GUIDELINES FOR

CANADIAN RECREATIONAL WATER QUALITY

PHYSICAL, AESTHETIC AND CHEMICAL CHARACTERISTICS

Guideline Technical Document

Health Canada Santé Canada

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Foreword

The *Guidelines for Canadian Recreational Water Quality* are comprised of multiple guideline technical documents that consider the various factors that could interfere with the safety of recreational waters from a human health perspective. This includes technical documents on understanding and managing recreational waters, fecal indicator organisms, microbiological methods for monitoring fecal contamination, cyanobacteria and their toxins, physical, aesthetic, and chemical characteristics, and microbiological pathogens and other biological hazards. These documents provide guideline values for specific parameters used to monitor water quality hazards and recommend science-based monitoring and risk management strategies.

Recreational waters are considered to be any natural fresh, marine or estuarine bodies of water that are used for recreational purposes; these include lakes, rivers, and human-made constructions (e.g., quarries, artificial lakes) that are filled with untreated natural waters. Jurisdictions may choose to apply these guidelines to natural waters that have limited treatment applied (e.g., short-term disinfection for an athletic event) although applying the guidelines in these scenarios should be done with caution as indicator organisms are easier to disinfect than other disease-causing microorganisms (e.g., protozoan pathogens).

Recreational activities that could present a human health risk through intentional or incidental immersion and ingestion include primary contact activities (e.g., swimming, bathing, wading, windsurfing and waterskiing) and secondary contact activities (e.g., canoeing and fishing).

Each guideline technical document has been established based on current, published scientific research related to health effects, aesthetic effects, and beach management considerations. The responsibility for recreational water quality generally falls under provincial and territorial jurisdiction, and therefore the policies and approaches, as well as the resulting management decisions, may vary between jurisdictions. The guideline technical documents are intended to guide decisions by local authorities that are responsible for the management of recreational waters.

This document includes information on the physical, aesthetic and chemical characteristics of recreational areas. For a complete list of the guideline technical documents available, please refer to the *Guidelines for Canadian Recreational Water Quality* summary document available on the Canada.ca website (in publication).

Physical, aesthetic and chemical characteristics of recreational areas

This document outlines the physical, aesthetic and chemical characteristics of the water and surrounding beach area that may affect their suitability for recreational activities. Guideline values or aesthetic objectives are recommended where possible. The values and associated guidance are intended to be applicable to all recreational waters, regardless of the types of activities practised. Responsible authorities may, at their discretion, wish to establish separate guideline values or aesthetic objectives for waters intended for secondary contact use. The division of duties (e.g., responsibility for monitoring or the communication of results) between the provincial or territorial authorities and the beach managers or service providers may also vary depending on the policies in place.

A risk management approach that focuses on the identification and control of water quality hazards and their associated risks before the point of contact with the recreational water user represents the best strategy for the protection of public health. More details on the risk management of recreational water quality are available in the *Guidelines for Canadian Recreational Water Quality - Understanding and Managing Risks in Recreational Waters* technical document (Health Canada, in publication-c).

1.0 GUIDELINE VALUES AND THEIR APPLICATION

1.1 Physical and Aesthetic Parameters

Physical and aesthetic parameters can be useful to help determine the overall quality of a recreational area (Table 1). Although this guideline document includes numerous parameters, they may not be applicable in all waters. Site-specific characteristics, such as biological, chemical, or physical conditions should be considered. This may include considering historical water quality sampling results when determining the overall quality of a recreational area.

Table 1. Physical and aesthetic parameters

Parameter	Value	Justification
pH	5.0 – 11.0	pH values outside this range may cause skin and eye irritation. Most natural waters have pH ranges from 4.0 to 9.0, therefore some natural waters may fall outside the acceptable pH range.
Dissolved oxygen	Low oxygen conditions may cause water quality issues	Although dissolved oxygen does not directly impact recreational uses, low oxygen conditions may be associated with the growth of nuisance organisms and other aesthetically objectionable water quality characteristics (e.g., odour).
Temperature	Avoid time-temperature combinations that appreciably increase or decrease core body temperature	Tolerance to temperatures can vary therefore no defined temperature range can be set.
Turbidity	<50 nephelometric turbidity units (NTU)	Values below this level should maintain water clarity and ensure aesthetic acceptability.
Clarity	Not significantly decreased compared to background values	Individuals engaged in primary contact activities need to be able to estimate depth and see subsurface hazards. Secchi depth measurements are useful for determining clarity.
Colour	Should not impede visibility	Intense colour can impede visibility in areas used for primary contact activities
Oil and grease	None visible	Should not be detected as an extensive visible film, sheen or discoloration on the surface, or detectable by sight or odour as deposits on shorelines and bottom sediments make water aesthetically unattractive. Low levels of contamination are considered to be of low risk for adverse human health impacts.
Litter	None visible	Floating debris may be aesthetically objectionable, pose a safety hazard, and may settle to form objectionable deposits.

