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Water

# SEDIMENT QUALITY CRITERIA DEVELOPMENT WORKSHOP

#### SEDIMENT QUALITY CRITERIA DEVELOPMENT



.

SUMMARY REPORT

on

## SEDIMENT QUALITY CRITERIA DEVELOPMENT WORKSHOP November 28-30, 1984

to

## CRITERIA AND STANDARDS DIVISION U.S. ENVIRONMENTAL PROTECTION AGENCY

February 28, 1985

BATTELLE Washington Environmental Program Office 2030 M Street, N.W. Washington, D.C. 20036

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#### INTRODUCTION

The presence of toxic contaminants in the bottom sediments of the Nation's lakes, rivers, and coastal waters creates the potential for continued environmental degradation even though control of effluent discharges may allow compliance with established water quality criteria. The U.S. Environmental Protection Agency is exploring the technical approaches available to establish numerical sediment quality criteria.

Because the Agency wished to avail itself of the knowledge and technical expertise gained from previous research, a three-day workshop was convened in Alexandria, Virginia, in November 1984 to bring together experts from around the country familiar with the various facets of the sediment quality criterion development process. These experts consisted of a diverse group of biologists, chemists, and engineers from within and outside EPA. These individuals were broadly representative of varying technical outlook and organizational perspective.

This report summarizes the most salient points brought out during the Sediment Quality Criteria Development (SQCD) Workshop discussions and portrays the technical viewpoints of the proponents of the various approaches to criterion development. The organization of the document is based on the conceptual discussion and evaluation process used during the workshop. The following sections include a brief description of the historical and legal perspective for the setting of numerical sediment quality criteria. From this perspective, the difficulties inherent in the establishment of criteria are then critically discussed. Finally, the recommended approaches and necessary information bases are presented.

# LEGAL AND HISTORICAL PERSPECTIVE

Questions relating to the need for numerical sediment quality criteria and the optimum means of generating and applying them have received some attention for many years, although not in a cohesive regulatory-policy context. The SQCD Workshop began with a presentation by Mr. Pat Tobin, Director of the Criteria and Standards Division, regarding EPA's perspective on the necessity for criteria, particularly numerical criteria as opposed to qualitative criteria. In addition, the legal authority available under the Clean Water Act was discussed. This presentation was followed by a brief introduction to the historical basis for sediment criteria as embodied in each of the four general approaches currently being considered.

### Need for Criteria

As stated previously, there is concern that the efforts exerted by the Agency in establishing credible water quality criteria are not sufficient to ensure protection of aquatic systems consistent with the Clean Water Act provisions. The need for sediment quality criteria hinges on the belief that organisms interact with sediment both directly through physical contact and indirectly as components in and as part of the food chain. Thus, specific limits for both aqueous and solid phase contaminant levels are necessary.

From the context of discussions during the first two days of the workshop it was apparent that numerical sediment criteria development is not being slowed by a lack of concern for aquatic organism protection, but rather by the insufficiency of the present status of research necessary to provide

quantification. Research to date has not resolved how to differentiate the effect of interstitial versus bulk water exposure or whether in fact there is a difference to resolve. Benthic organisms are affected by water regardless of whether the medium is interstitial or bulk water. Similarly, numerical criteria development is hampered because consistent interpretation of chemical data is difficult and descriptive information on organism abundance and diversity is often not available. The question of whether numerical criteria for sediments would be useful is not a question of need because there is ample evidence identifying contaminated sediment as causing significant adverse effects.

From a regulatory standpoint, the range of specific cases where numerical criteria are applicable is a concern. The diversity of backgrounds of the workshop participants was evident in the responses to this area of discussion. The possible uses for such criteria might include: (1) the identification of historically contaminated areas without the intent to assess costs for clean up among sources, (2) the need to partition historical damages among known historical dischargers, (3) the incorporation of allowable sediment contaminant loads in wasteload allocations and discharge permits, (4) the determination of whether dredge material is acceptable for disposal in a given manner or location, and (5) the assessment of degradation in ocean areas subject to dumping of discharge of wastes.

