4. Nuisance Organisms

Maximum Limits

The bathing area should be as free as possible from nuisance organisms that could affect swimmers. Nuisance is defined as something that can cause harm or is annoying, unpleasant, or obnoxious (Webster's Third New International Dictionary 1986).

It is impossible to have natural areas "free" from nuisance organisms, so no limits can be quantified. Only the possible hazards caused by such organisms and the environmental situations that could promote their presence are discussed.

Recreational areas should not be developed if there is an excessive growth of aquatic plants where entanglement could occur, thus causing a hazard to water-related recreational activities, unless control measures are taken to remove the plants from areas used for swimming.

Criteria

Description

Two principal types of biological factors influence the recreational value of surface waters: those that endanger the health or physical comfort of people and animals, and those that render water aesthetically objectionable or unusable as a result of excessive nutrient enrichment or the presence of unsightly substances. The former include vector and nuisance organisms; the latter include aquatic growth of microscopic and macroscopic plants.

Vector organisms

Massive emergences of non-biting midges, phantom midges, caddisflies, mayflies, etc. cause serious nuisances in shoreline communities and impede recreational pursuits (National Academy of Sciences 1973). In addition to the physical annoyance of their presence, biting insects such as mosquitoes and black-flies can inflict serious irritation from their biting attacks.

Human respiratory allergic reactions such as hay fever have been reported to be due to inhalation of caddisflies, mayflies, and midges, or their parts, when large insect swarms are present (Henson 1966).

Abrupt changes in water quality, especially if accompanied by organic loading, may precipitate high midge production. A sudden decline in oxygen supply in organically enriched bodies of water can disrupt established faunal communities and favour the less sensitive species of midge larvae and other

tolerant organisms that can withstand low dissolved oxygen. Part of this change is caused by the increase in food from organic waste. Upon emergence as adults, these midges can cause a nuisance with their dense swarms.

In the marine situation, nuisance or hazardous conditions can exist at bathing beaches because of the presence of organisms such as jellyfish and some species of sea urchins.

Aquatic vascular plants and algae

Aquatic vascular plants (macrophytes) affect water quality, other aquatic organisms, and the uses that are made of the water. It is difficult to estimate the magnitude of the adverse effects of aquatic macrophytes in terms of loss of recreational opportunities or the degree of interference with recreational pursuits. For example, extensive growths of aquatic macrophytes interfere with boating of all kinds, but the extent of interference depends, among other things, on the growth form of the plants, their density, the fraction of the water body affected, and the purposes, attitudes, and tolerance of the boaters.

Dense growths of aquatic macrophytes are generally objectionable to the swimmer, diver, water-skier, and scuba enthusiast. Plants obstruct the view of the bottom and underwater hazards, and swimmers can become entangled in the fronds. Water-skiers' preparations in shallow water are hampered by dense growths of plants, and fear of falling into such growths while skiing detracts from enjoyment of the sport.

Recreational activities such as boating and fishing are less appealing and may even be almost impossible if aquatic plants are very dense. Rafts of free-floating plants or attached plants that have been dislodged from the substrate often drift onto beaches or into swimming areas. Drying and decaying aquatic plants often produce objectionable odours and provide breeding areas for a variety of insects.

Increased plant growth can be caused by the presence of excess nutrients, for example, from various agricultural practices and private waste inputs that increase the amount of phosphorus and nitrogen. The results of this increase in nutrients is called cultural eutrophication. The natural aging (eutrophication) of bodies of water occurs much more slowly and does not change on a time scale to be of significant interest in the context of this document. Increased silt loads, changes in shorelines, and land use all contribute to alterations in aquatic habitats.

Some odours from lake water originate from natural decomposition of algae and other aquatic plant materials. These kinds of odours are typically vegetable or "earthy" in nature; however, decomposing masses of the filamentous alga ***Cladophora*** in Lake Erie and Lake Ontario have been described as "pigpen" (Neil 1975).

Several species of algae produce very different, sometimes offensive odours while actively growing in lake water. Odours described as fishy, grassy, aromatic, or musty have been attributed to several species of diatoms, blue-green algae, and Chrysophyceae (Palmer 1962; Taft 1965). Nicholls *et al*. (1980) reported serious odour production by the prymnesiophyte ***Chrysochromulina breviturrita*** in recreational lakes in Ontario and New Hampshire. The odour produced by this species, described by cottagers as "rotten-cabbage" or "garbage-dump," seems to be restricted to slightly acidic lakes. ***Chara***, a rooted macroscopic alga often mistaken for an aquatic vascular plant, has a very strong, objectionable odour. It is commonly found growing in extensive mats on lake bottoms (Warrington 1989).

Odours from lake water can be measured by the Threshold Odour Test (American Public Health Association 1989). The Threshold Odour Number (TON) is the ratio by which the sample must be diluted with odour-free water so that the odour is just detectable by a test panel of several people. Many natural surface waters not influenced by odour-producing algae have a TON of 5, whereas others with excessive algal growth may have a TON value exceeding 200.

Summary

1. Some biota that could be a nuisance to bathers if present in large numbers – e.g., leeches, mussels, biting insects, floating or rooted aquatic plants, phytoplankton, periphyton, and growths such as sewage fungus – should be absent from areas intended for development as bathing beaches.

2. The presence of large numbers of midges and aquatic worms, which can tolerate polluted, especially organically enriched, conditions (e.g., as caused by sewage), would indicate that the water quality was probably not good enough for recreational use.

