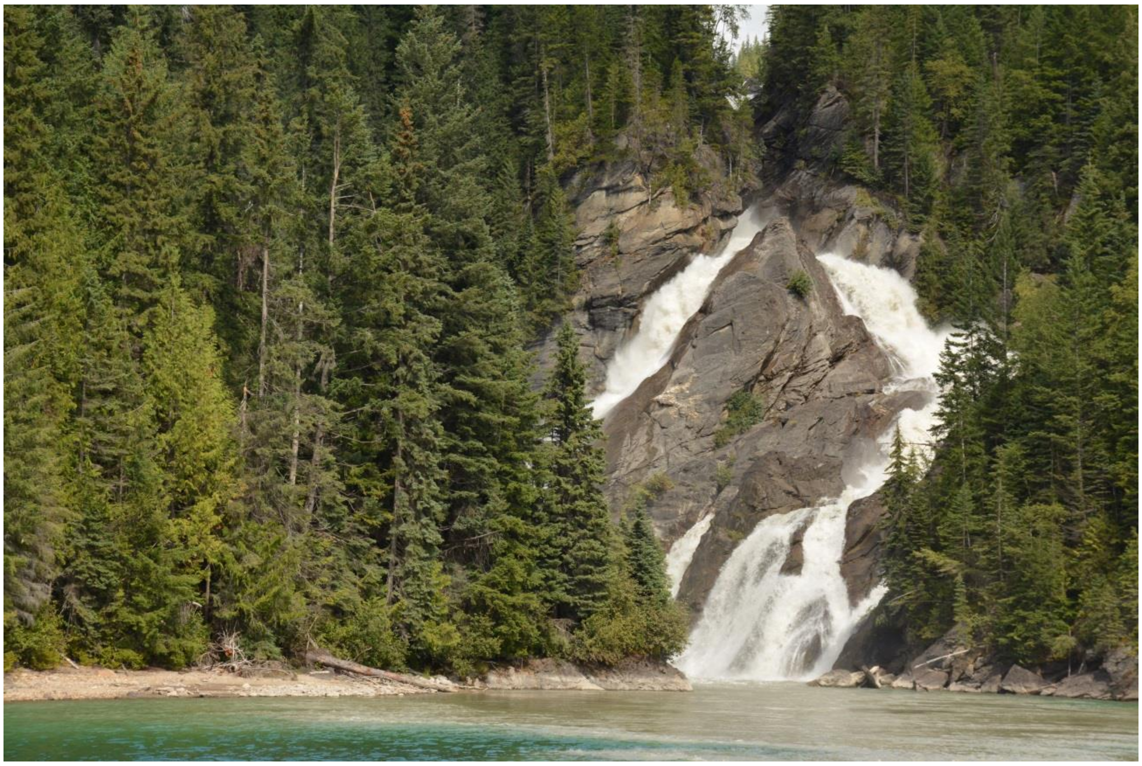
WATER QUALITY GUIDELINE SERIES

Copper Water Quality Guidelines
Wildlife, Livestock Watering, and Irrigation
(Reformatted Guideline from 1987)

Ministry of Environment and Climate Change Strategy

Water Protection & Sustainability Branch



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The Water Quality Guideline Series is a collection of British Columbia (B.C.) Ministry of environment and climate change strategy water quality guidelines. Water quality guidelines are developed for to protect a variety of water uses: aquatic life, drinking water sources, recreation, livestock, irrigation, and wildlife. The Water Quality Guideline Series focuses on publishing water quality guideline technical reports and guideline summaries using the best available science to aid in the management of B.C.'s water resources. For additional information on B.C.'s approved water quality parameter specific guidelines, visit:

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EXECUTIVE SUMMARY

The B.C. Ministry of Environment and Climate Change Strategy (ENV) develops province-wide ambient Water Quality Guidelines (WQGs) for substances or physical attributes that are important for managing both the fresh and marine surface waters of B.C. WQGs do not have direct legal standing but are used to provide a basis for the evaluation of data on water, sediment, and biota for water quality and environmental impact assessments. Ambient WQGs may be derived for the protection of designated values, including aquatic life, wildlife, livestock watering, irrigation, drinking water sources, and recreation.