Given this diversity of purpose, the need for a single set of nationally applicable criteria has not been not universally accepted. Because site-specific evaluation approaches are being developed to address several of these potential applications, the need for an additional general criterion set was questioned by those participants already involved in site-specific evaluations.

## Legal Authority

Although peripheral to the general purpose of this workshop, participants were told that the Agency believes that it has not only the authority but potentially the mandate to develop sediment quality criteria. EPA's Office of General Counsel has established authority under the 1977 Clean

Water Act to develop and implement these criteria. Recent legislative activities, most notably a version of the Water Quality Act reauthorization in the U.S. House of Representatives. directly address the sediment criteria issue.

#### RESEARCH BACKGROUND

Some effort has been expended to develop both the theoretical and field/laboratory data bases for sediment quality criteria. This section presents an overview of the theoretical basis as presented at the workshop as well as a portion of the field/laboratory data base used to validate the competing approaches. It should be noted that while the alternatives are discussed as discrete, mutually exclusive entities, the intent of the workshop was to meld the approaches balancing their relative advantages and disadvantages.

Four general approaches were presented for the development of sediment quality criteria. These four approaches have been developed under the auspices of various sponsoring organizations, and all are or have been under consideration by regulatory agencies for specific applications. Thus, they have survived at least preliminary scrutiny. More detailed discussions of the following approaches can be obtained from the "Background and Review Document on the Development of Sediment Criteria (1984) by J.R.B. Associates, prepared for the U.S. EPA.

# Background Concentration Approach

This approach relies on the establishment of a legally-allowable reference concentration which can be compared to concentrations at more contaminated sites to determine the extent and magnitude of effects. Because the allowable concentration is not necessarily linked to a toxicologically safe concentration, this approach avoids the questions posed by other techniques requiring the establishment of environmentally safe concentrations.

In order for such a system to have regulatory utility, some means must be established whereby the reference concentration can be specified in an unambiguous and non-arbitrary way. Several ways of attacking this problem were suggested by the workshop participants. The options ranged from using values indicative of pristine areas to simply prohibiting further degradation of a site. The group agreed that both approaches fail when applied in a non site-specific manner, i.e. as a national criterion.

If the pristine area approach is used nationally, the results are criteria that are overly conservative, being set at the analytical detection limit for most anthropogenic organic contaminants. Prohibition of further degradation is meaningless in a national context. The reference concentration would have to be established on the basis of a set of guidelines rather than a numerical value.

Previous work on the development of this approach has been performed for dredge material disposal in the New York Bight and several areas within Puget Sound. The workshop participants familiar with this work agreed that the criteria are extremely site-specific and that locations typifying "background" must be carefully selected.

## Water Quality Criteria Approach

The key assumption of this approach is that the water quality criteria and the associated laboratory data base are directly applicable to interstitial water quality. Several workshop participants noted that while the idea of extending the usefulness of the water quality criteria to interstitial waters and the protection of infaunal animals is desirable, there are several key research areas that have not be adequately addressed by previous work on this approach. The potential for contaminant uptake by ingestion of contaminated sediment particles and the adequacy of current techniques for sampling and analysis of interstitial waters are the most significant of these issues.

More data are required to determine the potential for non-aqueous uptake that yields body burdens higher than those expected from interstitial water alone. Too few experiments have been performed to demonstrate why

contradictory results have been observed. This point was addressed later in the workshop and is reflected in the additional data requirements discussion.

In this discussion, the practical problems associated with interstitial water chemistry measurements were raised. Though the sampling of pore waters has been accomplished in a variety of ways, the methodology necessary to standardize procedures to minimize changes in pore water chemistry is not yet available. Another practical problem is the lack of water quality criteria for many contaminants despite strong implication of these contaminants as significant sediment pollutants in several coastal areas including Puget Sound.

## Equilibrium Partitioning Approach

Considerable effort has been devoted to the development and application of the equilibrium partitioning approach. Previous theoretical work has been concentrated on demonstrating the thermodynamic basis for the distribution coefficients used to establish concentrations in environmental phases of interest. The interrelationship of various distribution coefficients is illustrated in Figure 1.

