Table A-1. Interim Assessment Criteria for Soil and Water (Continued)

	Soil	Water
Inorganic Parameters (cont'd)		
silver	2	5
sulphur (elemental)	250	---
thallium	0.5	---
tin	5	10
vanadium	25	---
zinc	60	50
Monocyclic Aromatic Hydrocarbons		
benzene	0.05	0.5
chlorobenzene	0.1	0.1
1,2-dichlorobenzene	0.1	0.2
1,3-dichlorobenzene	0.1	0.2
1,4-dichlorobenzene	0.1	0.2
ethylbenzene	0.1	0.5
styrene	0.1	0.5
toluene	0.1	0.5
xylene	0.1	0.5
Phenolic Compounds		
non-chlorinated[2] (each)	0.1	0.1
chlorophenols[3] (each)	0.05	1.0
Polycyclic Aromatic Hydrocarbons (PAHs)		
benzo(a)anthracene	0.1	0.01
benzo(a)pyrene	0.1	0.01
benzo(b)fluoranthene	0.1	0.01
benzo(k)fluoranthene	0.1	0.01
dibenz(a,h)anthracene	0.1	0.01
indeno(1,2,3-c,d)pyrene	0.1	0.1
naphthalene	0.1	0.2
phenanthrene	0.1	0.2
pyrene	0.1	0.2
Chlorinated Hydrocarbons		
chlorinated aliphatics[4] (each)	0.1	0.1
chlorobenzenes[5] (each)	0.05	0.3
hexachlorobenzene	0.1	0.1
hexachlorocyclohexane	0.01	---
PCBs[6]	0.1	0.1
PCDDs and PCDFs[7]	0.00001	---

Table A-1. Interim Assessment Criteria for Soil and Water (Continued)

	Soil	Water
Miscellaneous Organic Parameters		
non-chlorinated aliphatics (each)	0.3	---
phthalic acid esters (each)	30	---
quinoline	0.1	---
thiophene	0.1	---

Table A-1 footnotes.

[1]Set equal to the Agricultural Remediation Criteria value (see Table A-2).

[2]Non-chlorinated phenolic compounds include
2,4-dimethylphenol
2,4-dinitrophenol
2-methyl 4,6-dinitrophenol
nitrophenol (2-, 4-)
phenol
cresol

[3]Chlorophenols include
chlorophenol isomers (ortho, meta, para)
dichlorophenols (2,6- 2,5- 2,4- 3,5- 2,3- 3,4-)
trichlorophenols (2,4,6- 2,3,6- 2,4,5- 2,3,5- 2,3,4- 3,4,5-)
tetrachlorophenols (2,3,5,6- 2,3,4,5- 2,3,4,6-)
pentachlorophenol

[4]Aliphatic chlorinated hydrocarbons include
chloroform
dichloroethane (1,1- 1,2-), dichloroethene (1,1- 1,2-)
dichloromethane
1,2-dichloropropane, 1,2-dichloropropene (cis and trans)
1,1,2,2-tetrachloroethane, tetrachloroethene
carbon tetrachloride
trichloroethane (1,1,1- 1,1,2-), trichloroethene

[5]Chlorobenzenes include
all trichlorobenzene isomers
all tetrachlorobenzene isomers
pentachlorobenzene

[6]PCBs include mixtures 1242, 1248, 1254, and 1260.

[7]PCDDs and PCDFs expressed in 2,3,7,8,-TCDD equivalents. NATO International Toxicity Equivalency Factors (I-TEFs) for congeners and isomers of PCDDs and PCDFs are as follows:

Congener	TEF	Congener	TEF
2,3,7,8-T_4CDD	1.0	2,3,7,8-T_4CDF	0.1
1,2,3,7,8-P_5CDD	0.5	2,3,4,7,8-P_5CDF	0.5
1,2,3,4,7,8-H_6CDD	0.1	1,2,3,7,8-P_5CDF	0.05
1,2,3,7,8,9-H_6CDD	0.1	1,2,3,4,7,8-H_6CDF	0.1
1,2,3,6,7,8-H_6CDD	0.1	1,2,3,7,8,9-H_6CDF	0.1
1,2,3,4,6,7,8-H_7CDD	0.1	1,2,3,6,7,8-H_6CDF	0.1
O_8CDD	0.001	2,3,4,6,7,8-H_6CDF	0.1
		1,2,3,4,6,7,8-H_7CDF	0.1
		1,2,3,4,7,8,9-H_7CDF	0.01
		O_8CDF	0.001

Table A-2. Interim Remediation Criteria for Soil

	Agricultural	Residential/ Parkland	Commercial/ Industrial
General Parameters			
pH	6 to 8	6 to 8	6 to 8
conductivity	2	2	4
sodium adsorption ratio	5	5	12
Inorganic Parameters			
antimony	20	20	40
arsenic	20	30	50
barium	750	500	2000
beryllium	4	4	8
boron (hot water soluble)	2	---	---
cadmium	3	5	20
chromium (+6)	8	8	---[1]
chromium (total)	750	250	800
cobalt	40	50	300
copper	150	100	500
cyanide (free)	0.5	10	100
cyanide (total)	5	50	500
fluoride (total)	200	400	2000
lead	375	500	1000
mercury	0.8	2	10
molybdenum	5	10	40
nickel	150	100	500
selenium	2	3	10
silver	20	20	40
sulphur (elemental)	500	---	---
thallium	1	---	---
tin	5	50	300
vanadium	200	200	---[1]
zinc	600	500	1500

Notes: All values in µg/g dry weight unless otherwise stated.