The approach to develop guidelines reflects the guiding principle that all forms of life and all stages of their life cycle are to be protected during indefinite exposure to the substance of interest. An exceedance of the WQGs presented in this document does not imply that unacceptable risks are present, but that the potential for adverse effects is increased and additional investigation and monitoring should be conducted.

The copper (Cu) WQGs for the protection of wildlife, livestock watering and irrigation were derived in 1987 by the B.C. Ministry of Environment and Parks. Although the format has been updated, all of the technical information remains unchanged. For updated information on industrial and economic importance of copper (Cu) and the analysis of Cu in environmental samples please see the Copper Water Quality Guideline for the Protection of Freshwater Aquatic Life-Technical Report[1] (ENV, 2019).

To protect wildlife, the maximum concentration of total Cu in waters frequented by wildlife should not exceed 300 µg/L. The maximum concentration of total Cu in livestock drinking water should not exceed 300 µg/L. In irrigation waters, the maximum total Cu concentration should not exceed 200 µg/L.

[1]Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/copper/bc_copper_wqg_aquatic_life_technical_report.pdf

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1. INTRODUCTION

The B.C. Ministry of Environment and Climate Change Strategy (ENV) develops province-wide ambient Water Quality Guidelines (WQGs) for substances or physical attributes that are important for managing both the fresh and marine surface waters of B.C. WQGs do not have direct legal standing but are used to provide a basis for the evaluation of data on water, sediment, and biota for water quality and environmental impact assessments.

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2. WILDLIFE

2.1. Effects

According to Demayo and Taylor (1981) there is little evidence in the literature to show conclusively that Cu is harmful to wildlife.

Connors et al. (1975) examined the low hatching success of common tern eggs as a consequence of heavy metal contamination near Hamilton, Ontario. Conclusive evidence of heavy metals as the causative factor could not be shown.

A survey by Ranta et al. (1978) showed that Cu levels in the primary feathers of black and mallard ducks decreased with distance away from the Sudbury area. Since the toxic effects of Cu on livestock are, in all likelihood, similar for wildlife, refer to the discussion on the toxic effects of Cu to livestock in Section 3.1.

2.2. Criteria from the Literature

Criteria specifically designed for the protection of wildlife have not been developed by other jurisdictions. Instead, wildlife has been grouped with the aquatic life category. In the practical sense, waters available for use by wildlife will usually be inhabited by aquatic life, and therefore the criteria for the more sensitive aquatic life would apply. However, for the rare circumstance where aquatic life is either absent or is not considered an important resource, the aquatic life criteria would be over-restrictive for wildlife protection. Therefore, this water use has been addressed separately so that the appropriate level of protection can be used.

2.3. Recommended Criterion

The criterion to protect wildlife from water-borne Cu is the same as that specified for livestock and is based on the safe daily dietary intake level for sheep, which are the most sensitive animals to Cu.

The maximum concentration of total Cu in waters frequented by wildlife should not exceed 300 µg/L.

[2]Available at: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/water-quality-guidelines/approved-wqgs/copper/bc_copper_wqg_aquatic_life_technical_report.pdf

2.4. Rational

The criterion for the protection of wildlife is the same as that specified for livestock watering. The basis for the use of the livestock criterion for the wildlife category is the likelihood that the safe concentration of Cu for both groups of animals is similar. The rationale for the livestock watering criterion is presented in Section 3.4.

In the practical sense, wildlife will almost always be protected incidentally by the aquatic life criteria because, in the case of multi-use waters, the criteria for the most sensitive designated water use will apply.

3. LIVESTOCK WATERING

3.1. Effects

3.1.1. Effects of Copper Alone

Copper is a component of a number of enzymes and therefore an essential element for animal metabolism. Excessive Cu, beyond the dietary requirement, accumulates in the tissues and can lead to liver, kidney, spleen, and nervous system disorders, and eventually death.