1.2 Chemical parameters

There is insufficient information to support the establishment of guideline values for specific chemical parameters in recreational waters. Risks associated with specific chemical water quality hazards will be dependent on the particular circumstances of the area in question and should be assessed on a case-by-case basis, taking local factors (including any applicable local guidelines or regulations) into account.

A risk management approach is the most effective way of protecting recreational water users from the risk of exposure to chemical contamination at recreational water areas. This approach uses an Environmental Health and Safety Survey to highlight potential chemical water quality hazards and to identify barriers to reduce the risk of chemical contamination (Health Canada, in publication-c). Beach operators or service providers should have a mechanism in place to ensure that risks from potential chemical hazards are identified and adequate action is taken, as necessary. This may include issuing beach notifications.

Although an increased risk of chemical water quality hazards may occur at some locations, the chemical concentrations typically found in most recreational waters are not sufficient to elicit either an acute or chronic illness response. Precautionary measures, such as showering with soap and water following primary contact activities and avoiding ingestion of the water, are recommended to ensure that any risk is minimized. In general, potential risks from exposure to chemicals will be much smaller than the risks from the microbiological hazards potentially present in recreational waters (WHO, 2003).

1.3 Application of the guidelines

Methods for determining physical, aesthetic and chemical characteristics of recreational waters can be found in Standard Methods for the Examination of Water and Wastewater (APHA et al., 2017). Sampling for these parameters is at the discretion of the responsible authority. Sampling may be most useful:

- when conducting the Environment Health and Safety Survey; further information on Environmental Health and Safety Surveys provided in Health Canada (in publication-c);
- at the start of, and at regular intervals during, the swimming season;
- after a wet weather (heavy rainfall) event;
- when there is evidence (site observations or site specific risk assessments) of impacts on water quality from human sources and activities (e.g., agricultural run-off, industrial discharges, spills); and
- in response to recreational water issues, including health complaints from beach users.

2.0 PHYSICAL CHARACTERISTICS

The physical characteristics of water can have an impact on the safe, enjoyable use of recreational waters. These include the physical properties of the water itself as well as potential hazards in the surrounding area.

2.1 pH

pH is a measure of the acidity or basicity of water. Further information on pH measurement methods can be found in Health Canada (2015). Natural waters usually have pH values in the range of 4.0 to 9.0; however, most are slightly basic (e.g., greater than a pH of 7.0 at 25°C) because of the presence of bicarbonates and carbonates of the alkali and alkaline earth metals (Health Canada, 2015).

pH can affect the solubility of some contaminants, such as heavy metals, causing them to leach from rocks or sediments into the water column. Therefore, the impacts of pH should be considered when identifying chemical hazards for a recreational area. Information on risk management for chemical contaminants is available in section 4.2. pH may also directly impact human health. When the pH of recreational waters is either very high or very low, it can contribute to skin and eye irritation.

Irritation of the skin appears to be linked to high pH, potentially through the exacerbation of existing irritation or dermatitis conditions in sensitive subjects (WHO, 2003). Extreme pH values (above 11.0 and below 4.0) have also been shown to enhance skin irritation effects of certain solutions (e.g., using strong detergents, hand cleaners, sodium hydroxide solutions) (Health Canada, 2015).

Exposure to extreme pH values can also result in irritation of the eyes. Depending on the pH, eyes may be protected from irritation by tears. Tears have the capability to rapidly neutralize an unbuffered solution from a pH as low as 3.5 or as high as 10.5 (Mood, 1968). However, unbuffered waters are not found in nature under normal conditions, and Mood (1968) suggested that the pH range for water with low buffering capacity should be between 5.0 and 9.0. A study conducted using water from two inland lakes in Ontario, Clearwater Lake (pH approximately 4.5) and Red Chalk Lake (pH approximately 6.5), found no significant differences in the effects on eyes after exposure to the waters of different pH values. The authors concluded that the exposure of healthy eyes to lake water having a pH as low as 4.5 is not harmful to the external ocular tissues (Basu et al., 1984).

Although the evidence for adverse effects on the eyes is not detailed enough to conclude a safe pH range, adverse effects in healthy individuals tend to occur outside the range of pH 5.0 to 11.0 (Health Canada, 2015). Some individuals may be more sensitive to pH and be susceptible to irritation within this pH range.

2.2 Dissolved oxygen

Dissolved oxygen is a measure of the oxygen concentration in a water body and detection methods are available (APHA, 2017). Although the dissolved oxygen level of a waterbody does not directly impact recreational users, it can be associated with other aesthetic water quality problems. Low oxygen concentrations allow the growth of nuisance organisms that can result in taste and odour problems, such as the formation of undesirable amounts of hydrogen sulfide (WHO, 2003; NHMRC, 2008).