--- value not established.

See page 10 for numbered footnotes.

Table A-2. Interim Remediation Criteria for Soil (Continued)

	Agricultural	Residential/ Parkland	Commercial/ Industrial
Monocyclic Aromatic Hydrocarbons			
benzene	0.05	0.5	5
chlorobenzene	0.1	1	10
1,2-dichlorobenzene	0.1	1	10
1,3-dichlorobenzene	0.1	1	10
1,4-dichlorobenzene	0.1	1	10
ethylbenzene	0.1	5	50
styrene	0.1	5	50
toluene	0.1	3	30
xylene	0.1	5	50
Phenolic Compounds			
non-chlorinated[2] (each)	0.1	1	10
chlorophenols[3] (each)	0.05	0.5	5
Polycyclic Aromatic Hydrocarbons (PAHs)			
benzo(a)anthracene	0.1	1	10
benzo(a)pyrene	0.1	1	10
benzo(b)fluoranthene	0.1	1	10
benzo(k)fluoranthene	0.1	1	10
dibenz(a,h)anthracene	0.1	1	10
indeno(1,2,3-c,d)pyrene	0.1	1	10
naphthalene	0.1	5	50
phenanthrene	0.1	5	50
pyrene	0.1	10	100
Chlorinated Hydrocarbons			
chlorinated aliphatics[4] (each)	0.1	5	50
chlorobenzenes[5] (each)	0.05	2	10
hexachlorobenzene	0.05	2	10
hexachlorocyclobexane	0.01	---	---
PCBs[6]	0.5	5	50
PCDDs and PCDFs[7]	0.00001	0.001	---
Miscellaneous Organic Parameters			
non-chlorinated aliphatics (each)	0.3	---	---
phthalic acid esters (each)	30	---	---
quinoline	0.1	---	---
thiophene	0.1	---	---

Table A-2 footnotes.

[1]Criteria not recommended for commercial/industrial. One possible recourse is to use the residential/parkland value.

[2]Non-chlorinated phenolic compounds include
- 2,4-dimethylphenol
- 2,4-dinitrophenol
- 2-methyl 4,6-dinitrophenol
- nitrophenol (2-, 4-)
- phenol
- cresol

[3]Chlorophenols include
- chlorophenol isomers (ortho, meta, para)
- dichlorophenols (2,6- 2,5- 2,4- 3,5- 2,3- 3,4-)
- trichlorophenols (2,4,6- 2,3,6- 2,4,5- 2,3,5- 2,3,4- 3,4,5-)
- tetrachlorophenols (2,3,5,6- 2,3,4,5- 2,3,4,6-)
- pentachlorophenol

[4]Aliphatic chlorinated hydrocarbons include
- chloroform
- dichloroethane (1,1- 1,2-), dichloroethene (1,1- 1,2-)
- dichloromethane
- 1,2-dichloropropane, 1,2-dichloropropene (cis and trans)
- 1,1,2,2-tetrachloroethane, tetrachloroethene
- carbon tetrachloride
- trichloroethane (1,1,1- 1,1,2-), trichloroethene

[5]Chlorobenzenes include
- all trichlorobenzene isomers
- all tetrachlorobenzene isomers
- pentachlorobenzene

[6]PCBs include mixtures 1242, 1248, 1254, and 1260.

[7]PCDDs and PCDFs expressed in 2,3,7,8-TCDD equivalents. NATO International Toxicity Equivalency Factors (I-TEFs) for congeners and isomers of PCDDs and PCDFs are as follows:

Congener	TEF
2,3,7,8-T_4CDD	1.0
1,2,3,7,8-P_5CDD	0.5
1,2,3,4,7,8-H_6CDD	0.1
1,2,3,7,8,9-H_6CDD	0.1
1,2,3,6,7,8-H_6CDD	0.1
1,2,3,4,6,7,8-H_7CDD	0.1
O_8CDD	0.001
2,3,7,8,-T_4CDF	0.1
2,3,4,7,8,-P_5CDF	0.5
1,2,3,7,8,-P_5CDF	0.05
1,2,3,4,7,8,-H_6CDF	0.1
1,2,3,7,8,9,-H_6CDF	0.1
1,2,3,6,7,8-H_6CDF	0.1
2,3,4,6,7,8-H_6CDF	0.1
1,2,3,4,6,7,8-H_7CDF	0.1
1,2,3,4,7,8,9-H_7CDF	0.01
O_8CDF	0.001

Table A-3. Remediation Criteria for Water[1]