On review of the available literature, Demayo and Taylor (1981) concluded that ruminants (e.g., sheep and cattle) are more sensitive than non-ruminants (e.g., swine) or poultry. The chronic toxic levels of Cu in the diet of ruminants are in the range of 20 to 30 µg/g, and those for non-ruminants are over 250 µg/g.

Ingestion of a diet containing 20 to 100 µg/g Cu chloride killed sheep within 24 to 48 hours (NAS, 1977). Ingestion of a diet containing 45 µg/g of Cu starting at 10 months of age killed Finnsheep rams after 307 days on the diet (Reynolds, 1976). Nubian goats receiving daily doses of Cu sulphate of 8 to 32 µg per gram Cu of body weight died after 54 to 144 days (Adan et al., 1977). Underwood (1971) reported that a diet containing 80 µg/g of Cu produced toxic effects in young sheep. Copper poisoning has been shown to occur in sheep grazing on plants containing up to 60 µg/g, grown on cupriferous soils in Australia. A recent joint publication by Agriculture Canada and the B.C. Ministry of Agriculture (1981) reported that pastures fertilized with manure from chickens fed high dietary levels of Cu have accumulated sufficiently high Cu levels to be toxic to sheep. Pastures fertilized with manure from hogs fed high dietary levels of Cu could also be hazardous for sheep. To prevent Cu deficiency in sheep, a dietary level of 5 to 10 µg/g was recommended (Adan et al., 1977). The National Research Council (1968) has stated a safe intake level of about 9 mg/d for sheep.

Calves were reported to be almost as sensitive to Cu poisoning as sheep (Kneale and Smith, 1977). Soil ingestion may also have been a factor in the Cu poisoning of these animals (Thonton, 1974).

Swine fed a diet containing 125 µg/g of Cu showed no significant differences from controls in terms of plasma Cu concentration, growth rate, and live weight (Wilkinson et al., 1977). A diet containing 250 µg/g of Cu significantly reduced the average daily weight gain of swine (Lillie et al., 1977).

According to Demayo and Taylor (1981), poultry appeared to show a greater tolerance than swine to Cu. Studies (Poupoulis and Jensen, 1976; Jackson, 1977) demonstrated that a dietary Cu concentration of 350 µg/g only slightly reduced weight gain in chicks, and turkeys tolerated a dietary concentration of Cu sulphate containing 676 µg/g Cu. A diet containing 500 µg/g of Cu slowed the growth of male broiler chicks, but gizzard erosion was noted at a dietary Cu level of 250 µg/g (Poupoulis and Jensen, 1976). Toxic signs have occurred in ducklings fed a diet containing 200 µg/g Cu, but only when they were subjected to stress (Agriculture Canada and B.C. Ministry of Agriculture, 1981). In terms of daily dietary

Cu/body weight ratio, mallard ducks tolerated 29 µg/g of body weight and chickens tolerated 60 µg/g (NAS, 1977). According to Demayo and Taylor (1981), the minimum lethal dose of Cu in chickens, pigeons, and ducks ranged from 300 to 1,500 µg/g of body weight, depending on the Cu form and the condition and species of the fowl.

3.1.2. Effects of Copper Mixed with Other Metals

The presence of molybdenum (Mo) in a diet appears to affect Cu poisoning in ruminants. When Cu levels are high, excessive Mo (5 to 10 µg/g) induces Cu deficiency and insufficient Mo induces Cu toxicity (Demayo and Taylor, 1981). According to Gupta (1979), chronic Cu poisoning can occur in sheep on a diet containing Cu at concentrations of 10 to 15 µg/g and very low levels of Mo (0.1 to 0.2 µg/g) and sulphate. Conversely, the National Academy of Sciences (NAS, 1977) reported that a diet containing a low Mo concentration (0.5 µg/g) and a Cu concentration of 8 to 10 µg/g, caused blood disorders in sheep. When the diet was Mo-free, the toxic level of Cu increased to 30 µg/g or more. The toxic symptoms occurred only when the liver accumulated Cu to a level of about 150 µg/g (wet weight). In terms of Cu deficiency in ruminants, Mo is suspected of impairing the utilization of dietary Cu, even at Mo concentrations below 5 µg/g (Suttie, 1973). Agriculture Canada and the B.C. Ministry of Agriculture (1981) recommend minimum, adequate, and ideal Cu/Mo ratios for cattle feed of 3.0, 4.3, and 6.0, respectively. Zinc (Zn) and iron ameliorate the toxicity of high Cu levels ingested by swine and sheep, and a deficiency of these metals intensifies Cu toxicosis (NAS, 1977). Similarly, Bremner et al. (1976) demonstrated that Cu in the liver of sheep was reduced by 40 percent when they were fed a diet containing 200 to 420 µg/g of Zn.