Equilibrium partitioning theory can be applied to any pair or group of phases known or assumed to be in equilibrium. To apply this approach as a basis for national sediment quality criteria requires that: (1) EPA water quality criteria or similar designations of "safe" aqueous concentrations can be established for interstitial waters and (2) the amounts of the appropriate geochemical materials controlling sediment-water interactions are accurately known at the locations where the criteria are to be applied.

Previous work has not provided complete answers to either of these requirements. As stated previously, water quality criteria have been developed for relatively few contaminants. Some experimental work has been performed which demonstrates that interstitial water concentrations and organism toxicity can be related to the sediment concentrations by the proper normalization. This conclusion is principally true for the non-polar organic contaminants.





From a practical applications standpoint, the equilibrium partition approach has been examined for the regulation of contamination in Puget Sound, but the linkage between the chemical measurements and the toxicological effects has not been completed. Preliminary data analysis is planned for the current study program, but more effort is necessary.

## Bioassay Approach

The establishment of dose-response relationships using sediments has been practiced for many years. Proponents of this approach maintain that the test procedures are adequate, are specific to species of concern and can be used to estimate chronic as well as acute effects. The methodology for conducting the tests is relatively straightforward and comparable results have been obtained in interlaboratory comparison studies.

The bioassay toxicity observed is correlated with the quality of the interstitial water if the interstitial water concentration is in equilibrium with the contaminant concentrations in the sediment, in the food source and in the interior of the organism. The observed sensitivity of the bioassay results to the amount of binding components in the sediment corroborates the effects expected from thermodynamic partitioning.

The bioassay approach can be used to identify the toxic effects of specific contaminants. However, in multiple component mixtures, the identification of cause-effect relationships becomes cumbersome and parallel chemical analyses of sediments are necessary to assess suspected contaminant components responsible for a level of toxicity.

# THEORETICAL AND PRACTICAL BARRIERS TO CRITERION DEVELOPMENT

An accurate and defensible set of criteria are unlikely to be developed within the near-term. The participants believe that an interim set of numbers could provide the basis for refinement of methodology and that field validation could be obtained for some contaminants within a year. The

following section summarizes the most important points raised in the selection and categorization of contaminants and in the application of criteria to a variety of locations.

#### Selection and Categorization of Contaminants

Resources will not be available in the near-term to develop criteria for all contaminants. Therefore, it becomes important to determine a subset of contaminants of interest for which there is evidence of significant environmental contamination and for which an adequate theoretical basis is or could be made available. With respect to the first constraint, Battelle prepared a national perspective document for workshop use. During the workshop, the existing field data base derived from this document and from the research of the workshop participants was discussed. Following the workshop discussion, EPA elected to further refine the national perspective document for publication.

# National Perspective Document

A synopsis of the information contained in the working document disseminated to participants prior to the SQCD workshop indicated that a preliminary working list of priority contaminants could be made based on the extent of available chemical measurements. The suitability of this preliminary listing for criterion development is constrained by the fact that few ancillary measurements such as total organic carbon or grain size are available to interpret and compare with the bulk chemical measurements.

A lack of an extensive available biological data base also limits the interpretation of the existing chemical measurements. Because the only basis for indicating severity of impacts to biota prior to the development of criteria is the observance of actual field effects, the existing chemical data base can only indicate the trends in the extent and magnitude of contamination.

<u>Marine/Estuarine Systems</u>. This database consists of relatively few (392) sample sites, albeit the data sets include a greater amount of correlative biological survey data to augment the chemical data than were accessed for the freshwater areas.

Only a limited number of sites contained contamination at high levels. The principal non-polar organic constituents of concern were polychlorinated biphenyls, DDT and polynuclear aromatic hydrocarbons. Most metals also exhibited high concentrations at a number of locations. Data gaps were apparent for several classes of organic compounds including PAH and other aromatic hydrocarbons, pesticides, most chlorinated pesticides except PCBs, and the phthalate esters.

