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GUIDELINES FOR CONDUCTING TMDL CONSULTATIONS ON SELENIUM

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TECHNICAL ASSISTANCE REPORT TO THE U.S. FISH AND WILDLIFE SERVICE
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BACKGROUND:

This report was prepared to provide Environmental Contaminants Specialists in the U.S. Fish and Wildlife Service (Service) with a step-by-step procedure for consultations involving Total Maximum Daily Loads (TMDL's) for selenium. The need for this information stems from recent actions taken by the U.S. Environmental Protection Agency (EPA) that will involve the Service in TMDL consultations on impaired water bodies. The states are required to identify impaired water bodies pursuant to Section 303(d) of the Clean Water Act. The EPA is working with states and implementing the TMDL process as a way to gauge point and non-point sources, allocate/regulate discharges, and improve overall water quality. The EPA has requested that the Service provide input in this process for substances ranging from nutrients and sediments to pesticides and trace elements such as selenium. Every substance identified as a priority must be given a separate TMDL assessment, and this must be done independently for each impaired water body. The Service's role may range from a simple review and recommendation based on available information to coordination/conduct of field work to assess contaminant cycling and fate, fish and wildlife exposure, toxicity, etc., involving considerable time and resources.

The magnitude of this effort becomes apparent when one considers that each state may have hundreds of impaired water bodies that will need TMDL's, many of which could require Service consultation on selenium. Although the EPA has published an overview document that explains principles underlying the development and implementation of TMDL's (USEPA, 1999), no procedures specific to selenium are given. This leaves Service biologists and Environmental Contaminants Specialists without the assessment framework necessary to effectively address the TMDL issue for selenium. Due to selenium's propensity to bioaccumulate and cause reproductive impairment in fish and wildlife, and persist in the environment, selenium-specific methods are needed. It is critical to have a technically sound approach for evaluating selenium because it is a priority contaminant for both the Service and EPA. Moreover, proposing TMDL's for this trace element is likely to generate attention by groups with widely divergent interests, which could lead to opposition and challenging of the methods used. This report provides guidance by laying out an assessment framework that links the basic components of the TMDL process to the site-specific data requirements necessary for selenium. The hazard assessment procedures and interpretive guidelines used in the report have all been published in the peer-reviewed literature.

PROCEDURE:

The framework presented here is structured to answer two basic questions:

(1) Is selenium impairing the water body based on biological criteria, and
(2) If so, what level of selenium load reduction and what allocation among selenium sources/discharges is necessary to correct the problem.

A 7-step procedure can be used to answer these questions and develop environmentally safe TMDL limits for selenium.

Step 1): Delineate and characterize the hydrological unit (HU) of concern.

Local water quality criteria for selenium, and associated TMDL's, should be based on an assessment of the degree of toxicological hazard to fish and wildlife, which is influenced by the spatial and temporal variation of the selenium cycle at the site under consideration. The physical area from which measurements are taken to evaluate selenium residues ad biological threats/effects, i.e., the database for setting criteria and TMDL's, must encompass more than an isolated segment of a river, a tributary stream, etc. Because of hydrological connections between the various aquatic habitats that may be present in a watershed basin – wetlands, rivers, streams, lakes, and impoundments – the toxic threat from selenium contamination is also connected. For example, a TMDL limit that is appropriate for a stream or river where low bioaccumulation occurs may result in *seemingly* harmless concentrations becoming a problem in downstream impoundments or in off-channel bays and wetlands where bioaccumulation is greater. The hydrologically connected parts of a basin downstream of a selenium discharge (natural or anthropogenic selenium source), extending to the point at which new sources of low-selenium water dominate the hydrology (e.g., confluence with a larger tributary or river, spring or groundwater inflow), should be the area evaluated and given a specific TMDL, not isolated parts. Thus, a hydrological unit (HU) should be identified and used as the "site" for the purpose of setting TMDL limits. Importantly, TMDL's derived is this manner will reflect the transport and bioaccumulation of selenium within the entire HU rather than simply focusing on a small, artificially designated segment of the system. Failure to use a HU approach can set the stage for significant biological problems. Consult Lemly (1999) for more information on the rationale and justification for using HU's.