Cadmium (Cd) has been shown to affect the absorption of Cu by ruminants (Williams, 1977). Goats fed a diet containing 75 µg/g of Cd for up to 19 months had a 60 percent reduction of Cu in the liver. The reduction of Cu in the liver of their kids was over 90 percent, which resulted in a short life expectancy (Anke et al., 1970). In chickens, a Cd-supplemented diet (200 µg/g) reduced Cu in the muscles, bones, and feathers, and accumulated it in the liver and kidneys (Anke et al., 1970).

Underwood (1971) reported that calcium (Ca) carbonate and ferrous sulphide in the diet of sheep impaired Cu absorption in the intestine, presumably by increasing the pH which favours the formation of insoluble Cu sulphide.

Copper appears to ameliorate selenium (Se) toxicity in animals by causing the accumulation of an apparently harmless compound in the tissues (Jensen, 1975). For example, ponies were protected from fatal doses of selenium (6 to 8 µg/g of body weight) by single oral doses of Cu of 20 to 40 µg/g of body weight (Stowe and Brady, 1978). Similarly, Se-induced growth reduction and mortality in ducks was reduced by diets containing 1,000 µg/g of Cu (Jensen, 1975). According to Agriculture Canada and the B.C Ministry of Agriculture, Cu and Se deficiency frequently occur concurrently in B.C. cattle (Agriculture Canada and B.C. Ministry of Agriculture, 1981). Copper also reduced the toxic effects of silver (Ag). A diet containing 10 to 25 µg/g of Cu inhibited the growth reduction, increased mortality, reduced hemoglobin levels and reduced aortic elastin in chicks caused by 10 to 200 µg/g of Ag in the diet (Hill, 1976). Hill et al. (1964) also showed that symptoms of Cu deficiency were emphasized in the presence of Ag.

Mercury (Hg) reduced growth and increased mortality in chicks fed a Cu supplemented diet. In Cu-deficient chicks, Hg failed to produce either of these effects (Hill et al., 1964).

3.2. Criteria from the Literature

Copper criteria from other jurisdictions, specifically designed for the protection of livestock, generally range between 400 and 5,000 µg/L (see Table 3.1). Some jurisdictions such as Alberta (Alberta

Environment, 1977) and Saskatchewan (Environment Saskatchewan, 1975) have not established water-use categories. Instead, these provinces have established a single criterion for total Cu (20 µg/L) designed to protect the most sensitive use. For Cu, the most sensitive use would apply to aquatic life, and therefore a level of 20 µg/L is over-restrictive for water used for consumption by livestock.

The criteria developed by the Inland Waters Directorate (Demayo and Taylor, 1981) are specified in two parts. One criterion is for ruminants and another one is for all other forms of livestock, including non-ruminants and poultry. These criteria are based upon maximum safe dietary intake levels reported by Neathery and Miller (1977a-b; see Table. 3.1). For ruminants, they use safe dietary intake Cu levels of 20 µg/g (sheep) and 100 µg/g (cattle), and the daily water requirements of 4 to 15 L/d for sheep and 26 to 110 L/d for cattle, as reported by the National Academy of Sciences (NAS, 1974). Hence, using the maximum water requirement for sheep (15 L/d) and the safe dietary level (20 µg/g) a Cu criterion in water of 1,000 µg/L (rounded off) was calculated. Similarly, for non-ruminants the maximum safe dietary intake level of 150 µg/g (for pigs) was used to calculate a criterion of 5,000 µg/L.

