WATER MANAGEMENT BRANCH
ENVIRONMENT AND LANDS HEADQUARTERS DIVISION
MINISTRY OF ENVIRONMENT, LANDS AND PARKS

Water Quality Criteria for Total Gas Pressure

OVERVIEW

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SUMMARY

THIS REPORT IS based on a technical report prepared by a consultant on behalf of the provincial Ministry of Environment, Lands and Parks, Environment Canada, and Department of Fisheries and Oceans. It is one in a series which establishes ambient water quality criteria for British Columbia. The criteria are safe conditions or levels of contaminants, applicable province-wide, which protect various water uses. This summary provides the criteria for total gas pressure (TGP), also referred to as dissolved gas supersaturation, to protect aquatic life in fresh and marine waters. No criteria are established for drinking water, wildlife, livestock watering, irrigation, recreation and aesthetics, or industrial water uses since TGP affects only aquatic life. The criteria in Tables 1 and 2 at the back of this report can be summarised as:

Water Use	Criteria
Freshwater and Marine Aquatic Life	
Local Water Depths <1 metre	$\Delta P = 73.89 \bullet h + 0.15 \bullet pO_2$ *
Local Water Depths >1 metre	Maximum $\Delta P \leq 76$ mmHg (or $\leq$110% at sea level)
Background levels higher than criteria	No increase in ΔP or %TGP

* The maximum ΔP should not exceed 76 mm Hg regardless of pO_2 level.

Excess TGP produces a class of physiological signs referred to as gas bubble trauma which are harmful or fatal to fish and other freshwater and marine organisms. Fish are the most sensitive organisms in marine and freshwater environments. TGP criteria for fish should protect all aquatic life. The criteria need to reflect the diverse conditions where TGP may affect aquatic life such as variable water column depths, situations with background levels higher than the criteria, and for fish hatcheries (due to the higher densities of fish and subsequent higher stress levels encountered in these environments). The Canadian Council of Ministers of the Environment (CCME) have not yet established TGP criteria.

A major use of criteria is to set ambient water quality objectives. The objectives are the criteria modified or adopted to protect the most sensitive designated water use in a particular body of water. The objectives are used in the preparation of waste management permits, orders, or approvals, which are the only documents to have legal standing. The objectives, however, are not usually part of the permit.

PREFACE

THE MINISTRY OF ENVIRONMENT is developing province-wide ambient water quality criteria for variables that are important in the surface waters of British Columbia. This work has the following goals:

(i) to provide criteria for the evaluation of data on water, sediment, and biota;

(ii) to provide criteria for the establishment of site-specific ambient water quality objectives

The ambient water quality objectives for specific waterbodies will be based on the criteria as well as on present and future uses, waste discharges, hydrology/limnology/ oceanography, existing background water quality, and other site-specific conditions. The process for establishing water quality objectives is more fully outlined in "Principles for Preparing Water Quality Objectives in British Columbia", copies of which are available from the Water Quality Branch, Environmental Protection Department, B.C. Ministry of Environment, Lands, and Parks, Victoria.

Neither criteria nor objectives which are derived from them have any legal standing. The objectives can be used in calculating the limits to be allowed in waste discharges. These limits are set out in waste management permits, orders or approvals which do have legal standing. The objectives are not usually incorporated as conditions of the permit.

The definition for criterion is: "A maximum and/or a minimum value for a physical, chemical or biological characteristic of water, sediment or biota, which should not be exceeded to prevent specified detrimental effects from occurring to a water use, including aquatic life, under specified environmental condition."

The criteria are use-specific, have province-wide application, and are being developed for the following water uses:

-Drinking, public water supply and food processing[1]
-Aquatic life and wildlife
-Agriculture (livestock watering and irrigation)
-Recreation and aesthetics[2]
-Industrial (water supplies)

The criteria are set after considering the scientific literature, criteria from other jurisdictions, and general conditions in British Columbia. The scientific literature gives information on the effects of toxicants on various life forms. This information is rarely totally conclusive because it is usually based on laboratory work which, at best, only approximates actual field conditions. To compensate for this uncertainty, criteria have built-in safety factors which are conservative but reflect natural background conditions in the province.

Given this procedure for setting criteria, the objectives will, in most cases, be the same as the criteria. However, in some cases, such as when natural background levels exceed the criteria, the objectives could be less stringent than the criteria. In relatively rare instances, for example if the resource is unusually valuable or of special provincial significance, the safety factor could be increased by using objectives which are more stringent than the criteria. Another approach in such special cases would be to develop site-specific criteria by carrying out toxicity experiments in the field. This approach is costly and time-consuming and therefore seldom used.

The criteria will be subject to review and revision as new information becomes available, or as other circumstances dictate.

[1] The criteria apply to the ambient raw water source before it is diverted or treated for domestic use. The Ministry of Health regulates the quality of water for domestic use after it is treated and delivered by a water purveyor.