Substitute HU for the term "water body" used by states and EPA in the TMDL documentation, and use the entire HU as a "mixing zone" for the purpose of evaluating potential selenium transport and bioaccumulation. Characterize and map the aquatic system of the HU using available information in combination with field reconnaissance to identify/verify hydrological connections. Identify all aquatic habitat types within the HU: wetlands, streams, rivers, lakes, reservoirs; map their spatial and gradient/hydrological relationships, i.e., know what flows where, and into/out of what. Obtain information on trophic status and volume replacement/retention times for lakes and reservoirs; describe general level of primary productivity (low-oligotrophic, moderate-mesotrophic, high-eutrophic), flow regime (slow, moderate, swift), and dominant sediment characteristics (depositional, erosional, particle size, organic, inorganic, mixed) of flowing-water habitats. Characterize fish and wildlife uses (feeding, breeding, migration, etc.) and identify biota of special concern, i.e., endangered or threatened species and selenium-sensitive species.

Step 2): Determine if selenium is present at hazardous levels in the HU.

Gather information on selenium concentrations. If there is no recent monitoring data (within the past year), then it will be necessary to collect and analyze new samples. Measure selenium concentrations in 5 ecosystem components: water, sediments, benthic macroinvertebrates, fish eggs, aquatic bird eggs (use fish/bird tissue to egg conversion factor of 3.3 if no eggs are available; Lemly and Smith, 1987). If bird eggs **OR** fish eggs cannot be obtained (but not both missing), a 4-component assessment can be done. Spread samples across the entire HU so that several (>5) measures of each component are generated from each habitat type. Maintain high quality assurance/quality control in all sampling and analysis; document QA/QC procedures for future reference. Evaluate selenium concentrations with hazard assessment protocol (Lemly, 1995 for 5-component datasets; Lemly , 1996 for 4-component datasets) to determine the hazard rating. A rating of low, moderate, or high hazard indicates that the TMDL process should continue. A rating of minimal hazard indicates that TMDL calculations are not necessary, but the HU should be monitored by applying the assessment protocol to selenium measurements collected on a 5-year basis. If subsequent monitoring reveals that hazard has increased, TMDL reductions are needed. A rating of no hazard indicates that no further action is necessary.

Step 3): Determine selenium sources, concentrations, and discharge volumes.

Identify all possible sources of selenium (agricultural, industrial, petrochemical, mining, etc.) and map them in the HU, noting their proximity/discharge to specific habitat types, i.e., wetlands, streams, rivers, etc. Determine/verify selenium concentrations from each source using existing data or by analyzing new samples; determine/estimate average discharge volume from each source. Calculate total existing selenium loading rate to the HU (kg/day).

Step 4): Estimate the assimilative capacity of the HU for selenium.

A key part of the TMDL process is to estimate assimilative capacity (AC). This will determine the sensitivity of the HU to selenium and, thereby, serve as an indicator of how much selenium the system can tolerate. For the purposes of this report, assimilative capacity (AC) is defined as the propensity of a system to retain selenium. Components of AC include accumulation, metabolic processing, physical and chemical sequestration, and recycling within the HU. The more that selenium is held within a HU – whether incorporated in biota, deposited in sediments, etc., – the higher the AC. It is necessary to know AC in order to develop an environmentally sound TMDL because the higher the AC, the lower the TMDL has to be to prevent toxic threats to fish and wildlife.

To a large extent, AC depends on the degree of bioaccumulation and internal recycling in the HU, which is reflected in primary productivity, water flow regime, and sediment type. Information on these three factors should be available from the characterization of HU done in Step 1 (above). Once this information is available, use the matrix in Table 1 to assign each of these factors a separate AC rating; low, medium, or high.

Table 1. Assimilative Capacity (AC) ratings for aquatic systems based on habitat type and general biological/physical characteristics.