5. Physical and Chemical Characteristics

Methods for determining physical and chemical characteristics of recreational water can be found in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1989) and the **Analytical Methods Manual** (Environment Canada 1981).

5.1 pH

Maximum Limits

Both alkaline and acidic waters may cause eye irritation; consequently, the pH of the waters used for total body contact recreation should be in the pH range of 6.5 to 8.5. If the water has a very low buffering capacity, pH values from 5.0 to 9.0 should be acceptable.

Criteria

Mood (1968) concluded that exposure to water is foreign to the eye and may, under certain circumstances, be very irritating. He assumed that the ideal, non-irritating solution would have the same physico-chemical properties as tears, including a pH of 7.4, although there is some evidence to suggest that ophthalmologic solutions slightly more alkaline are actually preferred (Raber and Breslin 1978).

Mood (1968) reported that tears have the capacity to rapidly neutralize an unbuffered solution from a pH as low as 3.5 or as high as 10.5. The neutralizing capacity of the tears would be exceeded by highly buffered waters. However, Mood (1968) concluded that unbuffered waters are not found in nature under normal conditions; hence, he suggested that the pH range for water with low buffering capacity should be between 5.0 and 9.0. Dillon *et al*. (1978) reported that most lakes in south-central Ontario have 10 to 200 μeq/L (microequivalents per litre) of acid-neutralizing capacity (ANC), and many of these lakes have depressed pHs. Detailed maps depicting sensitive areas in some provinces have been prepared by the United States-Canada Research Consultation Group on the Long-Range Transport of Air Pollutants (1979).

Studies completed by Basu *et al*. (1984) used water from two inland lakes in Ontario: Clearwater Lake (pH about 4.5) with an ANC of -40 μeq/L (Yan 1980), and Red Chalk Lake (pH about 6.5) with an ANC of 70 μeq/L. The eyes of both test rabbits and human volunteers were exposed to these waters, and no significant differences were observed in their reactions (Basu *et al*. 1984).

In all cases, 1 eye was exposed to the low-pH water and the other to the higher-pH water. The human eyes were exposed for 5-minute periods, and no unusual signs or symptoms occurred. The rabbit eyes were exposed for periods of 15 minutes and checked for ocular reactions in terms of conjunctival congestion, corneal epithelial staining with fluorescein, epithelial cell and leucocyte content of tears, changes in tear molarity, and the penetration of fluorescein into the anterior chamber. Basu *et al*. (1984) 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.

5.2 Temperature

Maximum Limits

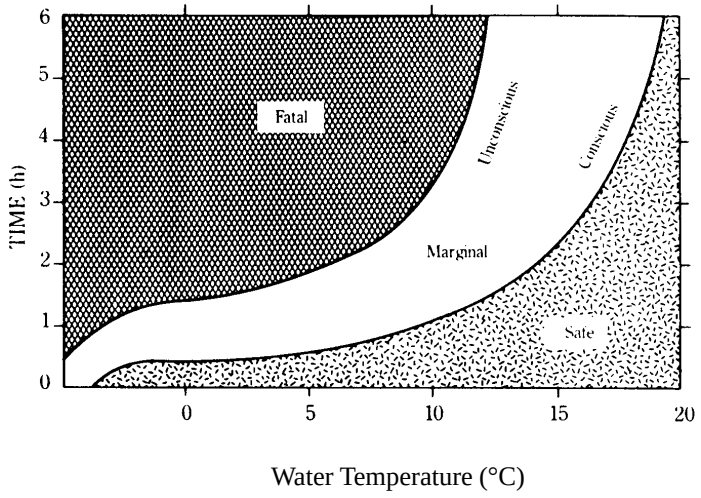
The thermal characteristics of waters used for bathing and swimming should not cause an appreciable increase or decrease in the deep body temperature of bathers and swimmers.

Criteria

The temperature of natural waters is an important factor governing the character and extent of recreational activities, primarily in the summer months. The upper recommended limit of temperature is 30°C. Scientific evidence suggests that prolonged immersion in water warmer than 34 to 35°C is hazardous. The degree of hazard varies with the water temperature, immersion time, and the metabolic rate of the swimmer.

Persons engaging in winter water recreation such as ice skating and fishing do so with the knowledge that whole body immersion must be avoided. Accidental immersion in water at or near freezing temperatures is dangerous, because the median lethal immersion time is less than 30 minutes for children and most adults (Molnar 1946; National Academy of Sciences 1973) (Figure 1).

Figure 1. Relationship between water temperature and survival time in cold water



(Adapted from the Royal Life Saving Society of Canada 1978)

There is considerable variation from one individual to another in the rate of body cooling and the incidence of survival in cold water. The variability is a function of body size, fat content, prior acclimatization, and overall physical fitness. The ratio of body mass to surface area is greater in large, heavy individuals, and their temperatures change more slowly than those of small children (Kreider 1964).

In cold temperatures, the critical problem is to maintain body temperature. In cold water, body heat is lost primarily by conduction from the inner organs through the trunk. Exposure of the limbs plays a relatively minor role in overall heat loss. In several instances where drowning was reported as the cause of death, exposure to cold was probably the responsible factor (Keatinge 1969).

Contrary to earlier opinion, exercise in the water increases the loss of body heat and correspondingly decreases survival time. This is reflected in frequent reports of drownings of expert swimmers who tried to reach shore after a sinking, whereas those who remained in the water near the lost ship survived until rescued. A careful study of reported drowning cases carried out by Press (1969) seemed to bear out much of the above as regards survival in cold waters. He reported that 299 out of 874 drownings, or 34 per cent, occurred in waters that were listed as very cold (assumed to be below 20°C). In addition, a much higher percentage of those succumbing in cold water were considered to be good swimmers.

