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APPENDIX D: Vermont Watershed Management Division's Recommended Guidelines for Evaluating Contaminant Concentrations in Freshwater Sediments and the Potential for those Contaminants to Adversely Affect Aquatic Biota

Sediments in aquatic ecosystems serve as habitat for a wide variety of aquatic organisms which are dependent on the quality of that sediment for their well-being. Higher trophic level organisms can be affected through bioaccumulation and biomagnification of sediment pollutants. The purpose of this document is to provide guidance for assessing the results of chemical testing of sediments in the context of the potential for contaminants in sediments to adversely affect aquatic organisms either through direct toxicity or bioaccumulative exposure.

Evaluation of sediment chemistry serves as an initial screening assessment for the purpose of identifying contaminants of potential concern and ranking the relative risk those contaminants pose to aquatic organisms. This initial screening is accomplished by comparing sediment chemistry results to levels of contaminants that have a high probability of causing adverse effects to aquatic biota. These values are generally referred to as Sediment Quality Guidelines (SQGs), and are located on Table C.1.

Vermont Department of Environmental Conservation recommended SQGs for use in assessing sediment contaminant concentrations are provided in Table D.1. These SQGs are predominantly from MacDonald et al. (2000). These SQGs include a Threshold Effect Concentration (TEC) and a Probable Effects Concentration (PEC). The TEC is a concentration below which adverse effects are unlikely to occur. The PEC is a concentration above which adverse effects are likely to be observed.

SQGs are derived primarily from co-occurrence data collected from field studies with additional laboratory confirmatory toxicity testing data. MacDonald et al. (2000) demonstrate the relative precision of the ability of the SQGs to predict the absence or presence of toxic effects. However, there is a considerable degree of imprecision when extrapolating sediment contaminant concentrations to actual environmental effects, e.g. adverse impacts on ambient organisms and communities. Therefore, SQG comparisons should be the first step in the context of an hierarchal evaluation of sediment impacts.

Exceedence of SQGs may indicate the need for further site assessment, usually based on assessments which increase the precision with which biological impacts are predicted or observed. Such hierarchal assessments may include direct assessment of ambient biological communities or sediment toxicity testing. In the case of bioaccumulative compounds, additional assessment may include biomagnification modeling, laboratory testing of biomagnifications or direct measurement of contaminant concentrations in appropriate organisms. Rarely are SQGs used independently to draw conclusions about environmental impacts or to direct site management decisions.

The SQGs in Table D.1 should be used to 1) identify contaminants of concern, 2) rank the relative site risk based on the extent (number of contaminants and spatial extent) and magnitude of SQG exceedances, and ultimately 3) assess the need for more intensive site evaluations of biological impacts related to the site and the contaminants. For contaminants not included in Table D.1, reliable effects-based sediment quality guidelines published in the scientific literature may be used to find appropriate SQGs. Other potential resources include, but are not limited to:

1. Buchman M.F. 2008. NOAA Screening Quick Reference Tables. NOAA OR&R Report 08-1. Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, Seattle, WA. 34 pp. http://response.restoration.noaa.gov/sites/default/files/SQuiRTs.pdf

2. Long E.R., Morgan L.G. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. NOAA Tech. Memo. NOS OMA 52. National Oceanic and Atmospheric Administration, Seattle, WA. 175 pp.

3. Wisconsin DNR Consensus-Based Sediment Quality Guidelines – December 2003, 35 pp.

4. NYDEC Technical Guidance for Screening Contaminated Sediments – January 1999, 45 pp.

5. Persaud D., Jaagumagi R., Hayton A. 1993. Guidelines for the Protection and Management of Sediment Quality in Ontario. Water Resources Branch, Ontario Ministry of the Environment, Toronto, ON, CAN. 27 pp.

6. EPA Region 3 Biological Technical Assistance Group (BTAG) Screening Values

7. Guidance for the Use and Application of Sediment Quality Targets for the Protection of Sediment-Dwelling Organisms in Minnesota. February 2007, 64 pp.

The SQGs cited in Table D.1 and in the above references are primarily for the protection of benthic organisms. Other approaches such as food chain modeling and fish tissue back calculations may be more appropriate for calculating sediment concentrations protective of fish and wildlife (including humans) at higher trophic levels. The following are some general considerations that may be useful when using SQGs for screening potential adverse effects to aquatic biota:

1. Compare sediment contaminant concentrations with SQGs.
    a. evaluate the quantity, quality and analytical characteristics of the data;
    b. evaluate the spatial and horizontal (depth) distribution of the data;
    c. determine biological receptors likely to be exposed;
    d. describe the number of contaminants and the magnitude of SQG exceedances;

2. For naturally-occurring substances such as metals, determine reference condition (minimally affected by human activity) concentrations for the assessment site and compare to sediment concentrations. Normalize data (e.g. percent fines, total organic carbon (TOC) for organics) if appropriate for inter-site comparisons or comparisons to reference conditions.

3. If data are being used to evaluate impacts from a discrete source (e.g. discharge, site) it may be necessary to evaluate local background conditions (conditions upstream of or outside the influence of the source being evaluated).