Table 3.1. Copper criteria for livestock watering

Criteria Statement	Criteria Values	Jurisdiction	Date	Reference
Recommended upper limit of 500 µg/L for livestock drinking water	500 µg/L	U.S. EPA	1972	USEPA, 1973
The derived working level for copper in livestock drinking water will range from 500 to 2,000 µg/L depending upon the dietary intake of copper	500 to 2,000 µg/L	Australia	1974	Hart, 1974
Recommended copper concentration of 500 µg/L in drinking water for live-stock and poultry	500 µg/L	National Academy of Sciences	1974	NAS, 1974
Maximum concentration of copper 20 µg/L	20 µg/L	Saskatchewan Alberta	1975 1977	Environment Saskatchewan, 1975; Alberta Environment, 1977
For sheep, the estimated maximum safe dietary concentration ranges from just above 5 µg/g (when molybdenum levels are low) to perhaps 20 µg/g	5 to 20 µg/g of diet			

Table 3.1. (Continued).

Criteria Statement	Criteria Values	Jurisdiction	Date	Reference
For cattle, the estimated maximum safe dietary con of diet centration is 100 µg/g	100 µg/g of diet	Neathery and Miller	1977	Neathery and Miller, 1977a-b
For swine, the estimated safe dietary concentration ranges from 150 to 400 µg/g	150 to 400 µg/g of diet			
For chicks, the estimated maximum safe dietary concentration is 250 µg/g	250 µg/g of diet			
For turkeys, the estimated maximum safe dietary concentration is 500 µg/g	500 µg/g of diet			
Recommended objective of 1000 µg/L (as total copper) if sheep and cattle present and 5,000 µg/L for all other cases	1000 to 5,000 µg/g	Canada	1981	Demayo and Taylor, 1981
Maximum acceptable concentration of 1,000 µg/L as total copper.	1,000 µg/L	Manitoba	1983	Manitoba Department of Environment and Workplace Safety and Health, 1983
Copper in water used for livestock should not exceed 500 µg/L.	500 µg/L	Ontario	1984	Ontario Ministry of Environment, 1984
Recommended average concentration of 200 µg/L total copper in water for livestock.	200 µg/L	United Kingdom	1984	Mance et al., 1984
The copper concentration in livestock drinking water should not exceed 1.0 mg/L for cattle and 5.0 mg/L for swine and poultry. For sheep a maximum of 0.5 mg/L is recommended. However, these levels should be revised downward, especially for sheep, if levels of copper are high in forage plants and in soil, or if copper is regularly given to livestock as a dietary supplement.	1,000 µg/L 5,000 µg/L 500 µg/L	CCREM	1987	Canadian Council of Resource and Environment Ministers, 1987

In developing water quality criteria for Australia, Hart (1974) points out that the safe level of Cu in livestock drinking water will depend upon the dietary intake of Cu. Considering this factor and the aggravation of Cu toxicity by Mo deficiencies, Hart (1974) derived a working level for Cu in livestock drinking water of 500 to 2,000 µg/L.

The National Research Council (1968) recommends a safe dietary intake level of about 9 mg/d for sheep.

3.3. Recommended Criterion

The criterion to protect livestock from Cu in water is based on the safe dietary intake level of 9 mg/d for sheep, recommended by the National Research Council (1968). As sheep are the most sensitive livestock to Cu, the criterion will provide sufficient protection for all other species of livestock.

The maximum concentration of total Cu in livestock drinking water should not exceed 300 µg/L.

3.4. Rationale

The criterion recommended in this document for the protection of livestock has been developed from information obtained from the National Research Council (1968), the National Academy of Science (NAS, 1974), the Inland Waters Directorate (Demayo and Taylor, 1981), and a joint publication of Agriculture Canada and the B.C. Ministry of Agriculture (1981).