The safe upper limit of water temperature for recreational immersion varies from individual to individual and seems to depend on psychological rather than physiological considerations. Unlike cold water, the mass to surface area ratio in warm water favours the child. Physiologically, neither adult nor child 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). The rate at which heat is conducted from the immersed human body is so rapid that thermal balance for a body at rest in water can be attained only if the water temperature is about 34°C (Beckman 1963). The survival of an individual submerged in water at a temperature above 34 to 35°C depends on the tolerance to an elevation of the internal temperature, and there is a real risk of injury with prolonged exposure. Water ranging in temperature from 26 to 30°C is comfortable for most swimmers throughout prolonged periods of moderate physical exertion.

5.3 Aesthetics

Webster's Third New International Dictionary (1986) defines aesthetic as "appreciative of, responsive to the beautiful" in nature. Not only should a recreational area be free from objectionable factors, but various aesthetic components of the aquatic ecosystem and surrounding land should be present; for example, trees, other plants, birds, mammals, fish, and insects all play a role in the natural beauty of a recreational area.

All waters should be free from substances attributable to wastewater or other discharges in amounts that would interfere with the existence of life forms of aesthetic value:

- materials that will settle to form objectionable deposits
- floating debris, oil, scum, and other matter
- substances producing objectionable colour, odour, taste, or turbidity
- substances and conditions or combinations thereof in concentrations that produce undesirable aquatic life.

The absence of visible debris, oil, scum, and other matter resulting from human activity is a strict requirement of aesthetic acceptability. Similarly, suggested values for light penetration, colour, and turbidity must be measured as being not significantly increased over natural background.

5.3.1 Turbidity

Maximum Limits

A limit of 50 Nephelometric Turbidity Units (NTU) is suggested.

Criteria

Because filtration equipment and modern water treatment processes are not feasible at natural bathing areas, safety hazards associated with turbid or unclear water are dependent upon the intrinsic quality of the water itself. However, 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 quite well while under water.

The current method of choice for turbidity measurements is the nephelometric method (American Public Health Association 1989). Nephelometric turbidimeters measure the intensity of light scattered at 90 degrees to the path of incident light, and levels can be approximately related to the standard Jackson candle method.

One special component of organic turbidity is microorganisms, which may accumulate in such large amounts that waters become unsightly and turbid. The summer blooms of blue-green algae in recreational surface waters and algal debris are examples of turbidity due to microorganisms (Mackenthun and Keup 1970).

Raw water levels can vary from 1 to 1000 NTU. Runoff water quality measurements indicated levels of 4.8 to 130 NTU during the first hour of an urban rainfall occurrence (U.S. Environmental Protection Agency 1978b). In the quiescent zone of a bathing beach or reservoir impoundment, turbidity measurements in the vicinity of 50 NTU would be sufficient to satisfy most recreational uses, including boating and swimming.

The natural turbidity of some bathing and swimming waters is often so high that visibility through the water is dangerously limited. If such areas conform with all other requirements, they may be used for bathing and swimming, provided that subsurface hazards are removed and the depth of water is clearly indicated by signs that are easily readable (National Academy of Sciences 1973).

5.3.2 Clarity – Light penetration

Maximum Limits

Water should be sufficiently clear that a Secchi disc is visible at a minimum depth of 1.2 m.

Criteria

It is important that water at bathing and swimming areas be clear enough for users to estimate depth, to see subsurface hazards easily, and to detect the submerged bodies of swimmers or divers who may be in difficulty. Aside from the safety factor, clear water fosters enjoyment of the aquatic environment. The clearer the water, the more desirable the swimming area (National Academy of Sciences 1973).

For primary contact recreation waters, 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). In "learn to swim" areas, the clarity should be such that a Secchi disc on the bottom is visible. In diving areas, the clarity shall equal the minimum required safety standards, depending on the height of the diving platform or board (National Technical Advisory Committee 1968).

The Secchi disc is a device used to measure visibility depths in water. The upper surface of a circular metal plate, 20 cm in diameter, is divided into 4 quadrants and painted so that the 2 quadrants directly opposite each other are black and the intervening ones are white. When suspended to various depths of water by means of a graduated line, its point of disappearance indicates the limit of visibility. It is then raised until it reappears, and 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 plants and animals, suspended mineral particles, stains that impart a colour, detergent foams, dense mats of floating and suspended debris, or a combination of these factors.

5.3.3 Colour

Maximum Limits

An objective for the colour of recreational water largely depends on the preferences of users, and it is impossible to put an absolute value on it. Colour should not be so intense as to impede visibility in areas used for swimming. A maximum limit of 100 platinum-cobalt (Pt-Co) units was proposed by Environment Canada (1972), but no supporting evidence was given.

Criteria

There are two measures of colour in water – true and apparent. The true colour of natural water is the colour of water from which turbidity has been removed (i.e., filtered water) (American Public Health Association 1989).

Natural minerals give true colour to water; for example, calcium carbonate in limestone regions gives a greenish colour, ferric hydroxide, red. Organic substances, tannin, lignin, and humic acids from decaying vegetation also give true colour to water (Reid and Wood 1976).

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 (living) blue-green algae imparts a dark greenish hue; diatoms give a yellowish or yellow-brown colour. There are algae that impart a red colour, and, rarely, zooplankton, particularly microcrustaceans, may tint the water red.

