not for geographically and temporally unpredictable releases from drinking water distribution systems. Regional-level control measures, potentially involving changes in treatment procedures, may have to be evaluated for regions with an abundance of aquatic environments that promote chloramine persistence, provide low dilution and contain sensitive aquatic ecosystems. Such measures must not compromise human health protection; selection of options must be based on optimization of treatment to ensure health protection, while minimizing or eliminating potential for harm to environmental organisms.

Although no existing marine or estuarine discharge scenarios were recommended for the probabilistic assessment, new discharges to marine and estuarine environments could produce negative ecological consequences. The marine environment contains aquatic organisms that are possibly even more sensitive to inorganic chloramines than freshwater species. Therefore, if a facility discharging chloramines to a marine environment is proposed, a precautionary risk assessment is recommended to evaluate site-specific characteristics that affect ecological risk.