Finally, there was a discrepancy between the biological effects observed in the field and the corresponding preliminary threshold biological effects levels estimated from the equilibruim partitioning approach. This finding suggests that a more cautious use of the equilibrium partitioning approach in screening contaminated sediments is recommended. The need for careful comparison of field observed effects (whenever possible) to calculated thresholds is emphasized as is the need for site-specific measurements of total organic carbon normalization factors which may vary from site to site.

<u>Freshwater systems</u>. These chemical data were drawn from the STORET data base. This system provides for extensive representation of the Nation's freshwater resources (over a quarter million sample locations) but because of the number of data points, spatial discrimination of contamination was limited.

As was the case with the marine areas, relatively few locations exhibited very high contamination levels when screened using criteria derived by the equilibrium partitioning approach. A large percentage of the data was in the "unaffected" range for metals, polynuclear aromatic hydrocarbons, and pesticides. Phthalate esters and PCBs were the non-polar organic compounds most often found at elevated concentrations.

Much of the available <u>in-situ</u> data was inappropriate to determine sediment related toxic effects. As found in the marine data review, discrepancies exist between the applicable <u>in-situ</u> data and the observed field effects for both metals and several organic contaminant categories, including PAHs and PCBs. In both marine/estuarine and freshwater systems it is recommended that a more extensive (geographical and parametrical) and/or intensive (spatial, at a given location or area) examination of the available data would be valuable.

## Criteria Transferability

With respect to the transferability of criteria, a concensus was reached that contaminants should be divided among three categories: nonpolar organic compounds, metals, and polar organic compounds. This categorization is based on the status of normalization theories for adjusting sediment bulk concentrations (or organism tissue concentrations) to account for varying amounts of biochemical and geochemical materials controlling partitioning. Available corroborative field data should be assembled and used to validate these normalization theories.

# Status of Normalization Theory

The key to derivation and validation of a national sediment quality criteria set is the ability to apply a single numerical value to any geographic location. One of the most significant research need facing the developers of criteria is building confidence that factors affecting partitioning have been appropriately considered. Much of the discussion during the second day of the workshop centered on the specification of the current state-of-knowledge and research needs for normalization parameters.

<u>Non-Polar Organic Compounds</u>. Because ionic mechanisms are not involved in the partitioning of non-polar organics among phases, the thermodynamic theory is relatively simple. Chemical and toxicological evidence suggests that the dominant factor in normalizing solid phase concentrations is the organic carbon content.

Two sets of data were discussed at the workshop which indicate but do not prove that the interstitial concentrations were correlated with organic carbon content. An example data set for kepone is presented in Figure 2. In this example, the pore water concentration is plotted against the bulk





FIGURE 2. SEDIMENT QUALITY CRITERION CONCENTRATION CALCULATIONS FOR NEUTRAL ORGANICS\*

sediment phase concentration for a range of organic carbon levels from 0.1 percent to 10 percent. The kepone pore water effect level is 10 ppb as determined by the most sensitive invertebrate chronic geometric mean maximum allowable toxicant concentration (MATC). Thus, if the sediment concentrations were organic carbon normalized, the allowable sediment criterion concentration would be 5 ppm. Data have been generated for three compounds of widely differing water solubilities (0.03, 1.0, 3.0 ppm) over the organic carbon range of 0.1 to 10 percent and each such plot yields identical results. Pore water concentrations for carbon normalized bulk sediment concentrations are linearly related to the organic carbon content.

The second data set is based on the equilibrium partitioning approach applied to Puget Sound data. Plots of contaminant concentrations of tetrachlorobiphenyls and DDT versus percent total organic carbon for various locations in the Sound can be used to demonstrate exceedance of the calculated chronic criteria. These areas have been examined, using limited available data, to relate the occurrence of biological effects to the exceedance of chemical criteria. The results to date are encouraging.

<u>Metals</u>. Normalization of metals data to total organic carbon has been less successful. Attempts to apply such a methodology to Puget Sound have resulted in criteria with broad bands of uncertainty. Additional variables are therefore involved in determining the partitioning of metals. Based on research conducted over the past decade, likely candidates for additional normalization parameters are the hydrous iron and manganese oxides content.