4. Information from 1-3 above may be used to prioritize future actions based on general weight-of-evidence (WOE) findings. For example:

    a. If all contaminants are below threshold effect concentrations (TECs) and no other site information indicates the presence of adverse effects, low priority for further action may be appropriate (all available chemical, physical and biological information should be reviewed prior to dismissing need for further evaluation of biological effects);

b. If threshold effects concentrations (TECs) are exceeded but probable effects concentrations (PECs) are not, it is likely that further site assessment in the form of biological community assessments, toxicity testing or both will be required. The degree of response would be dictated by the WOE from 1-3 above;
c. If one or more contaminants exceed probable effects concentrations (PECs), additional site assessment is very likely. In some cases where exceedances are extreme, biological impairment may be assumed with high confidence.

Sampling and Analysis Considerations:

Sediment samples should be collected using standard sampling protocols appropriate to the target analyte. Ancillary data required to utilize SQG comparisons (e.g. total organic carbon for organics) should be generated using standard analytical protocols. Chemical analyses should be conducted using standard operating procedures appropriate to the target analyte. Practical quantitation limits should be less than the SQG to which analytical results will be compared or based upon the best available technology. The precision and accuracy of all data should be documented using standard quality control and assurance procedures appropriate to the analysis. There are many guidance documents for sampling SOPs, two examples of which are referenced below.

Field Sampling Guidance Document #1215 - Sediment Sampling. U.S.EPA Region 9 Laboratory, Richmond, CA. 10 pp. 10.

Ohio EPA Sediment Sampling Guide and Methodologies 2nd Edition, November 2001 pp. 36.

General Comments Regarding SQGs:

1. The potential effects of multiple contaminants in sediments on aquatic biota are relatively unpredictable and unknown at this time; assumptions about independent action, additivity or synergism are not supportable. Hazard quotients (HQ), calculated by dividing the sediment concentration by the SQG (Sed. Conc./SQG) can be used to calculate a mean HQ (Σ HQs/no. of contaminants) and total HQ (ΣHQs) for consideration under WOE, remembering that while common sense would suggest that multiple contaminants at or in exceedance of SQGs present a greater risk than a single contaminant at or above an SQG, there is little scientific data to either support or refute that suggestion.

2. The amount of data necessary to make an appropriate evaluation of a site will vary depending on site-specific attributes. In general, data should be sufficient to estimate the spatial distribution (heterogeneous/homogeneous) of the contamination, have some estimate of temporal reproducibility (i.e., multiple sampling events) of findings, and address any seasonal or temporal considerations that may affect results.

3. The Minnesota Pollution Control Agency maintains a web site with useful resources for assessing and evaluating sediment contaminants.

D.1: Recommended Sediment Quality Guidelines for the Protection of Aquatic Biota in Freshwater Ecosystems
(TEC = Threshold Effect Concentration, PEC = Probable Effects Concentration, DW = dry weight)

Substance	TEC	PEC	Notes
Metals (in mg/kg - ppm DW)			
Arsenic	9.79	33.0	1,2
Cadmium	0.99	4.98	1,2
Chromium	43.4	111	1,2
Copper	31.6	149	1,2
Lead	35.8	128	1,2
Mercury	0.18	1.06	1,2,4
Nickel	22.7	48.6	1,2
Zinc	121	459	1,2
Polycyclic Aromatic Hydrocarbons (in µg/kg - ppb DW)			
Anthracene	57.2	845	1,3
Fluorene	77.4	536	1,3
Naphthalene	176	561	1,3
Phenanthrene	204	1,170	1,3
Benz(a)anthracene	108	1,050	1,3
Benzo(a)pyrene	150	1,450	1,3,4
Chrysene	166	1,290	1,3
Dibenz(a,h)anthracene	33	1,3	
Fluoranthene	423	2,230	1,3
Pyrene	195	1,520	1,3
Total PAHs	1,610	22,800	1,3
Polychlorinated Biphenyls (in µg/kg – ppb DW)			
Total PCBs	59.8	676	1,3,4
Organochlorine Pesticides (in µg/kg – ppb DW)			
Chlordane	3.24	17.6	1,3,4
Dieldrin	1.90	61.8	1,3,4
Sum DDD	4.88	28.0	1,3,4
Sum DDE	3.16	31.3	1,3,4
Sum DDT	4.16	62.9	1,3,4
Total DDTs	5.28	572	1,3,4
Endrin	2.22	207	1,3
Heptachlor Epoxide	2.47	16.0	1,3
Lindane (gamma-BHC)	2.37	4.99	1,3

Notes for Table D.1:

1. Consensus-Based Sediment Quality Guidelines (SQGs) from: MacDonald D.D., Ingersoll C.G. and Berger T.A. 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. Archives of Environmental Contamination and Toxicology 39(1). 20-31.

2. SQGs for metals are based on bulk (unsorted) sediment concentrations. Concentrations of metals in sediments can be normalized on percent fines for the purpose of inter-site comparisons but not for comparisons to these SQGs.

3. The SQGs for organics are derived from samples normalized to 1 percent total organic carbon (TOC) in the sediment. The SQGs presented here are based on an assumed TOC of 1 percent. If site specific data show organic carbon content to be significantly different from 1 percent, concentrations should be normalized to 1 percent TOC (divide the site concentration by the percent TOC) prior to comparison with the SQGs in this table. If non site-specific TOC data are available, assume 1 percent TOC.

4. Included on USEPA's list of important persistent, bioaccumulative, toxic compounds (PBTs).