

DRAFT RSET ISSUE PAPER #16 – Framework For Assessing Bioaccumulation Under RSET

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QUESTION/ISSUE: How should potential toxicity associated with bioaccumulation be addressed as part of the Pacific Northwest Region Sediment Evaluation Framework?

DISCUSSION:

Background: The current Dredged Material Evaluation Framework (DMEF) for the Lower Columbia River Management Area contains guidance for assessing bioaccumulation in section 9.4 of the manual (USACE et al. 1998). This manual is in the process of being updated and consolidated with other dredging manuals in the Pacific Northwest Region, and will apply to both marine and freshwater areas in Washington, Oregon, and Idaho. While primarily focused on dredging projects, it is also intended to provide a framework consistent with cleanup and habitat restoration projects in the region. The text included in the existing DMEF is something of a placeholder, to be used until the Regional Sediment Evaluation Team (RSET) is able to develop a more comprehensive and up-to-date approach to addressing potential risks associated with bioaccumulation.

In the DMEF manual, bioaccumulation testing is a Tier III requirement when there is reason to believe that specific chemicals of concern may be accumulating in target tissues at levels of concern. Reason to believe is established by comparing sediment concentrations to bioaccumulation triggers (BTs) listed in Appendix C. However, most of these bioaccumulation trigger values are based on the Screening Levels (SLs) and Maximum Levels (MLs), which are themselves derived from sediment toxicity tests rather than bioaccumulation tests or bioaccumulation-based risk assessments. Therefore there has been a recognized need to update the bioaccumulation triggers to be directly reflective of toxicity through the bioaccumulation pathway.

In the existing process, once the bioaccumulation tests are triggered the results are first compared to tissue concentrations from the reference samples. If concentrations are not statistically greater than in the reference tissues, the DMEF manual states that sediments are assumed to be associated with no adverse effects (which may or may not be the case). If test sample concentrations exceed reference sample concentrations, they are compared to human health and ecological levels of concern.

Human health comparisons are currently based on Food and Drug Administration (FDA) action levels, above which tissue concentrations would be considered to be of concern. For chemical concentrations lower than or without FDA action levels, risk assessment

techniques are to be used. For ecological effects, a simple exceedance of reference conditions is enough to trigger a determination of unsuitability. However, the text also references the Environmental Residue Effects Database (ERED) as information that could be used in assessing potential ecological risks. These tissue levels need to be updated and expanded to be more reflective of actual risks to humans and wildlife associated with bioaccumulation.

In addition, the SEF is attempting to expand its scope to include not only dredged material management projects, but also sediment cleanup projects. A more holistic approach to bioaccumulation issues is needed that allows both types of projects to be integrated on a watershed-wide scale to meet common risk-based goals, and which also incorporates regional monitoring. Ideally, a cost-effective approach could be developed to assess and integrate tissue concentrations, sediment concentrations, and effects endpoints.

Discussion: The Bioaccumulation Subcommittee identified a number of areas where the bioaccumulation approach needs to be clarified and/or updated:

- Methods for establishing “reason to believe” that bioaccumulation is a concern for a particular project
- Identification of bioaccumulative chemicals of concern for freshwater and marine areas
- Determining what type of tiered approach is appropriate for assessing bioaccumulation and whether there are differences between dredging and cleanup projects in this respect
- Methods for establishing sediment and/or tissue guidelines based on risks associated with bioaccumulative chemicals
- Bioaccumulation testing protocols, especially for freshwater
- Identification of appropriate freshwater reference areas (this issue is being addressed by the SQG subcommittee)

Of these issues, one of the most difficult is establishing a link between tissue concentrations, which have the most direct association with risks from bioaccumulative chemicals, and sediments. This consideration led to spirited discussion of the use of a “top-down” approach – i.e., assessing bioaccumulative risks on a watershed-wide basis in tissues and only then moving to sources in sediments – vs. a “bottom-up” approach more traditional in dredging programs, with chemical triggers in sediments and bioaccumulation testing in a subsequent tier. The most significant obstacle in pursuing the traditional dredging program approach is establishing sediment bioaccumulation triggers that are scientifically defensible. Nevertheless, the committee recognizes this as a clear goal of the dredging program, to simplify the decision process for applicants and reduce the cost of testing. The recommended framework outlined below blends the two approaches.