	Habitat Type		
	Stream/River	Lake/Reservoir	Wetland
Productivity			
High (eutrophic)	High	High	High
Moderate (mesotrophic)	Medium	Medium	Medium
Low (oligotrophic)	Low	Low	Low
Flow			
Swift	Low	Low	Low
Moderate	Medium	Medium	Medium
Slow	High	High	High
Sediment			
Inorganic	Low	Low	Low
Mixed	Medium	Medium	Medium
Organic	High	High	High

An overall AC rating for each habitat type is determined by combining the three factor ratings as follows:

3 low ratings = low AC

2 low and 1 medium = low AC

2 low and 1 high = medium AC

2 medium and 1 low = medium AC

2 medium and 1 high = medium AC

2 high and 1 low = medium AC

2 high and 1 medium = high AC

3 high ratings = high AC

The final AC rating for the HU should be set equal to the highest individual factor rating. For example, if there are two habitat types with low AC and one with medium AC, the final AC rating for the HU is medium AC.

Step 5): Estimate the total allowable selenium load.

Begin by plugging the hazard rating from Step 2, and the AC from Step 4, into the matrix in Table 2. The table indicates the appropriate degree of load reduction needed: small, medium, or large.

Table 2. Amount of selenium load reduction necessary for the HU based on hazard rating and assimilative capacity.

	Hazard Rating		
	Low	Moderate	High
AC of HU			
Low	Small	Medium	Large
Medium	Medium	Medium	Large
High	Medium	Large	Large

The existing total selenium load should be reduced by 10% if the amount designated is small, 25% if it is medium, and 50% if it is large. Subtract the indicated amount from the total existing selenium loading rate (kg/day) calculated in Step 3. This will yield the total allowable selenium load for the HU.

Step 6): Allocate total allowable selenium load among discharge sources.

Designate allowable discharges making sure to keep habitat type and sensitive species in mind. For example, it would be inappropriate to allow the largest loading to occur in habitats occupied by priority species (threatened or endangered, or management priority) or where bioaccumulation would be greatest (e.g., in a wetland, off-channel backwater area of a river, or reservoir).

Step 7): Monitor to determine effectiveness of selenium load reduction in meeting environmental quality goals.

The objective of the TMDL process is to keep selenium concentrations below levels that are toxic to biota. Therefore, it is important to use environmental quality goals as a guide in follow-up effectiveness monitoring. For this purpose, I recommend that the following guidelines be used as maximum allowable selenium concentrations (Lemly, 1993, 1995):

Water = 2 µg/l, filtered samples (0.45 µm)
Sediment = 4 µg/g dry weight
Benthic invertebrates = 3 µg/g dry weight
Fish tissues: whole body = 4 µg/g dry weight
skeletal muscle (skinless fillets) = 8 µg/g dry weight
liver = 12 µg/g dry weight
ovary and eggs = 10 µg/g dry weight
Aquatic bird tissues: liver = 10 µg/g dry weight
eggs = 3 µg/g dry weight

These guideline values represent concentrations that are protective of fish and wildlife reproduction. Monitor selenium residues annually, and apply hazard assessment protocols (same as for Step 2) to determine if hazard is reduced to an acceptable level. If yes, then no further load reductions are necessary – conduct environmental monitoring every 5 years. If no, repeat Step 5 to determine the additional amount of selenium load reduction necessary, implement load reduction, and monitor annually. The entire TMDL process is summarized in Figure 1.

FIGURE 1. TMDL DECISION TREE FOR SELENIUM

Delineate and Characterize Hydrological Unit (HU)

▼

Measure selenium (Se) concentrations

▼	▼
Hazardous levels present	Safe levels present
▼	▼
Determine existing Se Load	No further action
▼	
Estimate HU Assimilative Capacity	
▼	
Determine allowable Se load	
▼	
Prescribe and implement Se load reduction	
▼	
Monitor effectiveness of load reductions	

▼	▼
Environmental Goals met	Goals Not met
▼	▼
No further action	Further load reductions
	▼
	Monitor effectiveness

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