	Freshwater Aquatic Life[2]	Irrigation[2,3]	Livestock Watering[2]	Drinking Water[4,5]
General Parameters				
oxygen, dissolved	5–9.5 mg/L	---	---	---
pH (unitless)	6.5–9.0	---	---	6.5–8.5
total dissolved solids	---	500–3500 mg/L	3000 mg/L	≤500 mg/L[6,7]
Inorganic Parameters				
aluminum	5–100[8]	5000	5000	---[6]
ammonia	1.37–2.2 mg/L[9]	---	---	---
antimony	---	---	---	---
arsenic	50	100	500–5000	25[10]
barium	---	---	---	1000[10]
beryllium	---	100	100[11]	---
boron (hot water soluble)	---	---	---	---
boron (total)	---	500–6000	5000	5000[6]
cadmium	0.2–1.8[12]	10	20	5
calcium	---	---	1000 mg/L	---
chloride (total)	---	100–700 mg/L	---	≤250 mg/L
chloride (total residual)	2	---	---	---
chromium (+6)	---	---	---	---
chromium (total)	2–20	100	1000	50
cobalt	---	50	1000	---
copper	2–4[12]	200–1000[13]	500–5000	≤1000[6]
cyanide (free)	5	---	---	---
cyanide (total)	---	---	---	200[6]
fluoride (free)	---	---	---	---
fluoride (total)	---	1000	1000–2000	1500[6]
iron	300	5000	---	≤300[10]
lead	1–7[12]	200[11]	100	10[10]
lithium	---	2500	---	---
manganese	---	200	---	≤50[10]
mercury	0.1	---	3	1
molybdenum	---	10–50	500	---
nickel	25–150[12]	200	1000	---
nitrate	---[14]	---	---	45 mg/L[10,15]
nitrate and nitrite	---	---	100 mg/L	---
nitrite	0.06 mg/L	---	10 mg/L	4.5 mg/L[10,15]

Notes: All values in µg/L unless otherwise stated.

--- value not established.

See pages 15–16 for numbered footnotes.

Table A-3. Remediation Criteria for Water (Continued)

	Freshwater Aquatic Life[2]	Irrigation[2,3]	Livestock Watering[2]	Drinking Water[4,5]
Inorganic Parameters (cont'd)				
selenium	1	20–50	50	10
silver	0.1	---	---	---
sodium	---	---[16]	---	≤200 mg/L[10]
sulphate	---	---	1000 mg/L	≤500 mg/L[10]
sulphur (total)	---	---	---	---
thallium	---	---	---	---
tin	---	---	---	---
uranium	---	10[11]	200	100
vanadium	---	100	100	---
zinc (total)	30[11]	1000–5000[17]	50 000	≤5000[10]
Monocyclic Aromatic Hydrocarbons				
benzene	300[11]	---	---	5
ethylbenzene	700[11]	---	---	≤2.4
styrene	---	---	---	---
toluene	300	---	---	≤24
xylenes	---	---	---	≤300
Phenolic Compounds				
non-chlorinated[18] (each)	---	---	---	---
phenols (total)	1	---	---	---
chlorinated phenols				
monochlorophenol	7	---	---	---
dichlorophenols	0.2	---	---	900[19]; ≤0.3[19]
trichlorophenols	18	---	---	5[20]; ≤2[20]
tetrachlorophenols	1	---	---	100[21]; ≤1[21]
pentachlorophenol	0.5	---	---	60; ≤30
Polycyclic Aromatic Hydrocarbons (PAHs)				
benzo(a)anthracene	---	---	---	---
benzo(a)pyrene	---	---	---	0.01
benzo(b)fluoranthene	---	---	---	---
benzo(k)fluoranthene	---	---	---	---
dibenz(a,h)anthracene	---	---	---	---
indeno(1,2,3-c,d) pyrene	---	---	---	---
naphthalene	---	---	---	---
phenanthrene	---	---	---	---
pyrene	---	---	---	---

Table A-3. Remediation Criteria for Water (Continued)

	Freshwater Aquatic Life[2]	Irrigation[2,3]	Livestock Watering[2]	Drinking Water[4,5]
Chlorinated Hydrocarbons				
chlorinated aliphatics				
dichloroethane, 1,2-	100	---	---	5[10,11]
dichloromethane	---	---	---	50
hexachlorobutadiene	0.1	---	---	---
hexachlorocyclohexane isomers	0.01	---	---	---
tetrachloroethylene	260[11]	---	---	---[6]
trichloroethylene	20	---	---	50[10]
chlorinated benzenes				
monochlorobenzene	15[11]	---	---	80[10]; ≤30[10]
dichlorobenzene,1,2-	2.5[11]	---	---	200; ≤3
dichlorobenzene 1,3-	2.5[11]	---	---	---
dichlorobenzene, 1,4-	4[11]	---	---	5; ≤1
trichlorobenzene, 1,2,3-	0.9[11]	---	---	---
trichlorobenzene, 1,2,4-	0.5[11]	---	---	---
trichlorobenzene, 1,3,5-	0.65[11]	---	---	---
tetrachlorobenzene, 1,2,3,4-	0.1[11]	---	---	---
tetrachlorobenzene, 1,2,3,5-	0.1[11]	---	---	---
tetrachlorobenzene, 1,2,4,5-	0.15[11]	---	---	---
pentachlorobenzene	0.03[11]	---	---	---
hexachlorobenzene	0.0065[11]	---	---	---
PCBs[22]	1 ng/L	---	---	---[6]
PCDDs and PCDFs[23]	---	---	---	---
Halogenated Methanes				
carbon tetrachloride	---	---	---	5
trihalomethanes	---	---	---	350[6]
Phthalate Esters				
DBP	4	---	---	---
DEHP	0.6	---	---	---
other phthalate esters	0.2	---	---	---
Pesticides				
aldicarb	---	---	---	9
aldrin and dieldrin	4 ng/L	---	---	0.7[6]
atrazine	2	---	---	60[11]
azinphos-methyl	---	---	---	20
bendiocarb	---	---	---	40