To measure true colour, the water has to be filtered or centrifuged to remove the sources of apparent colour. True colour is measured on the platinum-cobalt scale (Pt-Co units) and ranges from very low numbers in clear lakes to over 300 units in the very dark waters of peat bogs (Reid and Wood 1976). Apparent colour is an aesthetic quality and cannot be quantified.

The colour imparted by organic compounds has been discussed by a number of authors. Colloidal material with a diameter of 3.5 to 10 nm accounted for most of the colour in water studies by Black and Christman (1963), and Schindler and Alberts (1974) confirmed this statement. Humic substances are compounds with high molecular weights (ranging from several hundred to tens of thousands) (Schnitzer and Khan 1972) that are resistant to bacterial decomposition (Felbeck 1965; Christman and Ghassimi 1966). The compounds are the result of polymerization and microbial synthesis, which alter plant components such as lignin (Flaig 1964; Felbeck 1971).

Colour in lakes may not be uniform from surface to bottom; also, the colour may change periodically. Increases in surface runoff contribute great quantities of inorganic and organic substances. Summer or early autumn production of phytoplankton blooms causes lakes to become a “soupy green,” which disappears later in the season. Exposure to light causes bleaching of certain colours in natural waters, and this effect will vary according to transparency.

Generally, a rich, highly productive lake may appear yellow, grey-blue, or brown as a result of quantities of organic matter, and less productive lakes tend toward blue or green caused by differential light absorption and scattering of different wavelengths (Ruttner 1963; Reid and Wood 1976).

The colour of stream water is due to the same factors contributing to the colour of lake water, but there is not as much variety as in lakes. The upper reaches of most streams are characterized by clear water, except in the flood season, because of the lack of true plankton. Streams draining swamps are usually coloured by dissolved plant substances such as tannin.

Many industrial effluents and irrigation cause both true and apparent colour in receiving water.

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 give 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 colour of water affects aquatic life, but this subject will not be discussed in this document. The main effects of water colour on recreational activities are aesthetic and safety related. The aesthetic colour of water cannot be quantified, as there are as many preferences as there are people. Very dark water restricts visibility both for swimmers and for people concerned with their safety. In recreational waters, it is desirable that the natural colour of the water is not altered by any anthropogenic activities.

5.3.4 Oil and grease

Maximum Limits

Oil or petrochemicals should not be present in concentrations that:

- can be detected as a visible film, sheen, or discoloration on the surface
- can be detected by odour
- can form deposits on shorelines and bottom sediments that are detectable by sight or odour (International Joint Commission 1977).

Criteria

Contamination of recreational waters with oily substances may have natural origins or may be a result of human activities. Some oils are of natural origin, such as seepage from natural underwater oil deposits or from the decomposition of some materials. Natural biological populations release lipid compounds, which can form natural slicks.

The man-made contamination is of greatest concern. It can come from a number of sources, such as 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, and shipwrecks.

The analytical method for oil and grease (detection limit 1.0 mg/L) gives only a gross idea of the amount present, and individual compounds cannot be identified (Environment Canada 1981).

It is very difficult to establish criteria for oil and grease, as the mixtures falling under this category are very complex. Very small quantities of oily substances make water aesthetically unattractive. The water may have an odour, or it may foul equipment or the bodies of bathers and shorelines, but the possibility exists that recreationists might still use the water in cases of low contamination. The toxicity of oily substances from ingestion, skin absorption, or inhalation of vapours is relatively low except in the case of aromatics (Gage 1924).

5.4 Chemical Characteristics

Some concern has been expressed about a risk to bathers from the presence of chemicals in recreational waters. Very few studies have been found in the literature that equate a hazard to the health of swimmers and others to skin absorption of contaminants present in river or lake water (Brown *et al*. 1984).

5.4.1 Inorganic chemicals

National surveys of the water quality of lakes and rivers used for recreational activities indicate that concentrations of inorganic chemicals are low (National Water Quality Data Bank 1988). Analyses (1983-1988) for heavy metals indicated that they are present in concentrations considerably below those recommended as guidelines for drinking water (Department of National Health and Welfare 1989). Aquatic life is considerably more sensitive to most toxic chemicals than are humans. It is very unlikely that there is a hazard to people engaged in recreational activities in and around rivers and lakes as a result of the presence in water of inorganic chemicals.

5.4.2 Organic chemicals

There are many sources of contamination by organic chemicals, including industrial manufacture and use and domestic use of such items as paints, fuels, dyes, glues, pesticides, and cleaning supplies (National Water Quality Data Bank 1988).

National surveys have analyzed the level of contamination of recreational waters by organic chemicals. The concentrations of organic chemicals that have been detected in waters that could be used for recreational purposes were lower than the recommended drinking water guidelines (Department of National Health and Welfare 1989) and should not pose any threat to human health.

A review by Brown *et al*. (1984) of volatile solvents compared the estimated skin absorption dose with the oral dose ingested under a number of exposure situations, including swimming, bathing, and drinking. Their findings indicated that skin absorption contributed between 29 and 91 per cent of the total dose. For example, if a 21.9-kg child swam 1 hour in water (90 per cent submerged) and drank 1 L (his normal daily intake) of water containing 0.5 mg/L of toluene, the dose of toluene absorbed by the dermal route would be 91 per cent of the daily absorbed dose from the two sources.