[2] Criteria relating to public health at bathing beaches will be the same as those used by the Ministry of Health which regulates their use.

RECOMMENDED CRITERIA

THESE CRITERIA ARE based on information presented in a technical report and are summarised in Tables 1 and 2.

1.0 Freshwater Aquatic Life

A. ***For Water Depths Less than One Metre***: Where local water depths at a given location is less than one metre, the criteria are based on the following equation which describes the threshold for swim bladder over-inflation as a function of water depth and partial pressure of dissolved oxygen. However, the maximum ΔP should not exceed 76 mmHg regardless of the pO_2 level.

$$\Delta P = 73.89 \bullet h + 0.15 \bullet pO_2 \qquad (1)$$

where:

ΔP = excess gas pressure in mmHg. It is the difference between the total gas pressure (TGP) in the water column minus the atmospheric pressure (pAtm)[3] at the site. A water column is saturated with dissolved gases when $\Delta P > 0$,

h = depth of water column (metres)

pO_2 = partial pressure of dissolved oxygen (mmHg) in the environmental water

For example, at a water depth of zero metres and a pO_2 of 157 mmHg, the ΔP must not exceed 24 mmHg. For sea level conditions (*i.e.*, pAtm = 760 mmHg), this corresponds to a TGP of 103% (*i.e.*, = (24+760) x 100 ÷ 760).

B. ***For Water Depths Greater than One Metre:*** Where local water depths at a given location exceeds one metre, the maximum ΔP should not exceed 76 mmHg regardless of water pO2 levels. For sea level conditions, this corresponds to a TGP of 110%.

[3] pATM will vary with altitude. For every 900 ft (275 m) of rise in elevation, the pressure decreases by approximately one-thirtieth of itself. For example, the atmospheric pressure at sea level and at 540 m elevation are 760 mm of Hg and 713 mm of Hg, respectively.

In cases, such as a water licence clause, where it is necessary to determine whether to use criterion A or B, criterion A should be used in absence of information to the contrary. Information on the lack of residence of juvenile fish at river margins could be a basis to apply the less conservative criterion B, provided the presence of other stressors do not suggest the need for an even more conservative application.

C. ***For Background Levels Higher Than the Recommended Criterion:*** If the natural background levels of dissolved gas exceed the recommended criteria, there should be no increase in ΔP or %TGP over the background levels. This recognises that background levels that are higher than the recommended criteria may be harmful to fish, and hence, any increase over background levels should not be tolerated for the protection of aquatic life.

D. ***For Hatchery Environments:*** It is recommended that the excess gas pressure (ΔP) criteria be defined by the equation in Section 1A at h=0. This corresponds to a sea level ΔP of 24 mmHg or TGP of 103% at pO_2 = 157 mmHg (i.e., the threshold for swim bladder over-inflation under sea level normoxic conditions and zero water depth). If pO_2 levels in the hatchery drop to 100 mmHg, the criteria should be a maximum ΔP of 0 mmHg.

2.0 Marine Aquatic Life

There are limited data from the literature which describe the effects of dissolved gas supersaturation on marine fish. However, the available data indicate that marine fish display the same signs of gas bubble trauma as do fresh water fish. Also, marine invertebrates display a similar level of sensitivity to dissolved gas supersaturation as adult fish. No data are available which would indicate the effects of dissolved gas supersaturation on marine plants or algae, but it is not anticipated that these would be any more sensitive than either marine fish or invertebrates. Therefore, suggested criteria for the protection of marine aquatic life are the same as those recommended for the protection of fresh water fish (see Section 1.0).

APPLICATION OF CRITERIA FOR AQUATIC LIFE

THE RECOMMENDED CRITERIA are based on the fact that the first sign of gas bubble trauma due to dissolved gas supersaturation is expressed in terms of swim bladder over-inflation. It is also recognised that some fish may seek depth to avoid swim bladder over-inflation or to compensate for over-buoyancy. Nevertheless, there are situations where some fraction of the fish population will reside in shallow water less than one metre deep even when deeper water is available to them. Therefore, the application of the TGP criteria to man-made alterations of aquatic environments must focus on fisheries habitat. The first step in applying the criteria is to assess the habitat which is available for use by the various fish species of a river, lake, or marine environment. This includes assessment of habitats for spawning, rearing, and adult holding along with information on the temporal usage of these habitats. These data, along with information on water depth (which may vary over the year) and partial pressure of dissolved oxygen (which may also vary over the year as well as diurnally), provide the necessary information for application of the recommended criteria. A number of factors including fish species, fish age class, available habitat, habitat usage, the presence of suspended or deposited particulate matter, and the role of the swim bladder under normal conditions will also have to be considered in establishing criterion compliance.