Table A-3. Remediation Criteria for Water (Continued)

	Freshwater Aquatic Life[2]	Irrigation[2,3]	Livestock Watering[2]	Drinking Water[4,5]
Pesticides (cont'd)				
bromoxynil	---	---	---	5[11]
carbaryl	---	---	---	90
carbofuran	1.75	---	---	90
chlordane	6 ng/L	---	---	7[6]
chlorpyrifos	---	---	---	90
cyanazine	2[11]	---	---	10[11]
2,4-D	4	---	---	100[6]
DDT	1 ng/L	---	---	30[6,24]
diazinon	---	---	---	20
dicamba	---	---	---	120
diclofop-methyl	---	---	---	9
dimethoate	---	---	---	20[11]
diquat	---	---	---	70
diuron	---	---	---	150
endosulfan	0.02	---	---	---
endrin	2.3 ng/L	---	---	---
glyphosate	65	---	---	280[11]
heptachlor (+ metabolite)	0.01	---	---	3[6]
lindane	---	---	---	4[6]
malathion	---	---	---	190
methoxychlor	---	---	---	900
metolachlor	---	---	---	50[11]
metribuzin	1	---	---	80
paraquat	---	---	---	10[11]
parathion	---	---	---	50
phorate	---	---	---	2[11]
picloram	29[11]	---	---	190[10,11]
simazine	---	---	---	10[11]
2,4,5-T	---	---	---	280; ≤20
temephos	---	---	---	280[11]
terbufos	---	---	---	1[11]
toxaphene	8 ng/L	---	---	---
triallate	---	---	---	230
trifluralin	---	---	---	45[10,11]

Table A-3. Remediation Criteria for Water (Continued)

	Freshwater Aquatic Life[2]	Irrigation[2,3]	Livestock Watering[2]	Drinking Water[4,5]
Radiological Parameters				
^{137}cesium	---	---	---	50 Bq/L[6]
^{131}iodine	---	---	---	10 Bq/L[6]
^{226}radium	---	---	---	1 Bq/L[6]
^{90}strontium	---	---	---	10 Bq/L[6]
^{3}tritium	---	---	---	40 000 Bq/L[6]

Table A-3 footnotes.

[1] Guidelines for freshwater aquatic life, irrigation, and livestock watering (columns 1, 2, and 3, respectively) are taken from the Canadian Water Quality Guidelines (CWQG) (CCREM 1987). The CWQG also recommends guidelines for recreational uses and several specific industrial uses, which are not included in this table. Guidelines for drinking water (column 4) are taken from the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health and Welfare Canada 1989).

[2] Guidelines for heavy metals and trace ions are reported as total concentrations in an unfiltered sample.

[3] Applies to all soils; for details on neutral to alkaline soils, refer to CCREM (1987).

[4] Drinking water guidelines are expressed as maximum acceptable concentrations (MAC), and are for unfiltered samples at the point of consumption. Heavy metals and trace ions are expressed as total concentrations (particulate and dissolved) unless otherwise indicated.

[5] Several parameters also have aesthetic objectives; these are indicated by a "≤" symbol.

[6] Guideline under review for addition to the GCDWQ or possible changes to the current value. Refer to the latest edition of the GCDWQ.

[7] The total dissolved solids concentration of 500 mg/L is approximately equal to a conductivity of 1 dS/m.

[8] Guideline varies with pH, calcium, and dissolved organic carbon concentrations.

[9] Guideline changes with temperature and pH.

[10] A modification to the previous guideline is proposed. If after one year, no evidence is presented that questions the suitability of this proposal, it will be adopted as the guideline. Refer to the latest edition of the GCDWQ.

[11] Tentative water quality guideline/interim drinking water guideline because of insufficient evidence; refer to the latest edition of the CWQG or GCDWQ.

[12] Guideline changes with hardness.

[13] Guideline varies depending on crop.

[14] Avoid concentrations that stimulate prolific weed growth.

[15] Equivalent to 10.0 mg/L nitrate as nitrogen. Where nitrate and nitrite are determined separately, levels of nitrite should not exceed 4.5 mg/L (1.0 mg/L as nitrogen).

[16] Refer to CCREM (1987).

[17] Guideline changes with pH.

Table A-3 footnotes continued.

[18]Non-chlorinated phenolic compounds include
2,4-dimethylphenol
2,4-dinitrophenol
2-methyl 4,6-dinitrophenol
nitrophenol (2-, 4-)
phenol
cresol

[19]As 2,4-dichlorophenol.

[20]As 2,4,6-trichlorophenol.

[21]As 2,3,4,6-tetrachlorophenol.

[22]Total PCB analysis only for freshwater aquatic life guidelines.