It should be noted that this approach to normalization for metals has been tested for adsorption of metals by sediments but has not been correlated with toxicological effects. Cadmium toxicity has been inversely correlated with increasing organic enrichment with sewage sludge, but other variables may have been affected simultaneously. At this point the proper normalization theory for metals remains speculative.

<u>Polar Organics</u>. The organic carbon normalization theory for nonpolar organic compounds is inadequate for polar organic compounds because partitioning between interstitial water and sediments can occur by mechanisms other than non-specific adsorption. Relevant variables for specific adsorption mechanisms are not known with certainty, but may include anion or cation exchange capacity, surface charge density and ionization fraction as a function of pH or other complex properties. Hence, the normalization approach for non-polar organics is still largely at a theoretical stage. Any significant progress in deriving criteria will require substantial basic research.

### Corroborative Field Data

The validation of the normalization theories and ultimately any derived criteria rests on the collection of a number of complete sets of environmental and toxicological data from a variety of marine, estuarine and freshwater systems. The field data sets should consist of a comprehensive chemical analysis, including ancillary data for normalization, bioassays conducted on field collected sediments, and a detailed habitat analysis with the computation of species diversity indices and population sizes.

Currently, the availability of such a comprehensive data set is limited to a few marine/estuarine environments and possibly some Great Lakes freshwater areas. While such a limitation may be tolerable for the development of a preliminary group of criteria, all workshop particpants agreed that a broader range of data will eventually be needed.

## RECOMMENDED APPROACHES

The workshop participants considered and debated each of several potential approaches to the development of quantitative criteria. The recommended approaches represent the best currently attainable balance between scientific rigor, maximum use of available field data and ease of application. The subsequent text describes separate criterion development approaches for determining toxic endpoint (either acute or chronic) and body burden (residuelimited) endpoint. The operational definition of each approach, the assumptions required for criterion development and/or application, and the advantages/disadvantages of each recommended approach compared to other

options are considered. Finally, the additional data required for criterion derivation, either laboratory experiments, field measurements or secondary data evaluations are described.

## Non-Polar Organic Compounds

Because the normalization theory is the most established for this group of contaminants, the recommended approaches will have the potential for rapid development of the most practical and useful output, namely, preliminary criteria.

#### Toxicity Endpoint

The toxicity endpoint for the non-polar organic compounds is based on the calculation of a statistically defined "probable no-effects level" (PNEL). This approach makes use of a considerable amount of field data.

In order to compute the overall contaminant PNEL one must first compile a list of environmental concentrations from field analytical data, for a variety of fresh and salt-water locations, where different species of organisms are present or not present. For each organism, one must plot the sediment concentrations on an organic carbon-normalized basis as a cumulative frequency distribution (Figure 3). An appropriate percentile of the frequency distribution (for example the 90th percentile) could be chosen. The corresponding concentration is then designated as the species probable no effect level (SPNEL). The normalized SPNEL values are plotted as a cumulative frequency distribution. Using a regression line fit through the data points, the overall PNEL at a suitably chosen percentile can be calculated. In order to be consistent with the water quality criterion development methodology, the 5 percentile value is selected.

If a water quality criterion is available for the particular sediment component, the sediment-water equilibrium partitioning approach can be used to compute a comparison value by an independent method. The PNEL approach yields a conservative (upper bound) estimate of the threshold concentration while the equilibruim partitioning approach would be expected to provide an estimate closer to the lower bound.



a. Calculation of Species Probable No-Effects Level (SPNEL)





FIGURE 3. CALCULATION OF PROBABLE NO-EFFECTS LEVEL (PNEL)

Several assumptions are implicit in the PNEL approach. Although the ideal data set would consist of only locations affected by a single contaminant, it is unlikely that this will be typically the case. Therefore, the calculated PNEL may be due to the effects of several contaminants in combination. This situation is acceptable in determining an upper bound estimate provided that the assumption is made that there are no antagonistic effects among contaminants.

Secondly, it must be assumed that sediment dwelling organisms are not obtaining a portion of their toxic exposure via the overlying water. Sediments or pore waters must be the only source(s) of exposure if the sediment criteria are to be computed with this technique. Two additional assumptions must hold for computations by this approach to be useable. Normalization on an organic carbon basis must be viewed as a valid way to account for variation in the retention capability of sediments at different site. No net contaminant transfer is assumed to be occurring between components in the system.