The criterion level for ruminants (1,000 µg/L) developed by the Inland Waters Directorate (Demayo and Taylor, 1981) was not considered to be restrictive enough to protect sheep adequately from waterborne Cu in addition to Cu uptake from food sources, or when Cu toxicity is aggravated by Mo deficiencies. In deriving the criterion for ruminants, the Inland Waters Directorate used the upper safe dietary level for sheep (20 µg/g) instead of the lower limit (just above 5 µg/g) estimated by Neathery and Miller (1977a). The upper safe limit appears dangerously close to levels shown to cause poisoning in sheep (NAS, 1974). However, the lower limit (5 µg/g) may be questionable in terms of Cu deficiency because the recommended dietary level for sheep is 5 to 10 µg/g (Agriculture Canada and B.C. Ministry of Agriculture, 1981).

We recommend a level based on the safe Cu intake level of 9 mg/d for sheep as stated by the National Research Council (1968). Assuming a dry food intake for sheep of about 1 kg/d (Demayo and Taylor, 1981), and an average Cu concentration in grass (NAS, 1977) and hay (Agriculture Canada and B.C. Ministry of Agriculture, 1981) in British Columbia of 5 mg/kg, the average Cu intake in food would be 5 mg/d. This would permit a daily uptake of 4 mg (9 mg - 5 mg) of Cu from the water. According to the National Academy of Sciences (NAS, 1974), the daily water requirement for sheep ranges from 4 to 15 litres. Therefore, assuming maximum water intake, the maximum acceptable concentration of Cu in water should be about 300 µg/L (rounded off) for sheep. Thus, a maximum of 300 µg/L is recommended for water used by livestock. This level will allow for Cu uptake from dietary sources other than drinking water.

Although this level is overprotective for other species of livestock it does not restrict an area to only the more tolerant species. In other words, the raising of sheep remains a viable option without the risk of toxic conditions.

In practice, levels of this magnitude are unlikely to be encountered, and for the majority of cases the criteria for the protection of aquatic life will apply to waters being used by livestock.

4. IRRIGATION

4.1. Effect

Copper is essential to plant life but, according to the U.S. EPA (1973), concentrations of 100 to 1000 µg/L in nutrient solutions have been found toxic to a large number of plants.

The effects of Cu on plants have recently been reviewed by the Inland Waters Directorate (Demayo and Taylor, 1981). One of the aspects reviewed was the availability of Cu in the soil to plants. According to Murphy (1974), Cu^{+} and Cu^{2+} are the forms of Cu which can be absorbed by plants. The availability of Cu to plants is dependent upon a number of factors including the soil type, its composition and texture, the microbial activity of the soil, pH, oxidation-reduction potential, moisture, rainfall, and the plant species. In general, Cu is less available to plants in soils with a high organic content or high pH due to complexing with the humic materials (Demayo and Taylor, 1981). Delas (1963) reported that the normal Cu concentration in uncontaminated soils from a number of countries ranged from 20 to 50 µg/g. The average Cu concentration in British Columbia soils ranged from 10 to 30 µg /g (Warren et al., 1970).

Levels as high as 2,190 µg/g have been reported in the surface layer of soil on a farm near a nickel-cobalt smelter (Frank et al., 1976a). Copper also tends to accumulate in orchard soils as a result of treatment with Cu fungicides (Frank et al., 1976b). According to Delas (1963), Cu tends to stay on the soil surface where it is strongly complexed with organic material and not available for rapid uptake by plants.

Demayo and Taylor (1981) noted that Cu does not appear to accumulate in plant tissues to the same degree as other elements. The normal range of Cu in plant tissues has been reported to be from 1 to 50 µg/g (dry weight) (NAS, 1977). In British Columbia, Cu levels in a number of vegetables ranged from 1 to 15 µg/g (Hill et al., 1964). In general, grasses appear to have lower average concentrations (5 µg/g) than legumes (15 µg/g). A review of several studies by Demayo and Taylor (1981) indicated that fertilization with Cu contaminated sewage wastes can increase the soil Cu content considerably, but accumulation of Cu in the plants was relatively small. In a number of cases, Cu-supplemented soil either increased or did not change the plant yield. Conversely, Webber (1972) demonstrated that Cu-supplemented sewage applied to a field at a rate of 20 µg/g of soil reduced the yield of red beets by 19 percent and the yield of celery by 13 percent.