[23]Quoted as 2,3,7,8-TCDD equivalents. PCDDs and PCDFs expressed in 2,3,7,8-TCDD equivalents. NATO International Toxicity Equivalency Factors (I-TEFs) for congeners and isomers of PCDDs and PCDFs are as follows:

Congener	TEF
2,3,7,8-T_4CDD	1.0
1,2,3,7,8-P_5CDD	0.5
1,2,3,4,7,8-H_6CDD	0.1
1,2,3,7,8,9-H_6CDD	0.1
1,2,3,6,7,8-H_6CDD	0.1
1,2,3,4,6,7,8-H_7CDD	0.1
O_8CDD	0.001
2,3,7,8-T_4CDF	0.1
2,3,4,7,8-P_5CDF	0.5
1,2,3,7,8-P_5CDF	0.05
1,2,3,4,7,8-H_6CDF	0.1
1,2,3,7,8,9-H_6CDF	0.1
1,2,3,6,7,8-H_6CDF	0.1
2,3,4,6,7,8-H_6CDF	0.1
1,2,3,4,6,7,8-H_7CDF	0.1
1,2,3,4,7,8,9-H_7CDF	0.01
O_8CDF	0.001

[24]Includes DDT metabolites.

Annex D: Canadian Sediment Quality Guidelines (Including Draft Interim Marine Sediment Quality Guidelines and Draft Interim Freshwater Sediment Quality Guidelines)

Evaluation and Interpretation Branch
Environment Canada
351 St. Joseph Blvd., 8th Floor
Hull, Quebec K1A 0H3

August 23, 1994

Doug Bright
Environmental Sciences Group
Royal Roads Military College,
FMO, Victoria
BC V0S 1B0

Dear Mr. Bright:

Thank you for your interest in Canadian sediment quality guidelines. I have enclosed a final draft copy of the protocol for the development of Canadian sediment quality guidelines, which has been vetted through the Canadian Council of Ministers of the Environment (CCME). The methods used for developing Canadian sediment quality guidelines are based on a weight-of- evidence approach, similar to that described by the Florida Department of Environmental Protection (FDEP) and the National Oceanic and Atmospheric Administration (NOAA). I anticipate that draft guideline documents for cadmium, mercury and several PAHs (13 individual compounds) should be available within the next two months for external review. These will include the development of guidelines for both freshwater and marine systems. The development of guidelines for other chemicals this year will include PCBs, dioxins and furans, arsenic, copper, lead, and zinc. I have added your name to the mailing list in order that you receive copies of our sediment quality guideline documents.

I have also enclosed a copy of a paper that has been just submitted to the Journal of Aquatic Ecosystem Heath. It contains draft sediment quality assessment values (please note that these have not been endorsed as Canadian guidelines as of yet) which are calculated from a biological effects database that has been jointly compiled (for marine sediments) by FDEP, NOAA, and MacDonald Environmental Sciences. You may wish to contact **Fred Calder** (FDEP) - 3900 Commonwealth Blvd., MS46 Tallahassee, Florida 32399-3000 USA and **Ed Long** (NOAA) - Coastal Monitoring and Bioeffects Assessment Division, BIN C15700, 7600 Sand Point Way NE, Seattle, Washington 98115, USA for their agency documentation. Both FDEP and ourselves are using a similar approach to calculating guidelines (using data on both effects and no effects), while those developed by NOAA are based on the effect data only.

I hope this information is useful. Please do not hesitate to call if we can be of any further assistance.

Sincerely,

Sherri Smith.

Karen Keenleyside/Sherri Smith
Guideline Specialists
819-953-4070 and 819-953-3082
fax 819-953-0461

Encl.

The Development and Implementation of Canadian Sediment Quality Guidelines

Sherri L. Smith[1], Donald D. MacDonald[2], Karen A. Keenleyside[1], & Connie L. Gaudet[1]

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Abstract

National sediment quality guidelines for the protection of aquatic life are being developed in Canada under the auspices of the Canadian Council of Ministers of the Environment (CCME). These guidelines are intended to provide nationally consistent benchmarks for evaluating sediment quality for the protection of aquatic life and represent one type of decision support tool for protecting and sustaining aquatic ecosystems in Canada. The Canadian protocol for developing these guidelines involves two separate approaches; the spiked-sediment toxicity test approach and the modified National Status and Trends Program (NSTP) approach. This paper presents draft interim sediment quality guidelines for both freshwater and marine sediments for nine trace metals, 13 individual polycyclic aromatic hydrocarbons (PAHs), total polychlorinated biphenyls (PCBs), seven pesticides and one phthalate ester that were derived using the modified NSTP approach. A preliminary evaluation of these draft interim guidelines has been performed to determine their applicability for evaluating sediment quality in Canada. These guidelines are presently under review by Environment Canada and the CCME.

Key Words: Sediment quality guidelines; Sediment assessment; Contaminants; Biological effects; Freshwater; Marine

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1. Introduction

Water quality concerns have historically been the major focus of environmental protection and assessment activities in Canada. In response to these concerns, Canadian water quality guidelines are developed under the auspices of the Canadian Council of Ministers of the Environment (CCME; a joint federal, provincial, and territorial council formerly known as the Canadian Council of Resource and Environment Ministers, CCREM) to define acceptable water quality for a number of chemical, physical, and biological parameters (CCREM 1987). Water quality guidelines are developed for each of five major water uses, including: 1) raw water for drinking water supply, 2) recreational water quality and aesthetics, 3) agricultural uses including irrigation and livestock water, 4) industrial water supplies, and 5) water to support and protect freshwater aquatic life.