One of the chief criticisms of the existing water quality criteria is that these criteria are derived from laboratory toxicological testing and have not been validated in the field. The PNEL approach has the advantage of using field data extensively and yet provides a clear-cut and statisticallybased definition of a numerical criterion.

The apparent disadvantages of the PNEL approach are that the data may not have been obtained along a smooth pollutional gradient, so plots are patchy and coarse. A further problem is that species sensitivities for freshwater and marine organisms may not be the same. In this case, separate curves would be required for each environment. The lack of a freshwater database would then delay development of criteria for freshwater.

Additional Data Requirements. Data needs were identified in both the experimental/monitoring category and in the data analysis category. Laboratory tests need to be conducted on the following topics:

• The procedures for conducting bioassays with benthic infauna and field-collected sediments must be refined, particularly for freshwater species.

- Testing is needed to determine the correlation between pore water concentrations (or predicted values) and toxicity for both freshwater and saltwater organisms.
- Optimal methods of sediment spiking and the handling of sediments should be selected, including preservation techniques and interlaboratory transfer procedures. These methods should be checked against toxicity findings.

At the same time certain data analysis and policy-related activities need to be undertaken:

- Available field data should be subjected to the TOC normalization process and plotted to compute preliminary PNEL.
- The technique of normalization of bulk chemical analysis on the basis of TOC needs to be validated.
- Different data bases (locations) may produce species sensitivities which are significantly different.
- Available information on the equivalence of species sensitivities from field to lab studies should be compiled.
- PNEL values produced from field data from multiple locations
- should be compared to preliminary criteria from the same contaminants derived from equilibrium partitioning calculations.
- The list of chemicals for criterion development should be defined according to toxicity, environmental occurence, and solubility.

# Body-Burden (Residue-Limited) Endpoint

There are two recommended approaches to determine a body-burden endpoint depending on the availability of FDA action limits for consumption of fish flesh for the contaminant of interest.

<u>FDA Action Limits Available</u>. If there is an FDA action limit set for the contaminant, it provides a predetermined concentration from which the maximum allowable sediment concentration can be back-calculated. Food chain transfers are calculated on the assumption that the burden of the food fish is thermodynamically equal to the body-burden in its food source after normalizing for the respective lipid contents of the two components. This concentration value is then equal to the TOC normalized sediment concentration that would be expected to produce a threshold body burden.

Several assumptions are inherent in this approach. The most significant assumptions are that the material cycle is in equilibrium (fish, food, sediment) and that the dominant source of contaminant to the fish originates in the sediment through interstitial water uptake by the food organisms. Furthermore, the concentrations thus calculated must not be limited by a chronic toxicity effect or they will not be true residue-limited endpoints.

The primary advantages of the recommended approach are that it allows a definite health-related endpoint to be identified and provides for a straight-forward, traceable calculation procedure. The drawback is that not very many contaminants have had FDA limits established. With regard to contaminants for which FDA limits exist, there are not necessarily close relationships between tissue content of contaminant in food species and effect levels for benthic species. Contaminants that are degraded by infaunal species are not necessarily in equilibrium with the environment and the FDA limits are unlikely to be applicable to break down products with different levels of toxicity from parent contaminants.

Additional Data Requirements. The data base for generating the lipid normalized body-burden calculations will require augmentation because the amount of this information available from the literature will be limited. Where data are available, sediment effects concentrations on marine species must be compared to the sediment concentrations calculated to produce an FDA action limit.

<u>No Available FDA Action Limits</u>. When there is a lack of an FDA limit, the situation becomes more involved in terms of data acquisition and data interpretation. The water quality criterion concentration can be used to compute an equivalent body burden using the equilibrium partition approach from the relationship:

> BCF = WQC\* 1/f lipid, where BCF = bioconcentration factory, WQC = water quality criterion, and 1/f lipid = reciprocal fraction of organism lipid content.