Dissolved oxygen concentrations can also help assess the extent of eutrophication. Eutrophic conditions may increase the potential for cyanobacteria overgrowth, leading to large daily fluctuations in the dissolved oxygen levels. The senescence and decay of cyanobacteria can also result in low dissolved oxygen content of waters. These low or fluctuating dissolved oxygen conditions can cause stress to aquatic life, potentially impacting recreational activities such as fishing. The overgrowth of cyanobacteria can also have potential health and aesthetic implications (Health Canada, in publication-a). It has been suggested that dissolved oxygen concentrations greater than 80% saturation would not support the overgrowth of nuisance microorganisms and would help prevent associated problems (NHMRC, 2008).

2.3 Water temperature

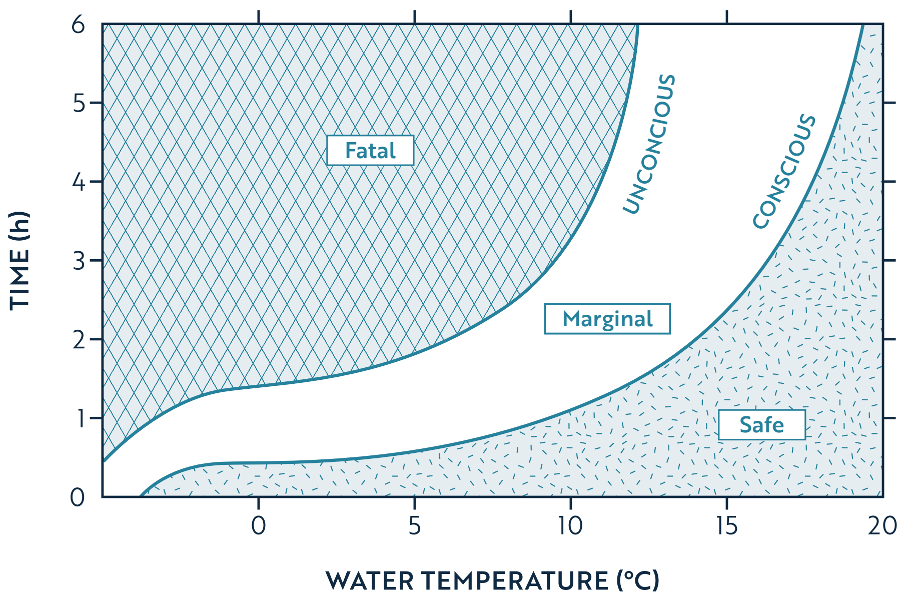
Precise guideline values for the temperature of waters to be used for primary and secondary contact activities cannot be established. Tolerance to water temperatures can vary considerably from individual to individual. Users should not engage in recreational activities at temperature-time combinations sufficient to cause an appreciable increase or decrease in their core body temperature.

2.3.1 Cold water exposures

In contrast to air, water is very efficient at conducting heat away from the body. In water, the surface area of the body available for heat exchange reaches close to 100% (Transport Canada, 2003). Water has 25 times the thermal conductivity of air and cools the body 4 to 5 times faster than air of the same temperature (Tipton and Golden, 2006).

The definition of cold water must be considered with respect to normal body temperature, duration of exposure and degree of protection by insulation (Canadian Red Cross, 2006). When heat loss exceeds heat production, the temperature of the body will drop below the normal value of 37 °C (Tipton and Golden, 2006). Even at comfortable temperature levels, water can result in the transfer of heat away from the body. Thermal neutrality in water is reported to occur at 35 °C. In Canada, the majority of recreational waters will always be below 35 °C. Below the thermal neutrality value, the human body is expected to lose more heat than it is capable of producing, and prolonged exposure can result in fatalities. Sudden, unprotected immersion in cold water of ≤ 15 °C is considered to be potentially life-threatening (WHO, 2003; Canadian Red Cross, 2006).

Figure 1. **Relationship between water temperature and survival time in cold water (adapted from the Royal Life Saving Society of Canada, 1976).**



Experts have identified four sequential stages that can occur following immersion in cold water: (1) gasping and cold shock, (2) swimming failure, (3) hypothermia and (4) post-rescue collapse (Transport Canada, 2003; Canadian Red Cross, 2006). It is believed that most deaths in cold water occur from drowning by submersion of the airways during the first two stages of cold water immersion (Canadian Red Cross, 2006). A flotation device needs to be worn or accessible in order for individuals to survive long enough to become hypothermic (Xu and Giesbrecht, 2018).