The application of the criteria in a variable mode, as just described, would permit a more flexible mode of operation for individuals or companies (*e.g.*, power generating companies and agriculture operations) that alter river or lake natural dissolved gas regimes. However, the application of criteria would require that river fisheries activities (*i.e.*, habitat usage), water depths, and dissolved gas levels be monitored on a regular or even continuous basis. This requirement could be incorporated into the water license for a particular operation. In cases where an individual or company did not wish to take advantage of a variable criterion, the criterion should be set at a conservative value which is protective to fish under all possible operations. In water bodies greater than one metre in depth, the most conservative situation will be when the criterion is expressed in terms of depth at which fish reside rather than water depth.

Example of Criterion Application

Camp Creek is a tributary of the Canoe River which flows into the northern reach of Kinbasket Reservoir near Valemount, B.C. The creek provides important spawning and rearing habitat for many of the sportsfish species of Kinbasket Reservoir. The headwaters of Camp Creek lie near Mt. Lulu in the Cariboo Mountains of British Columbia. From its headwaters, Camp Creek flows 12 km east through a steep mountain valley. It then turns north and meanders through a wide flat valley for 18 km where it joins the Canoe River about 7 km south of Valemount, B.C. Only the lower 18 km of Camp Creek are accessible to migratory fish species. This portion of the creek is relatively low gradient with run-riffle sections separated by slower meandering glide-pool sections. Creek substrate consists of large cobbles with considerable amounts of fine sand and silt deposited in the low velocity sections. Although there are a few deep pools in this section of the creek, they comprise a very small percent of the total habitat. The elevation of this section of the creek is approximately 925 m above sea level. The mean water depth for most of the year is about 0.5 m, with levels dropping to about 0.3 m in the fall and winter months.

Because the upper reaches of the creek (beyond the lower 18 km) are very steep, there is excellent potential for the development of a small hydroelectric facility on the creek. In any hydroelectric facility there are periods when the turbines cannot handle all of the water flow and some of the flow must be spilled. If this is done with a dam sluiceway system, there exists the potential for the creek below the dam to become supersaturated with dissolved gases.

Application of the criterion for dissolved gas supersaturation to this creek must consider the predominantly shallow water of the lower 18 km of the creek and the altitude. At an altitude of 925 m, the atmospheric pressure is approximately 690 mmHg and the partial pressure for oxygen (dry air) is approximately 145 mmHg. Assuming that the creek is in equilibrium with the atmosphere, the partial pressure of dissolved oxygen would also be approximately 145 mmHg. As noted above, most of the creek is at a depth of 0.3 m during the fall and winter months when some fish species will be spawning (*e.g.*, Kokanee salmon, burbot, and mountain whitefish) and

juvenile fish species will be rearing in the creek. Using this information in conjunction with the equation in Section 1.0, one would obtain a criterion of approximately 44 mmHg.

Although this would be the suggested criterion, other factors must be considered. For example, this criterion would protect juvenile fish if they spent most of their time on the creek bed. Because there are so few areas of deeper water in the creek during this time of year, additional protection should be considered. The situation just described would be very similar to that in a hatchery and a criterion of 24 mmHg would be more appropriate. This would allow fish to use the full 0.3 m of the water column as needed. In another creek where there may be a more even distribution of shallow and deep water, so that the 44 mmHg excess pressure (or ΔP) criterion might be more appropriate.

TABLE 1
SUMMARY OF CRITERIA FOR TOTAL GAS PRESSURE (TGP)

Water Use	Recommended Criterion
Drinking Water Supply	None Proposed
Freshwater and Marine Aquatic Life	
Local Water Depths <1 metre	$\Delta P = 73.89 \bullet h + 0.15 \bullet pO_2$*
Local Water Depths >1 metre	Maximum $\Delta P \leq 76$ mmHg (or ≤110% at sea level)
Background levels higher than recommended criteria	No increase in ΔP or %TGP
Hatchery Environments	Maximum $\Delta P = 24$ mmHg (or 103% at sea level); $\Delta P = 0$ mmHg when pO_2 is ≤100 mmHg
Wildlife	None Proposed
Livestock Water Supply	None Proposed
Irrigation	None Proposed
Primary-contact recreation	None Proposed

* The maximum ΔP should not exceed 76 mmHg regardless of pO2 level (See Table 2 for an example)

ΔP = excess gas pressure in mm of Hg;

h = depth of water column in metres, and

pO_2 = partial pressure of dissolved oxygen in mm of Hg.

Table 2
AQUATIC LIFE CRITERIA FOR TGP AS A FUNCTION OF WATER COLUMN DEPTH†

Local Water Depth (h)	Excess Gas Pressure (ΔP)
0 cm	24 mmHg
20 cm	39 mmHg
40 cm	53 mmHg
50 cm	61 mmHg
60 cm	68 mmHg
70 cm	76 mmHg
80 cm	76 mmHg
90 cm	76 mmHg

†pAtm (or atmospheric pressure) = 760 mmHg,

pO_2 (or partial pressure of dissolved oxygen)= 159 mmHg.