More recently, the focus of environmental protection and assessment activities has shifted to emphasize other important components of ecosystems. The Water Quality Guidelines Task Group of the CCME, which has the mandate to harmonize national aquatic guideline activities, has undertaken the development of guidelines to encompass other media, including marine water quality for the protection of aquatic life (CCREM 1987), marine and freshwater sediment quality for the protection of aquatic life (CCME 1994a), and tissue residues for the protection of wildlife consumers of aquatic life (CCME 1994b). Soil quality criteria (i.e., guidelines) are also being developed for four different land uses; they are vetted through the CCME Subcommittee on Environmental Quality Criteria for Contaminated Sites (Environment Canada 1991; CCME 1991, 1994c). Environment Canada (Evaluation and Interpretation Branch, Ecosystem Conservation Directorate) is the secretariat of both the Task Group and the Subcommittee and, as such, provides scientific and technical support to the development of environmental quality guidelines.

National environmental quality guidelines, which are developed using toxicological information, represent concentrations of individual chemicals below which adverse biological effects are not expected. They are developed with the intention to be conservative, national benchmarks (i.e., reference points) to protect and sustain aquatic and terrestrial life. In the context of the federal government, national environmental quality guidelines play an important role in the environmental legislative framework through the Canadian Environmental Protection Act (CEPA, specifically Parts I, II, IV, and VI), which was proclaimed in 1988. This legislation dictates the federal government's responsibilities with respect to monitoring activities, chemical assessments, pollution prevention and control strategies, and regulatory activities (e.g., ocean disposal of dredged sediments). As these guidelines are national in scope, they are also used in regulatory and non-regulatory activities in provincial and territorial jurisdictions.

Sediments provide habitat for many benthic and epibenthic organisms and, as such, are a critical component of aquatic ecosystems. They also influence the environmental fate of many chemical substances that enter the aquatic environment

since they act as a sink, and subsequently, as a source of these contaminants. Potentially toxic substances have been measured in the sediments of freshwater, estuarine, and marine ecosystems across Canada (Goyette & Boyd 1989; Allan & Ball 1990; Government of Canada 1991a,b; Wells & Rolston 1991). It is clear from these studies that the health of many ecosystems in Canada is threatened by point and/or non-point sources of contaminants. Although sediment chemistry data are essential for evaluating sediment quality, interpretive scientific tools are also required to support the consistent assessment, protection and management of sediment quality and aquatic ecosystems as a whole. Sediment quality guidelines for the protection of aquatic life are one type of decision support tool that help to interpret sediment chemistry data and help to assess the potential toxicity of sediment-associated chemicals to aquatic organisms. They are also useful for identifying and prioritizing areas and chemicals of concern. As national benchmarks, these guidelines help to set targets for sediment quality that will sustain aquatic ecosystem health for the long term.

In Canada, environmental quality guidelines are developed following methods which are described in formal protocols (CCME 1991; CCME 1993; CCME 1994a,b,c). The use of these protocols ensures that guidelines for individual chemicals are developed using consistent and scientifically defensible methods. Derivation procedures are developed to support the CCME intent that the guidelines provide broadly protective tools that will support the functioning of healthy ecosystems. Prior to the development of a formal protocol for the derivation of sediment quality guidelines, available approaches to guideline development were reviewed and evaluated to determine which procedures would be most applicable to the development of national, biological effects-based sediment quality guidelines in Canada (MacDonald *et al.* 1992). As described in the Canadian protocol (CCME 1994a), guideline derivation methods rely on the spiked-sediment toxicity test approach and the National Status and Trends Program (NSTP) approach (Long & Morgan 1990; Long 1992; Long *et al.* 1994), which uses a weight of evidence of the available toxicological information generated from all of the major approaches. A modified version of the NSTP approach will be used in Canada (CCME 1994a) and the state of Florida (MacDonald 1994). The objectives of this paper are to describe these modifications in the context of the Canadian protocol for deriving national guidelines, and to present the draft interim guidelines that have been derived using the modified NSTP approach for both freshwater and marine (including estuarine) sediments.

2.0 Methods

2.1 The Canadian Protocol

The formal process for developing and recommending national sediment quality guidelines in Canada involves a comprehensive evaluation of the available scientific information for each chemical (CCME 1994a). This evaluation includes a review of the sources of the chemical to the aquatic environment, its distribution in Canadian

sediments, its behaviour and persistence in sediments, its potential to bioaccumulate, and its effects on aquatic organisms that are exposed to sediments. A guideline is derived using the available toxicological information and the derivation procedures described in the protocol. Subsequently, the guideline is evaluated in the context of all supporting scientific information. A scientific report is prepared which presents the proposed guideline in the context of the scientific review. The report is endorsed by the CCME following national review by federal and provincial agencies.

The national protocol involves the use of both the modified NSTP approach and the spiked-sediment toxicity test approach to support the derivation of sediment quality guidelines (Figure 1). The latter approach specifically uses information from controlled sediment toxicity tests that investigate dose-response relationships; however, limited information is available and guidelines cannot be currently derived for many chemicals using this approach (see CCME 1994a for a description of these specific procedures). Draft interim sediment quality guidelines have, therefore, been developed using the modified NSTP approach. Information is also required to assess the relative importance of sediment characteristics (e.g., total organic carbon, TOC; grain size; acid volatile sulfides, AVS) in modifying the bioavailability (and hence toxicity) of chemicals, as well as the predictability of these relationships under field situations. This paper specifically focusses on the derivation of interim guidelines using the modified NSTP approach. Guideline documents for a number of substances (including cadmium, mercury, individual PAHs, and PCBs) are currently being finalized based on the formal protocol (Environment Canada, unpublished data).