The rate of body cooling and the incidence of survival in cold water can vary considerably from individual to individual. This variability can be related to age, sex, body size, ratio of body mass to surface area, percentage body fat and overall physical fitness. The ratio of body mass to surface area is greater in large, heavy individuals, and their body temperatures change more slowly than those of small children (Kreider, 1964). Other factors that can influence cooling include the degree of protective clothing and physical behaviour and body posture in the water (Xu and Giesbrecht, 2018; Canadian Red Cross, 2021b). Due to the number of factors that affect survival during cold water immersion, determining specific time/temperature combinations that are safe is not possible. Figure 1 shows general time/temperature combinations for risk of hypothermia. Mathematical modelling has also been used for predicting survival times (Tikuisis, 1995; Tarlochan and Ramesh, 2005; Xu et a., 2011). The use of recreational drugs or alcohol can also exacerbate the effects of cold water immersion by impairing alertness and motor skill use and by interfering with the body's temperature regulation mechanisms (Canadian Red Cross, 2006; Canadian Red Cross, 2021b).

Immersion in cold water (< 15 °C) may occur through intentional or unintentional activities. Persons using recreational waters should remain aware of the risks involved and take appropriate precautions. One very rare complication of contact with cold water is cold urticaria. This is an allergy-like reaction that can result in itchy, red, and swollen skin. It can also cause fainting, very low blood pressure and shock-like symptoms (Bentley, 1993). To prevent this condition from occurring, susceptible individuals should not swim in cold water unless habituated to it or wearing protective garments suitable to the water temperature. When engaging in activities with a risk of immersion, proper safety equipment should also be used (e.g., proper personal flotation device) (WHO, 2003). Lastly, users should take precautions to avoid ingesting water, regardless of water temperature, to minimize the risk of gastrointestinal illness.

The Canadian Red Cross (2021b) and Transport Canada (2003) have published information on survival in cold waters. Proper protective garments such as a wetsuit or survival suit should be worn during recreational water activities where cold water exposure is anticipated. Similarly, precautions should be taken against accidental immersions, including use of safety lines and wearing of proper personal flotation devices.

2.3.2 Warm water exposures

By comparison to the effects of cold water exposure, relatively little information is available regarding the physiological effects of human exposure to warm waters. Early work on this topic suggested that, physiologically, neither adults nor children would experience thermal stress under modest metabolic heat production, as long as the water temperature was lower than the normal skin temperature of 33 °C (Newburgh, 1949). Water ranging in temperature from 20 °C to 30 °C is considered comfortable for most swimmers (WHO, 2003, 2006). Warm waters can support the growth of microorganisms such as Naegleria fowleri, although no cases of infection with N. fowleri have been identified in Canada. Further information on this organism and other potential pathogens of concern can be found in *Guidelines for Canadian Recreational Water Quality – Microbiological pathogens and biological hazards* (Health Canada, in publication-b).

In Canada, under most circumstances, ambient temperatures observed during the summer months do not reach levels sufficient to raise recreational water temperatures above normal human body temperature. Natural hot springs—thermal springs that can reach temperatures in excess of 37 °C—are a notable exception. Individuals using these types of facilities should monitor their exposures carefully so as to avoid overheating. Symptoms of overheating may include headache, nausea, dizziness or weakness, and a change in heart rate (increase or decrease). For the majority of recreational water areas, the heat effects observed during summertime water activities are largely attributed to sun exposure (see Section 2.4).

2.4 Ultraviolet radiation and heat exposure

Exposure to ultraviolet radiation (UVR) from the sun and exposure to high temperatures are both common occurrences during recreational activities. Overexposure to UVR may result in acute and chronic damage to the skin, eyes, and immune system. The most noticeable acute effect of excessive UVR exposure is erythema, commonly referred to as sunburn. Chronic overexposure to UVR can cause skin cancers and cataracts (WHO, 2003; Institute of Medicine, 2011). There are, however, some beneficial effects to UVR exposure. For instance, vitamin D production in the skin is stimulated by UVR, although the amount of vitamin D synthesized depends on the season, time of day, cloud cover, smog, skin pigmentation, age, and sunscreen use (Institute of Medicine, 2011). Heat exposure can result in heat illnesses (e.g., heat exhaustion, heat stroke, heat cramps), particularly following vigorous exercise in warm environments. Signs of heat illness can include excessive sweating, elevated temperature or pulse rate, headache, dizziness and weakness.

There are many simple protective measures that should be taken to avoid overexposure to UVR and to avoid heat exposure related illnesses during recreational water activities (WHO, 2003; Canadian Red Cross, 2020). They include:

- minimizing the amount of time spent in the sun (particularly without protective measures in place);
- minimizing or avoiding spending time in the midday sun when UVR and air temperatures are at their highest;
- checking the local UV index report to assess the daily exposure limit;
- seeking shade when possible;
- wearing loose-fitting and tightly woven clothing, a broad-brimmed hat and wrap-around sunglasses;
- ensuring an adequate supply of cool fluids to drink (but avoiding caffeine and alcohol); and
- applying a broad-spectrum sunscreen liberally on all areas of the body not covered by clothing 20 to 30 minutes before sun exposure and reapplying after swimming and often throughout the day.