In summary, there are some chemical contaminants that could be a cause for concern in recreational waters. Given the paucity of information on the type of chemical, the effective concentration, and the effects, it is difficult to set guidelines at the present time.

Summary

1. It is recommended that no measurable limits be established for chemicals in recreational water for human exposure risk because of lack of sufficient scientific information. Decisions for use should be based on aesthetic quality (e.g., presence of odour or visible oil and grease) and other factors considered in the environmental health assessment (e.g., proximity to industrial discharge).

6. Microbiological Sampling and Analysis

6.1 Sampling

In recreational water quality investigations, the purpose of sampling is to obtain aliquots that are as representative as possible with respect to the microbiological properties of the area. Sampling should be conducted during the bathing season, but it is most appropriate when recreational waters are suspected as a source of waterborne disease. Regular sampling may not be necessary at all recreational water use areas. Historical data, combined with an annual environmental health assessment, may indicate that only occasional sampling is necessary. If a deterioration of water quality has occurred, then routine monitoring of the area should be carried out. Such an approach will allow health officials to concentrate their resources on beaches of questionable quality. By taking the following factors into consideration, an effective sampling program can be designed to optimize the estimation of fecal indicator bacteria in recreational waters.

6.1.1 Sampling locations

Most bodies of water used for recreational purposes frequently lack homogeneity with respect to their microbiological properties, thus making multi-point sampling necessary. The sites should be selected on the basis of information gathered during the environmental health assessment. Ideally, the sites chosen should be representative of the water quality throughout the whole bather exposure area. The selection of sites should pay particular attention to site-specific conditions that may influence the levels and distribution of indicator organisms and pathogens.

The sampling sites should include points of greatest bather activity as well as peripheral points subject to external fecal pollution. Natural or artificial streams discharging storm water and sewage can give certain sections of a body of water very different microbiological qualities than the body at large. The degree of heterogeneity can also be affected by rainfall, wind velocity and direction, and tides. In larger bodies, the contribution of local events is somewhat diminished by the large volumes of water involved.

The importance of sampling location has been considered in a number of studies. Brenniman *et al*. (1981), in a study of water sampling design at two Lake Erie beaches, observed that levels of indicator bacteria varied significantly with the time and day of collection, but not within the various sampling sites in the bathing areas. The authors concluded that at beaches

where the dispersion of any fecal input is incomplete, sampling at various locations as well as during periods of maximum bather load should be conducted.

The collection of subsurface samples at wading depth should be considered where the water has been stirred up either by bather activity or by the person collecting the sample (Warrington 1989). Two recent epidemiological studies have discussed the importance of sampling in shallow water frequented by young children (Fattal *et al*. 1986; Seyfried 1987).

6.1.2 Frequency of sampling

A water sample provides a quantitative estimate of the bacteria present at a particular site and instant. As the total number of samples increases, the more representative the data will be of the overall water quality.

Samples should be collected at random intervals and at times of greatest user activity (i.e., mid-afternoon on weekends or holidays, as recommended by Sherry 1986), as well as at times when maximum fecal contamination can be expected (e.g., periods of storm water runoff and high onshore winds that upwell bottom sediments). If concentrations of fecal indicator bacteria fluctuate cyclically (e.g., effluent discharges at regular intervals or tidal variations), as shown by Churchland and Kan (1982), then samples should be collected during all phases of the cycle in addition to periods of high bather density.

The minimum recommended sampling frequency for routine investigations is five samples in not more than 30 days from each sampling location. At beaches with higher bather densities or at those known to have poor water quality, or in cases of suspected waterborne diseases associated with bathing, then the sampling frequency should be increased. The number of samples will be determined from the identification of sampling locations described above. Occasional sampling should be adequate in areas that historically have had acceptable water quality. However, if information gathered prior to the bathing season indicates that the water quality may have deteriorated, then routine monitoring should be initiated.

When analyses indicate that a single sample contains more than 4000 ***Escherichia coli*** or fecal coliforms/L or more than 700 enterococci/L, resampling of the area is required. The number of samples collected and their location should be sufficient to indicate the possible sources of contamination.

6.1.3 Sampling procedures for water

Samples for microbiological examination should be collected in sterile, 200- to 500-mL “environmental sensitive” containers. When sampling is done by hand, the bottle should be held near the base with one hand, the cap removed, and the bottle mouth plunged downward into the water. The bottle is tilted slightly upward to displace the air, then pushed forward against the

current away from the hand and the boat or sampling platform (if used) to avoid contamination. The sampling depth should be 15 to 30 cm below the surface in both deep and shallow waters. When collecting is done with a sampling pole, the bottle should be fit into the holder in the recommended manner, the cover removed, and the sample collected, upstream away from the collector, by simulating the scooping motion of the hand-collected sample.

With either method, a small amount of sample should be poured out, leaving an airspace to allow for proper mixing prior to analysis. The cap should be replaced and the bottle labelled and stored in an ice chest. The samples must be collected and processed individually. Composite samples are not acceptable.

6.1.4 Sampling procedures for sediments

When evidence indicates that bathing beaches could be the source of waterborne diseases among bathers, sediment sampling and analysis for suspected pathogens are also recommended. Many investigations have demonstrated that pollution indicator bacteria and pathogenic bacteria survive for extended periods in sediments (e.g., Burton *et al*. 1987).