The addition of Cu to forest soils is reported to reduce the decomposition of organic matter by affecting biological and biochemical activity (Tyler, 1975). Mathur and Rayment (1977) noted some reduction in the nitrogen mineralization rate at a Cu concentration of about 50 µg/g in the soil which corresponded to three times the background concentration.

Regarding the acute toxicity of Cu, Berry (1977) reported that the 5-day lethal threshold for lettuce seedlings grown in solution was 1,000 µg/L. A concentration of 1,300 µg/L eventually killed the plants.

Regarding the chronic toxicity of Cu to plants, Davis and Beckett (1978) reported that the critical concentrations of Cu in plant tissue ranged from 14 to 25 µg/g (dry weight) for a variety of plants.

In nutrient solutions supplemented with Cu, the critical concentrations ranged from 300 µg/L for rape to 17,700 µg/L for barley (Hunter and Vergnanao, 1953). Nutrient solutions containing Cu at a concentration of 1,000 µg/L reduced root growth of tomatoes and lettuce (Hutchinson and Whitby, 1973), and a concentration of 2,000 µg/L caused blanching in oats (Hunter and Vergnanao, 1953). Delas (1963) reported that the minimum toxic concentration of Cu in soil solutions was about 1000 µg/L.

Wallace and Romney (1977) reported that Cu in conjunction with nickel (Ni) or Ni and Zn in soil resulted in synergistic effects on bush beans.

Delas (1963) noted that Cu became toxic to sensitive plants at levels of 25 to 50 µg/g of soil. In soil solutions, the minimum toxic level was about 1,000 µg/L. The toxicity of Cu was greater at pH values below 6 to 7 and in humid climates. A low soil exchange capacity also increased Cu toxicity.

4.2. Criteria from the Literature

Criteria to protect crops from the harmful effects of Cu in irrigation waters have been compiled from other jurisdictions (Table 4.1). Criteria levels are very consistent for the various jurisdictions and range from 200 µg/L for long-term use on all soils, or on sensitive crops, to 5,000 µg/L for short-term use on fine textured soils. The similarity of the criteria from the various jurisdictions indicates a common source or method from which the criteria have been derived. Both the U.S. EPA (1973) and the Inland Waters Directorate (Demayo and Taylor, 1981) have derived their criteria on the basis of the accumulation of Cu in the soil because a large portion of the available data specifies the toxicity of Cu to plants in terms of soil Cu concentrations. For example, Chaney (1973) assumed that 1 m^3 of water is used to irrigate 1 m^2 of land per year. If the Cu concentration of the irrigation water is 200 µg/L, the soil depth 15 cm, and soil density 1.7 kg/dm^3 then 0.8 µg/g of Cu will be added to the soil each year. Since the toxicity threshold of soil Cu to sensitive plants (e.g. vegetables) occurs at about 25 to 50 µg/g when soil conditions are favourable for the uptake of Cu by plants, then 30 years would be necessary before soil Cu concentrations reached minimum toxic levels if background Cu levels were negligible. Based on these determinations, Demayo and Taylor (1981) concluded that a maximum Cu level of 200 µg/L in irrigation water would provide an ample safety factor even if background soil Cu levels were not negligible.