2.5 Other hazards

It is not possible to include a list of all physical hazards that can occur in a recreational area. Some of the more common hazards that can present a risk to the health and safety of recreational water users include litter (e.g. bottles, broken glass, cans), logs, rocks, shells (e.g., zebra mussels) and other debris, both in the water or in the surrounding area. These hazards can present a risk of cuts, lesions, and punctures (Bartram and Rees, 2000). It is important that beach managers check for these hazards ahead of season opening, after rain or flooding events, and routinely throughout the beach season. While such injuries are generally minor, they can become infected if exposed to contaminated waters or beach sands. A study by Moran and Webber (2014) revealed that lacerations and abrasions on the feet and lower limbs from land-based activities or swimming are the most common injuries among children at the beach. Physical hazards should be removed when possible to minimize exposure. For some hazards, such as zebra mussels, signage informing the public of the importance of wearing personal protective equipment (e.g., water shoes) is also suggested. WHO (2003) suggests that the provision of litter bins, regular beach cleanings, regulations prohibiting glass containers, and general public awareness regarding litter control and safe behaviours (e.g., proper beach footwear, first aid availability) are appropriate measures to reduce the risk of injury from these physical hazards.

Strong water currents, rough waves, or highly variable tidal ranges are other physical characteristics that increase the risk of injury and drowning among recreational water users, particularly inexperienced swimmers or young children (Nathanson et al., 2007; American Red Cross, 2009; Canadian Red Cross Society, 2020). Every year in Canada, drownings are associated with hazardous surf or rip currents (Vlodarchyk et al., 2019). Increased awareness of these risks, through forecasting hazardous conditions (where necessary) or general education campaigns, is recommended. Educational materials and information about other strategies to minimize the risks associated with recreating in natural waters is available (Canadian Red Cross, 2021a). Recreational waters can also be rated according to their risk characteristics, and warnings and notices (e.g., “family friendly”, “suitable for beginners”, “strong currents”) should be posted to provide objective, easily understandable information to the public and to advise recreational water users to proceed with care (WHO, 2003). In some areas, water depth can also be considered a hazard. Shallow waters can present a hazard in locations where recreational users are apt to try diving, or conversely, deep waters close to the shoreline may make it unsafe for small children to play.

3.0 AESTHETIC CHARACTERISTICS

Good aesthetic quality is an important consideration in ensuring the maximum use and enjoyment of recreational waters and beaches. Recreational areas should be free of substances (whether attributable to human activities or to natural processes) that impair their aesthetic appreciation. These can include:

- substances producing objectionable colour, odour, taste or turbidity;
- floating debris, oil, scum and other matter;
- materials that will settle to form objectionable deposits; and
- substances and conditions that produce undesirable aquatic life (e.g., nutrient enrichment by nitrogen and phosphorous promoting algal blooms).

This section discusses parameters that may affect the aesthetic quality of a recreational water area. Some of these parameters may also have implications for human health and safety. For example, waters in which the visibility has become significantly impaired can present a safety risk for recreational water users. Other aesthetic issues can also impact user enjoyment, such as excess noise (e.g., motorized water craft, loud music), but these will not be discussed in this document.

Aesthetic objectives for turbidity, clarity and colour have been suggested; however, it is recognized that the natural levels of these parameters in Canadian waters can vary considerably. Thus, it is recommended that, when evaluating these parameters as part of an Environmental Health and Safety Survey, the site-specific natural background levels are taken into consideration.

3.1 Turbidity

Turbidity is a measure of the relative clarity or cloudiness of water. It is not a direct measure of suspended particles, but rather a general measure of the scattering and absorbing effect that suspended particles have on light. As the intensity of the light scattering increases, the turbidity increases. The current method of choice for turbidity measurements in Canada is the nephelometric method, and the unit of turbidity measured using this method is the nephelometric turbidity unit, or NTU (Health Canada, 2012). A standard method for turbidity analysis is available (APHA et al., 2017).

Turbidity in water is caused by suspended matter (including colloids), such as clay, silt, finely divided organic and inorganic matter, plankton and other microscopic organisms. When monitoring for turbidity, samples should be collected in a manner that avoids disturbing surrounding sediments. Turbidity is important for aesthetic, safety and health reasons. Turbidity measurements may also be used during the development of predictive water quality models. Further information on predictive modelling at recreational beaches is found in Health Canada (in publication-c).

High turbidity is aesthetically displeasing and can be a safety concern when it reduces visibility through the water. Because filtration equipment and modern water treatment processes are not feasible at natural swimming areas, safety concerns associated with turbid or unclear water are dependent upon the intrinsic quality of the water itself. Lifeguards and other persons near the water must be able to see and distinguish people in distress. In addition, swimmers should be able to see well while under water.