Sediment samples may be collected using sterile, 250- to 500-mL wide-mouth jars, observing the same precautions used with water sampling to ensure aseptic collection. In shallow waters, the jars are pushed along the bottom, collecting the material at the sediment-water interface, until half full. The excess water is poured off, and the sample is stored as described above. In deeper waters, sediment samplers used for collecting benthic invertebrates, such as the Ponar or Ekman grabs, can also be used (American Public Health Association 1989). When sediments are brought to the surface, a subsample is aseptically transferred from the centre of the material to the sterile jar.

6.1.5 Sample preservation and storage

Water and sediment samples should be maintained at 1 to 5°C and processed within 30 hours after collection. For transport to the laboratory, the sample bottles should be placed in an insulated ice chest containing melting ice or freezer packs; to prevent the possibility of contamination, total immersion of bottles in the water should be avoided. The samples should never be frozen. If freezer packs are used, the samples should be protected from direct contact to avoid freezing. Storage in the dark under these conditions (or at 4 to 5°C in a refrigerator) minimizes die-off and multiplication for at least 30 hours after collection. A sample preservation experiment conducted by Dutka and El-Shaarawi (1980) indicated that when water samples were stored at 1.5°C, the concentrations of indicator organisms were stable for at least 24 hours. Neither the original water temperature nor bacteria and nutrient load appeared to affect preservation.

If the microbiological counts are to be used in legal action, the samples must be delivered to the laboratory within six hours of collection and processed within two hours of receipt with proof of continuity of possession (American Public Health Association 1989).

6.2 Methods for Microbiological Analysis

6.2.1 *Escherichia coli* and fecal coliforms

The 16th edition of *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1989) contains two official methods for the determination of fecal coliforms: the multiple tube fermentation or most probable number (MPN) procedure, and the membrane filtration (MF) technique.

Multiple Tube Fermentation or Most Probable Number (MPN) Method

This procedure is not an actual enumeration of bacteria but is a statistically derived index that gives the probable number of bacteria present in a sample. A series of replicate tubes of lauryl tryptose broth (usually five) is inoculated with decimal quantities of the sample and examined for growth or gas production after a 48-hour incubation at 35°C. Positive tubes are transferred to EC broth and incubated at 44.5°C for 24 hours. The presence of gas within 24 hours or less is considered a positive reaction and indicates coliforms of fecal origin. The number of positive tubes per dilution is referred to a standard MPN (Most Probable Number) table, which provides an estimate of the fecal coliforms per 100 mL of sample. If an estimate of ***E. coli*** is desired, positive EC tubes are streaked on EMB agar and incubated at 35°C for 24 hours, and isolated colonies are subcultured and identified by routine IMViC procedures.

The method is time-consuming to perform, requires large amounts of media, glassware, and incubator space, and requires 72 hours for a confirmed test. Except for turbid waters or water suspected of containing stressed organisms, the method has been replaced by the membrane filtration technique. However, the addition of 4-methylumbelliferone glucuronide (MUG) to coliform and fecal coliform broths for the direct detection of ***E. coli***, described by Feng and Hartman (1982), should make it easier and quicker to enumerate ***E. coli*** in turbid samples.

Membrane Filtration (MF) Technique

In this procedure, fecal coliforms in water are measured directly. The sample (usually 100 mL) is passed through a filter that retains the bacteria; the filter is placed on the surface of an appropriate medium (mFC broth for fecal coliforms) and incubated. After 24 hours' incubation in a water bath at 44.5°C, blue colonies typical of fecal coliforms are counted and recorded as the number of fecal coliforms per 100 mL. In recreational water contaminated with sewage, dilution of the sample to avoid confluent growth may be necessary. The anaerobic incubation of membranes to suppress the growth of non-coliform bacteria has also been described (Doyle *et al.* 1984). One disadvantage with the mFC broth is its inability to distinguish between ***E. coli*** and other thermotolerant, lactose-fermenting species. To overcome this problem, an MF method for enumerating ***E. coli*** in water has been developed (Dufour *et al*. 1981). The procedure uses a medium (mTEC) for lactose-fermenting, Gram-negative bacteria, a resuscitation step for stressed organisms, and an ***in situ*** urease test to differentiate ***E. coli*** (urease-negative) from other thermotolerant fecal coliforms (mostly urease- positive). This method should be useful for counting ***E. coli*** in most surface waters. However, because some ***Klebsiella pneumoniae*** subspecies are also urease-negative, the method may not be useful in waters receiving industrial effluents known to contain high levels of ***Klebsiella pneumoniae***. In this case, the mTEC medium incorporating indoxyl ß-D-glucoside might be more appropriate (Shaw and Cabelli 1980). Most recently, the incorporation of 4-methylumbelliferone glucuronide (MUG) into the various fecal coliform media to increase their specificity for ***E. coli*** has also been examined (Freier and Hartman 1987; Brodsky 1989; Young 1989). Various laboratories in Canada may wish to evaluate the applicability of these methods to recreational waters in their regions.

The advantages of the MF technique include reduction of space, labour, and equipment necessary, ability to test large volumes of water, rapidity and ease of testing, and a high degree of reproducibility. With the use of portable equipment, it can also be employed directly in the field.

Widespread use of the MF technique has revealed some unforeseen problems. Many investigators have shown that there are significant differences between various membranes in their ability to recover fecal coliforms from natural waters. For example, Tobin and Dutka (1977) concluded that membrane filters were not equivalent in their ability to recover bacteria from water samples and pointed out the great need for standardization. Apart from brand differences in filters, many studies have also shown that the MPN method often yielded better recovery of fecal coliforms than the MF technique. It is believed that the broths used in the MPN test provide a more favourable environment than the selective medium and membrane structure of the MF test for the recovery and growth of stressed fecal coliforms. However, despite

this problem, the MF technique, particularly when used with resuscitation techniques, is probably sufficiently precise to detect small differences in the pollution index of a given area when sampled regularly.