Regardless of which approach is pursued, it was agreed that the first step is to establish scientifically defensible tissue triggers based on protection of human health, fish and aquatic ESA species, and higher trophic levels such as birds and mammals. Each of these three receptor groups will be addressed more specifically in a follow-up paper to this overall

bioaccumulation framework issue paper. Before any of this work can be done, bioaccumulative chemicals of concern need to be identified. Recommendations for this process are also discussed in more detail in a forthcoming paper.

REFERENCES:

USACE-PNW, EPA Region 10, WDOE, ODEQ, WDNR. 1998. Dredged Material Evaluation Framework Lower Columbia River Management Area. U.S. Army Corps of Engineers, Pacific Northwest Division, Portland, OR.

RECOMMENDATION:

1. Identify Bioaccumulative Contaminants of Concern (BCOCs). The committee has reviewed the approach established by the previous BCOC committee under the Dredged Material Management Program (DMMP), and most likely will adopt it after further discussion. The approach relies on a review of the occurrence of contaminants in sediments and tissue, chemical properties of contaminants such as K_{ow} , known toxicity of the contaminants to human and ecological receptors, and comparison of tissue levels to available action levels. Contaminants are placed on one of several lists depending on the amount of information available and the weight-of-evidence indicating their potential to be bioaccumulative chemicals of concern.

Upon adoption of this approach (with or without modifications as determined necessary), the committee will then review whether it can adopt the DMMP BCOC list without modification, either as an interim or a permanent list. If most of the data that went into developing that list are marine data, then the committee may adopt that list as a marine list and work on developing a separate freshwater list. To that end, the committee is currently compiling a database of existing freshwater tissue data in the region.

2. More Clearly Define “Reason to Believe.” Because of the cost of bioaccumulation testing and the potential lack of defensible sediment triggers for some time to come, the committee believes it is important to have a strong “reason to believe” prior to requiring bioaccumulation testing. This reason to believe may include both “top-down” and “bottom-up” types of information.

As soon as reasonably possible following the establishment of a regional BCOC list, tissue data should be reviewed by watershed to identify a subset of BCOC chemicals of concern in tissues for each watershed. This will only be possible in areas where sufficient tissue data have been collected; however, this may include the most contaminated areas where tissue assessments are currently or have previously been conducted. In this manner, the BCOC list can be narrowed down for each area to include only those chemicals that are currently detected in tissues (assuming that detection limits are appropriate). Once tissue triggers are available, the list can be narrowed further to those chemicals that exceed tissue triggers.

Chemical testing conducted in Tier 1 can be used to identify whether any chemicals on the watershed BCOC list are present in project or site sediments. In the absence of scientifically defensible sediment triggers, if such chemicals are present, then laboratory

bioaccumulation testing, *in situ* bioaccumulation testing, and/or tissue collection from the site or dredging area would need to be conducted in Tier 2, along with any bioassays being completed. Such testing could be limited to the BCOCs present to save analytical costs. The Bioaccumulation committee strongly recommends consideration of tests that combine measures of effects and exposure with tissue concentrations.

It is not recommended that the SEF continue to use the existing BTs to establish reason to believe, particularly those based on the SLs and MLs, as these are not likely to be protective for all BCOCs and are not defensible based on the best available science. Clearly it will be important to move ahead with all possible speed to establish tissue and sediment triggers, and there are some interim steps that can be taken (see below).

3. Establish Tissue Triggers. Tissue triggers are expected to be used by both dredging and cleanup programs to identify target levels that may be applied region-wide. Developing tissue triggers is the first step toward establishing sediment triggers and/or a watershed-wide approach to source reduction, and would also serve as the criteria to which the results of bioaccumulation testing would be compared. The subcommittee identified several groups of receptors for which tissue triggers need to be established:

- Human consumption of fish and shellfish
- Wildlife consumption of fish and invertebrates
- Fish
- ESA species (fish, mussels, snails, birds, etc.)

Tissue levels for the first two sets of receptors would be based on back-calculation using established risk assessment techniques and receptors common in the Pacific Northwest. Tissue levels for protection of fish would be based on tissue-residue-effects data contained in databases such as ERED. Three companion papers discuss each of these methods in greater detail. Member agencies involved in RSET are currently discussing whether separate levels need to be established to protect ESA species.