Health considerations associated with turbidity are related primarily to the ability of particles to adsorb microorganisms and chemical contaminants. This can have a number of important effects on water quality:

» Suspended particles can provide a measure of protection for microorganisms (bacteria, viruses, protozoa) that have been adsorbed to their surface by shielding them from the effects of environmental stresses such as UV radiation and predation by higher microorganisms;
» The presence of turbidity may interfere with the quantification of fecal indicator organisms. This could lead to an underestimation of indicator organisms using culture methods or could inhibit their detection using molecular methods, leading to improper decisions about the level of risk associated with the recreational area; and
» Particulate matter may also contain chemical contaminants such as heavy metals, phosphorus (which can support cyanobacteria growth) and biocides (Health Canada, 2012).

Surface water turbidity levels can vary from 1 NTU to more than 1000 NTU (Health Canada, 2012), and can be impacted by events such as surface runoff, sewer overflows, gross pollution, and development of cyanobacteria blooms. For example, runoff water quality measurements showed levels of 4.8 to 130 NTU during the first hour of an urban rainfall occurrence (U.S. EPA, 1978). In the quiescent zone of a swimming beach or other recreational water area, it is suggested that turbidity measurements around 50 NTU or less would safely allow most recreational uses, including swimming.

3.2 Clarity (light penetration)

Clarity is associated with the distance light can penetrate into a body of water and is often interpreted as "how far one can see into the water." In deeper waters, clarity is measured using a Secchi disc, a device used to determine the limit of visibility in water. A Secchi disk is a circular metal plate, about 20 cm in diameter. The upper surface of the Secchi disk is divided into four quadrants painted alternately black and white. It is lowered into the water by means of a graduated line, until it just disappears out of sight. Its point of disappearance indicates the limit of visibility, and this depth is recorded. It is then slowly raised until it reappears, and that depth is also recorded. The average of the two depths is taken as the Secchi disc transparency.

The principal factors affecting the depth of light penetration in natural waters include suspended microscopic and macroscopic organisms, suspended sediment particles, substances that impart a colour, detergent foams, dense mats of floating and suspended debris, or a combination of these factors.

It is important that water at swimming areas be clear enough for users to estimate depth, to see subsurface objects easily and to detect submerged swimmers or divers who may be in distress. Aside from the safety factor, clear water fosters enjoyment of the aquatic environment. In general, the greater the water clarity, the better the perception of the site for swimmability, recreational value and aesthetic appeal (Angradi et al., 2018).

For primary contact recreation waters, the clarity of the water should not be significantly decreased in comparison to the natural background values (i.e., the clarity naturally present for that waterbody). It has been suggested that clarity be such that a Secchi disc is visible at a minimum depth of 1.2 m (Environment Canada, 1972). However, this will not be applicable in all waters. In "learn to swim" areas, the clarity should be such that a Secchi disc on the bottom is visible. In diving areas, the clarity should equal the minimum required by safety standards. This depth will depend on the height of the diving surface (National Technical Advisory Committee, 1968). Secchi depth measurements can also be used as part of a monitoring strategy for cyanobacteria blooms (see Health Canada, in publication-a).

3.3 Colour

The observed colour of water is the result of light backscattered upward from a water body after it has passed through the water to various depths and undergone selective absorption (CCME, 1999). There are two measures of colour in water: true and apparent. The term colour is most often used to mean true colour, or the colour of water from which turbidity has been removed. To measure true colour, the water has to be filtered or centrifuged to remove the sources of apparent colour. The standard method for measuring colour is the platinum-cobalt (Pt-Co) method (APHA et al., 2017). Colour is measured by visual comparison of water samples with coloured solutions of known concentrations. The units for true colour are colour units (CU), with one colour unit being equivalent to 1 Pt-Co unit (APHA et al., 2017). True colour can range from less than 5 CU in very clear waters to 1200 CU in dark peaty waters (Kullberg, 1992). Natural minerals give true colour to water; for example, calcium carbonate in limestone regions gives a greenish colour, whereas ferric hydroxide gives a red colour. Organic substances, tannin, lignin and humic acids from decaying vegetation also give true colour to water (Reid and Wood, 1976).

Apparent colour includes colour due not only to substances in solution but also to suspended matter (APHA et al., 2017). Measurements for apparent colour are determined on the original sample without filtration or centrifugation (APHA et al., 2017). Similar to turbidity, when monitoring for apparent colour, samples should be collected in a manner that avoids disturbing surrounding sediments. Apparent colour is usually the result of the presence of coloured particulates, the interplay of light on suspended particles and such factors as bottom or sky reflection. An abundance of cyanobacteria can impart a dark greenish hue to water, whereas diatoms or dinoflagellates can give a yellowish or yellow-brown colour. Some algae and, rarely, zooplankton, particularly microcrustaceans, may tint the water red. Polluted waters may have strong apparent colour. Industrial discharges (particularly those from the pulp and paper and textile industries) can be highly coloured and thus may affect water coloration. Factors that increase the turbidity of natural waters may similarly affect apparent colour.