6.2.2 Enterococci

Enterococci in marine and freshwater recreational areas are usually enumerated by the MF technique described by the U.S. Environmental Protection Agency (1985). After filtering a portion of the sample, the membrane is placed on mE agar and incubated at 41°C for 48 hours. The membranes are then transferred to EIA plates and re-incubated for an additional 20 minutes. All pink to red colonies with black or reddish-brown precipitates are considered enterococci. A 1-step modification of this MF procedure is also being investigated (Dufour 1989). Highly turbid waters and those directly influenced by chlorinated sewage should be examined by an MPN method, using azide dextrose broth followed by confirmation with Pfizer selective enterococcus agar (American Public Health Association 1989).

6.2.3 *Pseudomonas aeruginosa*

A variety of enumeration procedures for ***Pseudomonas aeruginosa*** in natural waters is available. Levin and Cabelli (1972) described an MF technique and medium (mPA) that were more efficient and accurate than the MPN methods in use. Dutka and Kwan (1977) confirmed their findings and, by slightly modifying the mPA medium and using a longer incubation period, increased the sensitivity of the test. Brodsky and Ciebin (1978) further modified the medium and reported recoveries of ***P. aeruginosa*** comparable with those of Dutka and Kwan after only 24 hours' incubation.

However, if turbid waters or sediments are examined, the MPN method must be employed (Environment Canada 1978; American Public Health Association 1989). This procedure requires extended incubation periods and confirmation of presumptive positive tubes. Using an MPN procedure, Seyfried *et al*. (1985b) reported higher recoveries of ***P. aeruginosa*** from sediments than from ambient waters.

6.2.4 *Staphylococcus aureus*

The American Public Health Association (1989) lists a tentative MPN method for enumeration of ***Staphylococcus aureus*** from waters. An MF technique designed to count ***S. aureus*** in swimming pools (Alico and Dragonjac 1978) was also found useful for recreational waters (Seyfried 1980). Recently, a new MF medium for enumerating total staphylococci as well as ***S aureus*** has been formulated (Borrego *et al*. 1987a).

6.2.5 *Salmonella and Shigella*

Many methods are available for the isolation of ***Salmonella and Shigella*** from water and sediments using concentration and enrichment techniques followed by identification procedures or detection by fluorescent antibody techniques (Environment Canada 1978; American Public Health Association 1989). MPN and MF techniques for the quantitative determination of ***Salmonella*** have also been described (American Public Health Association 1989).

6.2.6 *Aeromonas*

There are a few methods available for the enumeration of ***Aeromonas*** in fresh and marine waters. MPN methods were used to count ***A. hydrophila*** in an estuary (Kaper *et al*. 1981). MF techniques for both fresh and marine waters have also been described (Rippey and Cabelli 1979; Havelaar *et al*. 1987).

6.2.7 *Campylobacter jejuni*

At present, there are no standard methods for the enumeration or detection of ***Campylobacter jejuni*** in water (American Public Health Association 1989). However, the enumeration of ***Campylobacter*** spp. using MPN methods followed by steps to identify ***C. jejuni*** has been reported (Bolton *et al*. 1987; Carter *et al*. 1987).

6.2.8 *Legionella*

Media and methods for the isolation and enumeration of ***Legionella*** in water have been described (Calderson and Dufour 1984; Hsu *et al*. 1984; Voss *et al*. 1984). The American Public Health Association (1989) has also summarized available information on specimen collection, identification, and isolation of ***Legionella*** species.

6.2.9 Protozoa

The technique for recovery of protozoa from waters is complex and involves two steps: the concentration of large volumes of water, and a microscopic identification using ordinary, phase-contrast, or fluorescent microscopy.

The American Public Health Association (1989) details a sampling device used for the detection of ***Giardia lamblia***. Quantification of ***Giardia*** cysts by membrane filtration has been suggested by Spaulding *et al*. (1983). Jakubowski and Ericksen (1979) reviewed the methods for the detection of ***Giardia*** cysts in water, and Sauch (1985) detailed their microscopic identification.

Cryptosporidium spp. can be concentrated from waters using polypropylene cartridge filters, as described by Musial *et al*. (1987). The identification of oocysts in river water has been reported by Ongerth and Stibbs (1987) and by Gallaher *et al*. (1989).

6.2.10 Viruses and coliphages

The development of methods for the concentration of viruses from large volumes of water (Wallis *et al*. 1972; Payment *et al*. 1976; Sobsey *et al*. 1980; Gerba and Goyal 1982; Block and Schwartzbrod 1982; Gerba 1983; Payment and Trudel 1988) and their detection by highly sensitive methods (Payment and Trudel 1985; Margolin *et al.* 1986) now allow the virological analysis of surface waters. The methodology for concentration and isolation of viruses in large volumes of water has been standardized to some extent (American Public Health Association 1989), so that monitoring of recreational waters is possible if epidemiological data indicate a need. The use of positively charged micro-porous filters has been recommended by Sobsey and Jones (1979), although wound fibreglass depth filters were found to be less expensive by Payment and Trudel (1988).

There are now available some rather simple, quick, and inexpensive procedures for the monitoring of coliphages and bacteriophages in water. One of the most sensitive procedures for enumerating coliphages from water or effluents is described in *Standard Methods for the Examination of Water and Wastewater* (American Public Health Association 1989) using ***E. coli*** (ATCC 13706) as host.