Table 4.1. Copper criterion for irrigation

Criteria Statement	Criteria values	Jurisdiction	Date	Reference
Recommended maximum for 200 µg/L U.S. EPA irrigation waters is 200 µg/L for continuous use on all soils	200 µg/L	U.S. EPA	1972	USEPA, 1973
Recommended maximum for irrigation waters is 5000 µg/L for short- term use on fine-textured soils	5,000 µg/L	U.S. EPA	1972	USEPA, 1973
The derived working level for copper in irrigation waters is 200 µg/L for continuous use on all soils	200 µg/L	Australia	1974	Hart, 1974
The recommended objective for total copper in irrigation waters is: (a) 200 µg/L for continuous use on all soils or inter-mittent use for copper sensitive plants, e.g. vegetables (b) 1000 µg/L for less sensitive plants, e.g. cereals (c) 5000 µg/L for short- term use	200 to 5,000 µg/L	Canada	1981	Demayo and Taylor, 1981
Where irrigation is the only source of water, the maximum acceptable concentration of total copper is 200 µg/L Where irrigation is used as a supplemental source of water, the maximum acceptable concentration of total Cu is 5,000 µg/L	200 µg/L 5,000 µg/L	Manitoba	1983	Manitoba Department of Environment and Workplace Safety and Health, 1983
Maximum concentration of copper in irrigation waters used continuously on all soil= 200 µg/L Maximum concentration of copper used up to 20 years on fine textured soils of pH 6.0 to 8.5 is 5,000 µg/L	200 µg/L 5,000 µg/L	Ontario	1984	Ontario Ministry of Environment, 1984
Recommended average concentration of 500 µg/L total copper in irrigation water	500 µg/L	United Kingdom	1984	Mance et al., 1984
The total copper concentration in irrigation water should not exceed 200 µg/L for continuous use on all soils For irrigation of crops that have a low sensitivity to copper, such as cereals, a maximum copper concentration in irrigation water of 1,000 µg/L is recommended. The concentration of copper may be increased to 5,000 µg/L for use on neutral to alkaline soils for up to 20 years.	200 µg/L 1,000 µg/L 5,000 µg/L	CCRM	1987	Canadian Council of Resource and Environment Ministers, 1987.

4.3. Recommended Criterion

A criterion to protect vegetation from the harmful effects of anthropogenically induced Cu in irrigation waters has been adapted from criteria recently developed by the Inland Waters Directorate (Demayo and Taylor, 1981) as follows:

In irrigation waters, the maximum total Cu concentration should not exceed 200 µg/L.

4.4. Rationale

The rationale for the choice of the criterion is based on calculations by Chaney (1973) (Section 4.2) of soil Cu accumulation through irrigation practises and upon the threshold toxicity of soil Cu to sensitive plants.

The criteria specified by the Inland Waters Directorate (Demayo and Taylor, 1981) were derived by Chaney's method (Chaney, 1973) and are reported to provide a good safety margin, especially in view that Chaney's calculations were based on irrigation practises for very arid areas such as California. The time for toxic conditions to develop (30 years) is underestimated for most agricultural regions in B.C., except perhaps for Okanagan fruit crops where application rates of 100 cm/year may occur in particularly arid years. In other regions of B.C., application rates of 10 to 40 cm/year are more typical (Canadian Council of Resource and Environment Ministers, 1987). Hence, at a Cu concentration of 200 µg/L in irrigation water, Cu-sensitive crops could be grown safely in most regions of B.C. for at least a century. Furthermore, since Chaney's calculations do not take into account the perpetual extraction of Cu from the soil by plants which, when harvested, redistribute the Cu through the food web, it is unlikely that Cu will ever reach toxic levels in the soils, even in arid regions.

As noted in Table 4.1, the Inland Waters Directorate (Demayo and Taylor, 1981) recommended separate criteria for Cu in irrigation water depending upon the irrigation frequency, the soil type, and the sensitivity of the crop to Cu. To simplify this approach and to remove qualitative judgements of soil type and irrigation frequency, a single criterion of 200 mg/L is recommended regardless of these factors. This single criterion will protect Cu-sensitive plants on all soils, regardless of the irrigation frequency so that crop rotation can be practised freely, and not restricted to certain Cu-tolerant crops because of elevated soil Cu accumulation from earlier applications.

On a practical basis, levels of this magnitude are unlikely to be encountered and, for the majority of cases, the criteria for the protection of aquatic life will apply to waters being used for irrigation purposes.

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