Colour in lakes may not be uniform from surface to bottom; also, the colour may change periodically. Increases in surface runoff contribute large quantities of inorganic and organic substances. Summer or early autumn production of phytoplankton/cyanobacterial blooms can cause discoloration in lakes (e.g., green, green/blue, tan, red/wine), which disappears later in the season (further information on cyanobacterial blooms can be found in *Guidelines for Canadian Recreational Water Quality: Guideline Technical Document – Cyanobacteria and their Toxins* (Health Canada, in publication-a)). Exposure to light causes bleaching of certain colours in natural waters, and this effect will vary according to transparency. Colour may also be dependent on factors that affect the solubility and stability of the dissolved and particulate fractions of water, such as temperature and pH.

The causes of colour in marine waters are not thoroughly understood, but dissolved substances are one of the contributory factors. The blue of the sea is a result of the scattering of light by water molecules, as in inland waters. Suspended detritus and living organisms impart colours ranging from brown through red and green. Estuarine waters are not as brilliantly coloured as the open sea; the darker colours result from the high turbidity usually found in such situations (Reid and Wood, 1976).

The main effects of water colour on recreational activities are aesthetic and safety related. Very dark water restricts visibility both for swimmers and for people concerned with their safety (e.g., lifeguards). Therefore, in recreational areas, colour should not be so intense as to impede visibility in areas used for swimming. It is also desirable that the natural colour of the water not be altered by any human activities.

3.4 Oil and grease

Standard Methods for the Examination of Water and Wastewater (APHA et al., 2017) defines “oil and grease” as “any material recovered as a substance soluble in the solvent.” The category of oil and grease includes many different substances of mineral, animal, vegetable or synthetic origin—all of which can have vastly different physical, chemical and toxicological properties. Consequently, it is very difficult to establish a numerical guideline value for oil and grease.

Contamination of recreational waters with oily substances may be of natural origin or the result of human activity. Some oils are of natural origin, such as seepage from natural underwater oil deposits or from the decomposition of some materials. In addition, natural biological populations release lipid compounds that can form natural slicks.

Human-made contamination is of greatest concern. It can come from a number of sources. These may include the discharge of industrial wastes, road runoff, residual hydrocarbon deposits from motorboat engine exhaust emissions, the discharge of fuel tank contents of ships (either accidentally or deliberately), oil drilling activities, and shipwrecks. Marinas and boat launches can also be important sources of oil and grease contamination for recreational waters. The risk management information for chemicals (section 4.2) may be applicable for managing some oil and grease contamination issues.

Very small quantities of oily substances make water aesthetically unattractive. Oils can form films, and some volatile components can create odours or impart a taste to water (WHO, 2003). Oil and grease can foul equipment and shorelines and come in contact with the skin of individuals involved in primary contact activities. Larger spills of oily substances may require the issuance of a beach advisory or beach closure. Recreational users might still use waters with low levels of oily substances as the risk of toxicity from exposure to oily substances through incidental ingestion, skin absorption or inhalation of vapours during recreational water activity is regarded to be low. Oils and greases of animal or vegetable origin are generally considered to be non-toxic to humans. Similarly, it is recognized that petroleum compounds become organoleptically objectionable (i.e., unacceptable taste, odor, or feel) at concentrations below the levels required for chronic human toxicity (Health Canada, 2014). Thus, the consumption of oil-polluted recreational water is unlikely to be a significant source of exposure for humans.

3.5 Litter

Various types of litter can be found in recreational waters or deposited on beaches. Some examples are discarded food and food packaging, cardboard and paper products, plastic containers, polystyrene foams, rubber goods, aluminum cans, broken glass, discarded clothing, diapers, cigarette butts, medical wastes and dead animals. Such 'urban' detritus may be associated with storm-water inputs that can contain sewage-borne pathogens. Large accumulations of seaweed/algae (e.g., beach wrack) or visible amounts of animal/bird feces on beaches are not technically litter, but they are likely to pose aesthetic problems (both visually and due to potential odour). Further information on seaweed and algae can be found in *Guidelines for Canadian Recreational Water Quality – Microbiological pathogens and biological hazards* (Health Canada, in publication-b).

In addition to being aesthetically undesirable, the presence of litter can also present a health and safety risk to recreational water users. Some materials can be hazardous to recreational water users who come in direct contact with them (e.g., broken glass). Others, such as beach wrack and animal/bird feces can impact beach water quality. Animal/bird feces may also pose a direct health risk to beach users as they can contain human pathogens. Litter also has the potential to attract wildlife, which can contribute to fecal contamination of recreational waters. Indeed, litter counts have been considered a possible indicator of the potential of acquiring gastrointestinal illness through recreational water activities. In particular, the occurrence of floatables (tampon applicators, condoms, syringes) associated with untreated sewage can be an indicator of previous sewage contamination problems. Flying and/or biting insects may also be associated with litter. They are considered at the very least a nuisance and could potentially pose a health threat in the form of zoonotic disease (NHMRC, 2008).