Likewise, the equivalent sediment concentration can be calculated from the relationship:

 $C_{sed} = K_{ow} f_{oc}^* WQC$ , where  $C_{sed} = bulk$  sediment concentration,  $K_{ow} = octanol-water partition coeffic,$ 

 $f_{oc}$  = fraction of organic carbon in sediment.

The obvious assumption in applying this approach to derive preliminary criteria is that the system must be in equilibrium. The advantage is that the calculation of the respective threshold concentrations is readily derived. For those contaminants where water quality criteria have been developed, the technique allows the calculation of numerical criteria. However, the relationships between water quality criteria (toxicity for aquatic species) and body burden (food consumption limits) is not clear and may not be a valid means to determine sediment criteria. Where water quality criteria are lacking, this approach cannot be used.

Additional Data Requirements. To maximize the applicability of this approach, effort should be expended toward evaluating the availability and validity of alternative action limits. For example, recommended levels have been developed by the Canadians through the International Joint Commission. Although many contaminants will be the same as those for which FDA limits exist, there may be a few that do not overlap. The availability of alternative action levels would remove them from this category and allow application of the approach used for compounds with FDA action limits.

The validity of the equilibrium partitioning approach to linking body burdens to sediment concentrations will require considerable amounts of additional data to establish. Bioassays with sediments spiked at various levels of contamination will be needed.

In both of the recommended approaches to deriving numerical sediment quality criteria for body-burden limited endpoints, the availability of a water quality criterion value is critical. To a lesser degree, this availability is necessary to implement the technique recommended for the toxicity endpoint. The need for water quality criterion lends support to the suggested policy of developing priority lists of contaminants for which the development of water quality criteria is planned and should give some weight to those contaminants which are considered important for the setting of sediment criteria.

## Metals

As stated previously, the recommended approaches for the development of sediment quality criteria for metals lean toward the theoretical side because the normalization theory is not fully developed. However, it is still possible to recommend a set of approaches that will produce a set of numerical values in as expedient a manner as possible.

### Toxicity Endpoint

A probable no-effects level can be calculated using the sedimentwater equilibrium partitioning technique. The threshold sediment concentrations should be calculated from the water quality criterion for pore waters that just meet the criterion. This computation should be done to provide an upper bound (conservative) estimate by using the partition coefficients for alpha-quartz and normalizing the bulk concentrations by iron oxide, manganese oxide, and TOC content. These concentrations have been shown to be biologically equivalent to those obtained from 0.1 <u>N</u> acid-extraction.

The assumptions inherent in the use of this particular application of equilibrium partitioning theory are basically the same as those listed earlier for the non-polar organic compounds. The advantages of this technique are twofold. First and most importantly, if the normalizations are correct, it is directly applicable to the free divalent metal which is the suspected toxic species. Second, it dispenses with the difficult and potentially inaccurate task of measuring pore water concentrations.

As with the non-polar organic compounds, the prior establishment of a water quality criterion is essential and not all contaminants of concern have had criterion values obtained. A second disadvantage, albeit not a serious one, is that additional bulk sediment property measurements are needed in order to perform the normalizations.

<u>Additional Data Requirements</u>. Some of the additional data required for the development of metal sediment criteria parallel those presented for the non-polar organic compounds while others are specific to the application of the normalization theory.

The recommended data evaluation studies are as follows:

- Using published partition coefficient (Kp) values for adsorption of metals on alpha-quartz, calculate the concentration of metal allowed in the sediment if the pore water concentration just equals the water quality criterion,
- As a corroborative exercise, compute the 5 percent PNEL by plotting field data appropriately normalized in a manner analogous to that described for non-polar organics,
- Review pore water data for metals to compare the field data with the water quality criterion. This review will allow an estimate on numbers of sites where porewater metals exceed water quality criterion. Also, the bulk sediment metals concentrations should be used to calculate Kp for sediments which have both pore water and bulk metals chemistry,
- Develop the methods to calculate the metal concentrations in pore water for sediments with known amounts of iron oxides, manganese oxides, and total organic carbon,
- Examine procedures for development of past and present sediment criteria on a worldwide basis.