Note that this approach will not protect fish against contaminants that do not appreciably bioaccumulate in tissues, or which are rapidly transformed to other compounds, such as PAHs. SQGs for such contaminants will need to be developed separately by the SQG subcommittee or the Bioaccumulation subcommittee, and this will be a follow-up task for one of the two committees.

Since each of these receptor groups is protected under all of the regulatory programs addressing sediments, it is assumed that generally, the lowest of the applicable levels will be used as the target tissue level. However, the approaches and input values used to derive each of the levels must be transparent and readily available for review, as some aspects may vary on a site-specific basis. For example, consumption rates may vary by region, disposal site, or watershed, as may the wildlife and ESA receptors present. Cleanup site managers, and to some degree dredging agencies, should be provided the opportunity to modify the values based on good science and site-specific factors, as long as the modifications are recorded in an appropriate document such as a suitability determination or record of

decision.

4. Establish Bioaccumulation Triggers for Sediments. Experience to date in the scientific and regulatory community is that it is difficult to back-calculate generally applicable sediment triggers from tissue levels using literature-derived BSAFs or other modeling approaches, due to significant uncertainties in BSAFs for the same chemical derived from different data sets. This may be due to differences in study design, sediment geochemistry, bioavailability of contaminants, and food webs from one data set to the next. However, BSAFs can be developed on a site-specific or watershed basis using tissue data paired with sediment data from the home range of the species being evaluated. Please see Attachment A for further discussion of methods for deriving sediment BTs from tissue BTs.

For the purposes of the dredging program, the most relevant BSAF would be that at the disposal site. It may be possible to use past monitoring data to develop disposal site-specific BSAFs that can be applied to derive BTs for each disposal site (or for a set of disposal sites that are similar in nature and receptors, such as ocean disposal sites along the coast of Oregon or those in Puget Sound). In deriving and applying such BSAFs, it will be important to consider whether sediment characteristics affecting bioavailability are similar at the disposal site and in the dredged material being disposed there.

Similarly, BSAFs may be developed for certain chemicals and watersheds as part of large Superfund sites currently in progress, and under source control (e.g., TMDL) and NRDA processes. In these cases, it may be more productive to use a GIS-based approach to determine which areas of sediment in the site or watershed need to be cleaned up to reduce overall loading to a level that would, in turn, reduce tissue concentrations to acceptable levels. This may be accomplished by identifying the factor by which tissue concentrations need to be reduced (e.g., to 50% of current levels), and then using GIS tools to identify areas that if cleaned up, would reduce the area-weighted average sediment concentration within that organism's home range to 50% or less of its previous value.

Because of both environmental and programmatic differences, it is not necessary or even possible to use the same approach or have the same criteria for bioaccumulation in sediments. What is important is that the programs and agencies are all using consistent target tissue criteria and are working toward meeting those criteria in whichever way best meets their project needs.

5. Collection of Missing Data. For areas where not enough data exist to establish watershed BCOCs, determine reason to believe, or develop BSAFs, it is recommended that the agencies and the regulated community share the burden of data collection. For example, the agencies should have the primary responsibility for collecting data to determine tissue concentrations and BSAFs at the disposal sites. The agencies should also establish a priority list of chemicals and areas to be monitored to fill key data gaps, and develop a plan for incorporating this monitoring into their budgets and programs. As part of this plan, it should be determined specifically how much and what types of data are enough for the purposes of the program needs. When projects and sites come up that involve lower-priority chemicals or which wish to proceed on a faster track than the agency monitoring

programs can accommodate, the project proponent should then bear the cost of providing the necessary data, as an alternative to proceeding to the next tier of testing.

Similar to the process recently completed in the SQG subcommittee, the Bioaccumulation subcommittee identified a need to develop data management and review procedures. Specifically, a single database needs to be identified to maintain bioaccumulation data, and an agency needs to be identified to manage the database. For consistency with the sediment data management system, SEDQUAL was selected since it has the capability of maintaining tissue as well as sediment data. In addition, some areas of bioaccumulation science are rapidly evolving, such as wildlife toxicity and the availability of tissue residue effects data. These areas need to be reviewed and updated frequently, and a mechanism needs to be established within RSET to accomplish this.