4.0 CHEMICAL CONTAMINANTS

Chemical contaminants in recreational waters may be organic or inorganic in nature. They can enter recreational waters directly or be deposited on beaches from both natural and anthropogenic sources (WHO, 2003). These include point sources, such as industrial outfalls or natural springs, and non-point (diffuse) sources, such as runoff from urban or agricultural areas.

4.1 Sources and exposure

There are many sources of contamination by organic and inorganic chemicals, including those from industrial manufacturing and industrial wastes, and domestic use of such items as paints, fuels, dyes, glues, pesticides and cleaning supplies (NAQUADAT, 1988; Health Canada, 1997). Sewage-contaminated waters are also more likely to contain mixtures of diverse chemical contaminants, such as pharmaceuticals and personal care products (Helm et al., 2012; Blair et al., 2013; Edge et al., 2020). Microplastics have also been detected in fresh water environments (WHO, 2019).

National surveys of the water quality of lakes and rivers used for recreational activities indicate that the concentrations of inorganic chemicals and most organic chemicals are lower than the recommended drinking water or environmental quality guidelines (NAQUADAT, 1988; Government of Canada, 1991; Marvin et al., 2004). A more recent survey of 173 river sampling sites across the country reported water quality to be fair to excellent in 82% of the monitoring sites. Land development (e.g., urban development, agriculture, mining, forestry) tended to have a negative impact on water quality (Environment and Climate Change Canada, 2021). Studies in the Great Lakes basin reported concentrations of many of the chemicals investigated to be below the Canadian Environmental Quality Guidelines (MECP, 2016).

Ingestion is considered the primary route of exposure for most organic and inorganic chemical contaminants. Skin absorption can also be a route of uptake for certain heavy metals and for some organic chemicals (Brown et al., 1984; Moody and Chu, 1995). However, it is generally concluded that given the low concentration of organic and inorganic contaminants encountered in most natural waters and the typical exposure scenarios encountered during recreational water activities, it is not likely that dermal or ingestion exposure presents a significant risk (Moody and Chu, 1995; Hussain et al., 1998; Cunningham et al., 2010; WHO, 2021). Nonetheless, precautionary measures such as showering with soap and water following primary contact activities and always avoiding ingestion of the water will further ensure that any risk is minimized.

4.2 Risk management for chemicals

The risk from human exposure to chemical contaminants in Canadian waters through recreational activities is considered low. Nevertheless, scenarios do exist that may contribute to an increased risk of a chemical water quality hazard at a particular recreational water body (e.g., spills, uncontrolled industrial discharges) and some waters may be permanently unsuitable for primary contact recreation (e.g., quarries and abandoned mine pits) (WHO, 2021). As a result, it is important for beach operators and service providers to have a mechanism in place to ensure that potential chemical hazards, and their risks, are recognized. An Environmental Health and Safety Survey is an important tool for helping recreational water area operators identify and assess potential sources of chemical contamination that are relevant to their beach area. Source tracking methods and predictive modelling approaches are also available. Further information on these topics can be found in Health Canada (in preparation –c).

Risks associated with specific chemical water quality hazards will depend on the particular circumstances of the recreational areas under consideration, both existing and new. The risk of human exposure to chemical contaminants in recreational waters must therefore always be assessed on a case-by-case basis, taking local factors (including any applicable local guidelines or regulations) into account. All appropriate agencies (e.g. health and environment departments, authorities responsible for drinking water) should be included in any follow-up discussions that are necessary.

In general, the key elements to include in an approach to assessing chemical water quality hazards in new and existing recreational waters are as follows:

- historical understanding of the area to identify past activities that may result in contaminated water and/or sediments;
- inspection of the recreational water area to identify any obvious sources of chemical contamination, including both point (e.g., outfalls, sewage discharges) and non-point sources (overland flow from contaminated areas);
- additional actions as necessary to support a quantitative health risk assessment, including chemical analysis of representative water and sediment samples (using methods deemed acceptable by the regulating agencies), review of the available toxicological information on the chemical contaminant(s) in question including a review of any available guideline or screening values;
- consideration of the pattern and type of recreational activity to determine whether significant pathways of human exposure exist (e.g., through ingestion, inhalation or skin absorption); and
- consideration of the effects of the water body dimensions (area, depth) and other hydrodynamic and meteorological characteristics (tides, currents, prevailing winds) on the impact of the chemical water quality hazard in question.

A risk management approach is the most effective way of protecting recreational water users from the risk of exposure to chemical contamination at recreational water areas. This approach uses an Environmental Health and Safety Survey to highlight potential chemical water quality hazards and to identify barriers that may be implemented to reduce the risk of chemical contamination and to restrict primary contact exposures during periods or in areas perceived to be of increased risk.

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