Experimental studies recommended for further development include the following:

- Develop toxicity and bioassay tests for screening contaminated sediments or testing chemicals spiked into sediments,
- Experimentally validate the use of the intrinsic geochemical coefficients for adsorption of metals on metal oxides and organic matter to determine metal concentrations in pore water.
- Conduct coordinated bioassays with appropriate geochemistry to relate pore water to chemistry, sediment properties, and toxicity and to test the hypothesis that metal oxides and organic carbon control the toxicity of metals.

#### Residue Endpoint

The proposed methodology for determination of preliminary numerical criteria values, as well as the assumptions, advantages, disadvantages, and recommended data acquisition are identical to those presented for the non-polar organic compounds. It should be noted that several workshop participants commented that residue endpoint concentrations for most metals probably (possibly excepting mercury) would not be as low as the toxicity endpoint. Also, unlike other metals where the primary interest is in the divalent metal ion, FDA action levels for mercury may be triggered by methylmercury concentrations. Other organometals should be considered and evaluated for potential toxicity.

## Polar Organics

No firm conclusions were reached at the workshop with respect to this contaminant group. An appropriate approach to either toxicity limitation or body-burden limitation of concentrations could not be agreed upon because of the lack of firm understanding of the appropriate normalization theory. Therefore, all recommendations are stated in the form of additional data requirements.

# Additional Data Requirements

The most important activity should be the initiation of a literature search followed by laboratory work to establish likely normalization factors. The initial investigation should include all variables currently being considered by chemists concerned with surface interactions of particles, e.g. cation/anion exchange capacity, pH, surface charge density, TOC, and ionization fraction.

At the same time, an inventory should be undertaken to decide which polar organic materials are extensively used and/or are of environmental concern. The possibilities include the broad classes of phenolics, polymers, surfactants, and some pesticides. Other data requirements, of somewhat lower priority include:

- Research into improved methods for quantitatively removing polar organic compounds from sediments,
- o Development of improved analytical methods not only for the contaminants but also for some of the normalization factors which are currently very difficult to measure accurately.

As with the other categories of contaminants, it is likely that the water quality criteria will provide a key linkage between the toxicological effect and the environmental concentrations in sediments. The need is, therefore, to emphasize a priority of water quality criterion development to address a polar organic compound or compounds of concern in sediments. This effort might begin with pentachlorophenol since a considerable body of both field sediment and toxicological data for benthic organisms presently exists in the literature.

## SUMMARY AND CONCLUSIONS

Participants at a three-day SQCD workshop in Alexandria, Virginia, provided a cohesive set of recommendations to EPA on the development of numerical sediment quality criteria. Contaminants of potential concern were divided into three groups--non-polar organic compounds, metals, and polar organic compounds--based on the status of bulk sediment concentration normalization theory. This approach can be used to ensure that all sediment locations can be compared on an equivalent basis. The use of existing field data was emphasized as was the validation of all theoretical criteria calculations by laboratory bioassay where practical and technically feasible.

For the non-polar organic compounds, normalization to organic carbon content is well established such that recommendations emphasized the practical development of the criteria rather than theory. Separate approaches were specified for toxicity limited concentrations and body-burden limited concentrations. The former makes considerable use of field data to compute a conservative probable no-effects level while the latter ideally works backward from FDA limits. Lack of water quality criteria and FDA or other appropriate action limits constraints the development of sediment quality criteria.

For the metals, an equilibrium partitioning approach was recommended. Because the normalization theory is as not well established for metals as it is for non-polar organics, the recommendations include some examination of the validity of iron oxide, manganese oxide, and total organic carbon content as normalization factors. The body-burden limited approach recommended was similar to that for the non-polar organics.

The criterion development process for polar organic compounds is the least well developed of the three groups. The recommendations emphasized the determination of appropriate normalization factors and the development of priority lists of compounds of environmental significance.

In conclusion, the SQCD workshop served to provide a direction for EPA's future efforts to develop sediment quality criteria. Tractable progress in criterion establishment can be expected for non-polar organic compounds and metals, but the theoretical basis for polar organic compound criteria is generally less well understood at this time.