6. Testing Procedures. Although this topic is somewhat outside the scope of this paper, laboratory and *in situ* bioaccumulation testing procedures, particularly for freshwater organisms, need to be reviewed and updated. The committee especially recommends that the agencies evaluate the use of procedures that allow bioassay and bioaccumulation testing to be conducted simultaneously, as well as new analytical methods developed by the Waterways Experiment Station that can reduce the tissue volume required for chemical analysis. Both of these areas of research may substantially reduce the cost burden of bioaccumulation testing, as well as allowing us to more directly link observed effects with tissue concentrations. Two companion papers have been developed reviewing emerging laboratory and in-situ testing procedures for freshwater.

7. Revise SEF. Once the framework outlined in this paper has been fully reviewed and approved by RSET, the Bioaccumulation subcommittee will develop specific language to replace the current Section 9.4 of the DMEF manual and several appendices to provide further information on topics such as testing procedures, methods for calculating BSAFs, and derivation of tissue and sediment BTs.

PROPOSED LANGUAGE: None yet available.

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Attachment A. Converting Target Tissue Levels to Sediment Quality Guidelines

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Once a protective tissue residue has been selected, a protective sediment concentration may also be generated from the target tissue level (TTL). Sediment guidelines may be generated for benthic and epibenthic fish (but not for pelagic fish) if reliable site-specific BSAFs can be determined or a distribution of BSAFs can be generated that would be used to determine a range in sediment concentrations that would lead to the selected TTL.

There are two ways to convert the TTL to a SQG using bioaccumulation factors. One uses the bioconcentration factor coupled with the sediment water partition coefficient. The other uses the BSAF to convert a TTL to an equivalent SQG. For each method, the best approach is to consider the distribution of all bioaccumulation factors, which can be used to generate a probability distribution of SQGs.

Bioconcentration approach

The first step is to compile all available bioconcentration factors. The organic-carbon normalized sediment-water partition coefficient (K_{oc}) for a compound needs to be obtained from empirical measurements or modeled.

Water-sediment partition coefficients for many neutral hydrophobic compounds can be predicted with the octanol-water partition coefficient (K_{ow}), a good predictor of K_{oc} . Several authors have developed equations that predict K_{oc} values from the K_{ow} for various hydrophobic compounds (Karickhoff et al. 1979, Means et al. 1980, Karickhoff 1981, Di Toro et al. 1991). These studies show the K_{oc} to range from $0.4 \cdot K_{ow}$ to $1.0 \cdot K_{ow}$.

For each TTL, the following equation would be used to generate the SQG:

$$[SQG_{oc}] = K_{oc} * \frac{TTL}{BCF}$$

BSAF approach

The BSAF approach has some advantages over the BCF approach because BSAFs generally exhibits much less variability than do BCFs. Because tissue concentrations are normalized to lipid and sediment concentrations are normalized to organic carbon, BSAFs for organic compounds will achieve a theoretical maximum value between 1 and 4, based on equilibrium partitioning between all phases (Di Toro, Boese, xxx). Metabolism or transformation of the toxicant, insufficient time to steady state for partitioning between phases will lead to BSAF values less than the theoretical maximum. For many compounds, a cumulative distribution function is the best way to select the highest BSAF for determining an SQG. If no BSAF data are available and the organic compound is known to behave according to equilibrium partitioning (EqP), the default value of 4 can be selected to represent the worst case bioaccumulation.

Ideally, representative bioaccumulation values from several species should be obtained to generate a cumulative density function. From this CDF, a percentile value, such as the 95th, can be selected to ensure that the most sensitive species are protected. Because the bioaccumulation factor is controlled by the uptake and elimination kinetics and these are variable among species and conditions, a high percentile value is desirable to account for this variability and to be protective of most species.

The sediment quality guideline can be determined by:

$$[SQG_{oc}] = \frac{[TTL]}{BSAF * f_{lip}}$$

For those organic compounds and metals that do not behave according to EqP, a standard bioaccumulation factor that is selected from a high percentile (e.g., 95th) of all BAF values should be used to convert the TTL to a SQG:

$$\frac{[TTL]}{BAF} = SQG$$