2.2 Development of Guideline Derivation Tables

The derivation of guidelines using the modified NSTP approach involves the evaluation and compilation of data from numerous studies conducted throughout North America (Long & Morgan 1990; Long & MacDonald 1992; CCME 1994a; Long *et al.* 1994; MacDonald 1994). These data were compiled in a database (referred to as the biological effects database for sediments; BEDS) and were evaluated to establish associations (i.e., not cause and effect relationships) between concentrations of chemicals in sediments and adverse biological effects. Chemical and biological data included in BEDS were obtained from various studies, including models of equilibrium partitioning in sediments, sediment quality assessment values from other jurisdictions (e.g., those derived using the apparent effects threshold approach and the screening level concentration approach), spiked-sediment toxicity tests and field studies (including results of sediment toxicity tests and analyses of benthic community composition). Candidate toxicological data sets were critically evaluated according to a number of screening criteria to ensure that high quality data were incorporated into BEDS and that the information compiled was internally consistent. These screening criteria have been described in more detail elsewhere (CCME 1994a; Long *et al.* 1994; MacDonald 1994).

Nearly 800 publications were evaluated for possible inclusion in BEDS. Of those reports describing studies in marine sediments, 121 were acceptable for inclusion,

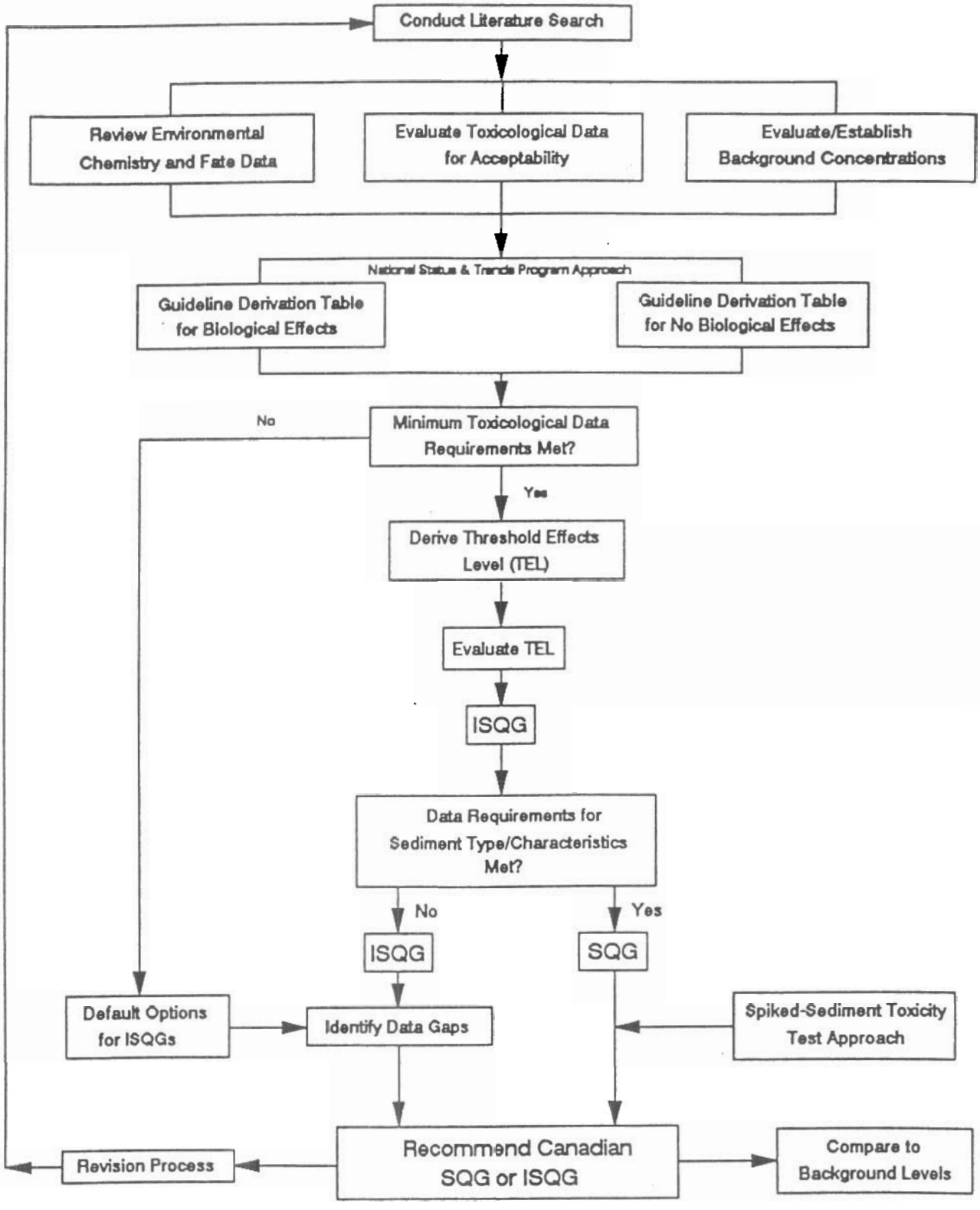

Figure 1. Overview of the Canadian protocol for deriving sediment quality guidelines.