6.2.11 Toxic phytoplankton

The presence of potentially toxic blue-green species can be determined microscopically, but this technique cannot distinguish toxic from non-toxic strains because the strains look alike.

Rapid chemical analyses using reversed-phase, high performance liquid chromatography (Harada *et al*. 1988), HPLC and internal surface reversed-phase columns (Meriluoto and Eriksson 1988) and high performance, thin-layer chromatography (Jamel Al-Layl *et al*. 1988) have been proposed, for toxins that affect the liver from ***Microcystis aeruginosa*** and ***Anabaena flos-aquae*** to replace the previous, more time- consuming methodology using gel filtration (Krishnamurthy *et al*. 1986).

The standard mouse bioassay (Bishop *et al*. 1959; Elleman *et al*. 1978) provides a rapid general assessment of the presence and toxicity of hepatotoxins. The survival time is a measure of toxicity. Falconer *et al.* (1981) and Siegelman *et al.* (1984) also provide guides to interpreting the results. Codd *et al*. (1989) describe in vitro cytotoxicity tests, immunoassays and other procedures now emerging to supplement the mouse bioassay.

Definite chemical analysis for the alkaloid neurotoxin anatoxin-a from ***Anabaena flos-aquae*** can be performed within a matter of hours (Smith and Lewis 1987). Ikawa *et al*. (1982) and Sasner *et al*. (1984) describe chemical analyses for aphantoxins from ***Aphanizomenon flos-aquae***.

A 100-mL glass jar with a snap cap lid should be used to collect water samples for microscopic identification and enumeration of algal species. When the sample is taken, it should be preserved by the addition of Lugol's solution from an eye dropper until the sample is the colour of tea. The sample should be kept refrigerated.

For the toxicity assay and the extraction and identification of toxins, samples should be collected in two 1-L Nalgene containers. Enough algal mass should be collected to fill each container about three-quarters full. The samples should be frozen immediately after collection and kept frozen to preserve the toxins from decomposition.

Animals suspected of dying from blue-green algae poisoning should be autopsied by the local veterinary surgeon. It may also be appropriate during any investigation to sample and test the water for priority pollutants and pesticides, bacteriological quality, routine chemical constituents, and nutrients.

7. Posting of Recreational Waters

When the appropriate authority has determined that a beach or body of water is not suitable for recreational use, the public should be notified. Normally this involves placing one or more signs in conspicuous places along the beach or shoreline. These signs should be clear and concise as to the health risk and recommended course of action. They should be written in simple understandable text and symbols. The authority making the determination should be clearly indicated on the signs. The signs should be left in place only as long as necessary and promptly removed when the health hazard no longer exists.

Appendix 1:

Bathing Area Environmental Health Assessment

Beach Name: _____ Body of Water: _____

Type of Water: Fresh _____ Marine _____ Estuarine _____

Location: _____

Owner/Operator: _____

Address: _____ Phone: _____

Microbiological Hazards

As appropriate, consult with Public Health, Environment, and/or Agriculture Departments.

Sewage	Y	N
Is the water quality likely to be affected by discharges from:		
1. private on-site sewage disposal systems?	___	___
2. communal sewage treatment facilities?	___	___
3. agricultural activities?	___	___

Storm Water Runoff	Y	N
Is the water quality likely to be affected by runoff from:	___	___
1. municipal storm drains?	___	___
2. agricultural fields?	___	___
3. natural drainage?	___	___

Note: any of the above with a Yes answer require(s) a Detailed Investigation and Risk Analysis.

Physical Hazards

Access	Y	N
1. Is the beach protected from vehicle access?	___	___
2. Is the swimming area protected from water craft access?	___	___

Shoreline	Y	N
1. Is the shoreline free of large rocks, sharp objects, or other impairments?	___	___
2. Is the shoreline free of trees and shrubs that may impair visibility?	___	___

Bottom Conditions	Y	N
1. Does the bottom consist of material that is not easily stirred up?	___	___
2. Are the slopes gentle?	___	___
3. Is the bottom free of large rocks, sharp objects, or other obstructions?	___	___
4. Is the maximum depth of the swimming area less than 4.5 metres?	___	___
5. Is the bottom free of weeds?	___	___

Water Conditions	Y	N
1. Is the water elevation constant throughout the season?	___	___
2. Have lateral and helical currents been assessed as safe?	___	___
3. Have surf conditions been assessed for potential to create undertows and rips?	___	___
4. Are there 2.8 to 3.7 square metres of space available per swimmer?	___	___

Note: any of the above with a *No* answer require(s) a Detailed Investigation and Risk Analysis.

Chemical Hazards

As appropriate, consult with Environment and/or Agriculture Departments.

Chemical	Y	N
Is the water quality likely to be affected by:		
1. discharges from industrial sources?	___	___
2. agricultural drainage?	___	___
3. water craft mooring or use?	___	___

Note: any of the above with a *Yes* answer require(s) a Detailed Investigation and Risk Analysis.

Reporting Systems

	Y	N
1. Are there formal mechanisms for the reporting of abnormal waste discharges, spills, treatment bypasses, etc., to the local health authority?	___	___
2. Is there an illness or injury reporting mechanism in place that would be effective for epidemiological monitoring?	___	___

Sampling or Posting Recommendations

_____

_____

_____

_____

_____

Date of Assessment _____ Responsible Authority _____

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