while data from 56 reports on freshwater sediment studies were included. Each entry in BEDS included information on the measured chemical concentration (expressed on a dry weight basis), the location of the study, the approach that was used, the test duration, whether associated biological effects were observed or predicted, the species and life stage tested, and the citation of the report. Other information on factors that are thought to influence bioavailability (e.g., TOC concentrations, AVS concentrations, and grain size) was also tabulated, if it had been reported. This information was sorted for each chemical and sediment type (i.e., freshwater vs. marine) and arranged according to ascending chemical concentrations to produce separate tables for individual chemicals and sediment types. These *guideline derivation tables* were originally reported by Long and Morgan (1990) and have since been updated by MacDonald (1994) and Environment Canada (unpublished data).

Entries in the guideline derivation tables were assigned an effect descriptor (*) if an adverse biological effect (e.g., acute or chronic toxicity observed during a controlled spiked-sediment test, an apparent effect threshold, or predicted toxicity based on equilibrium partitioning theory) was reported. An effect descriptor was also assigned to the entry if concordance was apparent between the observed biological response and the measured chemical concentration in a field (i.e., co-occurrence) study. Concentrations of individual chemicals reported in field studies were considered to be associated with the observed toxic response (i.e., concordance was apparent) if the mean concentration at sites at which significant adverse effects were observed was a factor of two or more greater than the mean concentration at sites at which effects were not observed (i.e., at toxic versus non toxic or reference sites). For each chemical, all of the entries designated by an effect descriptor, as described above, were collectively referred to as the effect data set.

All other entries in the guideline derivation tables were collectively referred to as the no effect data set, and were represented by those entries for which concentrations of the chemical were not associated with adverse biological effects. These entries include those associated with non-toxic, reference or control conditions (i.e., no effects; NE), as well as those for which the mean chemical concentration differed by less than a factor of two (i.e., no gradient, NG; small gradient, SG; or no concordance, NC) between the toxic and non-toxic groups. In the latter case, it was assumed that other factors (whether measured or not) were more important in the etiology of the observed effect than the concentration of the chemical under consideration.

2.3 Guideline Derivation Procedures

The guideline derivation procedures are based on those used in the NSTP approach, with modifications (see also Long & MacDonald 1992; CCME 1994a; MacDonald 1994). This approach, which considers the weight of evidence of sediment toxicological information, was originally described by Long and Morgan (1990). Sediment assessment values were calculated as the lower 10th percentile concentration (Effects Range Low; ERL) and the 50th percentile concentration (Effects

Range Median; ERM) of the effect data set for a chemical. These two values defined concentration ranges that were rarely, occasionally, or frequently associated with adverse effects. The definition of ranges was based on the assumption that the potential for observing toxicity of sediment-associated chemicals increased with increasing chemical concentrations (Long *et al.* 1994). In Canada (CCME 1994a) and in the state of Florida (MacDonald 1994), this original derivation procedure was modified to also include the no effect data set in the calculation of guidelines (as described below). It was considered appropriate to consider the no effect data, given the weight of evidence approach to deriving assessment values and the implicit manner in which varying conditions of bioavailability were addressed through the inclusion of toxicological data from a variety of sites across North America. The use of both the effect and no effect data for all acceptable studies was, therefore, thought to provide a balanced approach to defining the concentration of a chemical that represents no significant hazard to aquatic organisms

In the modified NSTP approach, two assessment values were also calculated for each chemical to define three ranges in the chemical's concentration (also referred to as the minimal, possible, and probable effect ranges, respectively). The lower value, which is referred to as the threshold effect level (TEL), represents the concentration below which adverse effects are expect to rarely occur; this value is generally recommended as an interim Canadian sediment quality guideline. The upper assessment value, referred to as the probable effect level (PEL), defines the level above which adverse effects are predicted to occur frequently. Concentrations which fall in the range between the TEL and the PEL are occasionally expected to be associated with adverse biological effects. These two assessment values refer to the total concentration of a chemical in surficial sediments (i.e., upper few centimetres) on a dry weight basis.

Minimum toxicological data requirements were set to ensure that the assessment values developed from the guideline derivation tables would be supported by the weight of evidence that links chemical concentrations to biological effects (i.e., that the chemical of concern is responsible for the observed biological effect). Both the effect data set and the no effect data set required at least 20 entries in the guideline derivation table for a particular chemical (CCME 1994a). Assessment values were derived separately for freshwater and marine sediments using the toxicological data compiled in the guideline derivation tables, if the minimum data set requirements were met.

For each chemical, a TEL was calculated as the geometric mean of the lower 15th percentile concentration of the effect data set and the 50th percentile concentration of the no effect data set. The objective of establishing the TEL in such a manner was to consistently define the range in chemical concentrations below which adverse effects were rarely anticipated, and thus, represented no significant hazard to aquatic organisms. The PEL was calculated as the geometric mean of the 50th percentile concentration of the effect data set and the 85th percentile concentration of the no effect data set. The objective of defining the PEL was to consistently define the range of chemical concentrations that was frequently associated with adverse biological