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# THE POTENTIAL FOR BIOLOGICAL EFFECTS OF SEDIMENT-SORBED CONTAMINANTS TESTED IN THE NATIONAL STATUS AND TRENDS PROGRAM

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## NOTICE

# Errata Sheet

Page 63, Table 21

83 Southern California

Moderate species richness: PCB concentration 400 ± 600 ppb should be 39 ± 60 ppb

(With this correction, the ER-M value for PCB in Tables 22 and B-11 would change from 400 ppb to 368 ppb.)

Page 126, Table 64

65 Spiked Sediment Bioassays

Significant toxicity to *R. abronius* with mixtures: 500 ppb should be 10,000 ppb

(With this correction, the ER-M values for phenanthrene in Tables 65 and B-29 would change from 1380 ppb to 1390 ppb.)

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A number of errors were discovered following the initial printing of this document. These errors have been corrected in this second printing. All corrected data are followed by a check (✔). Except for total PCB and phenanthrene, none of the ER-L or ER-M values changed as a result of these corrections.

# THE POTENTIAL FOR BIOLOGICAL EFFECTS OF SEDIMENT-SORBED CONTAMINANTS TESTED IN THE NATIONAL STATUS AND TRENDS PROGRAM

**Edward R. Long and Lee G. Morgan**

## ABSTRACT

National Oceanic and Atmospheric Administration (NOAA) annually collects and chemically analyzes sediment samples from sites located in coastal marine and estuarine environments throughout the United States as a part of the National Status and Trends (NS&T) Program. While the chemical data provide indications of the relative degrees of contamination among the sampling sites, they provide neither a measure of adverse biological effects nor an estimate of the potential for effects. Data derived from a wide variety of methods and approaches were assembled and evaluated to identify informal guidelines for use in evaluation of the NS&T Program sediment data. The data from three basic approaches to the establishment of effects-based criteria were evaluated: the equilibrium-partitioning approach, the spiked-sediment bioassay approach, and various methods of evaluating synoptically collected biological and chemical data in field surveys. The chemical concentrations observed or predicted by the different methods to be associated with biological effects were sorted, and the lower 10 percentile and median concentrations were identified along with an overall apparent effects threshold. The lower 10 percentile in the data was identified as an Effects Range-Low (ER-L) and the median was identified as an Effects Range-Median (ER-M). Note that these ER-L and ER-M values are not to be construed as NOAA standards or criteria. The ambient NS&T Program sediment data from sampling sites were compared with the respective ER-L and ER-M values for each analyte. The comparisons were used to rank sites with regard to the potential for adverse biological effects, assuming that the sites in which the average chemical concentrations exceeded the most ER-L and ER-M values would have the highest potential for effects. The rankings indicated that a sampling site located in the Hudson-Raritan estuary had the highest potential for effects, followed by a site located in Boston Harbor, a site located in western Long Island Sound, and a site located in the Oakland estuary of San Francisco Bay.

## INTRODUCTION

The concentrations of selected potentially toxic chemicals in marine and estuarine sediments have been quantified annually by NOAA in the NS&T Program since 1984. Sediments from about 200 sites nationwide have been sampled and analyzed for a variety of trace metals, petroleum hydrocarbons, and synthetic organic compounds. The chemical concentrations have been compared among sampling sites and among sampling years at many of the sites. These data have been useful in characterizing the chemical conditions at sampling sites (NOAA, 1987, 1988) and in determining whether or not conditions are changing over time. In selected geographic areas measures of biological effects have been performed to accompany the chemical analyses and used to determine or indicate the significance of the sediment contamination. However, biological measures of the effects or potential for effects of these mixtures of chemicals have not been determined at the majority of the sites.

The purpose of this report is to assess the relative likelihood or potential for adverse biological effects occurring due to exposure of biota to toxicants in sediments sampled and analyzed by the NS&T Program. In order to satisfy that objective, guidelines were developed for use in assessing the potential for effects. These guidelines were developed by employing a preponderance of evidence assembled from a variety of approaches and from data gathered in many geographic areas. These guidelines were used to rank and prioritize the NS&T Program sites with regard to the relative potential for contaminant-induced effects. The severity and geographic extent of adverse effects may be determined by NOAA in intensive regional surveys in areas in which high-priority sites are located. These guidelines were not intended for use in regulatory decisions or any other similar applications.

## METHODS

### Overall Approach

A three-step approach was followed to complete the evaluation: (1) assemble and review currently available information in which estimates of the sediment concentrations of chemicals associated with adverse biological effects have been determined or could be derived; (2) determine apparent ranges in concentrations of individual chemicals in which effects are likely to occur, based upon a preponderance of evidence; and (3) evaluate the NS&T Program sediment chemical data relative to these consensus effects ranges. The first step involved reviewing reports either (1) in which effects-based sediment quality values were reported or (2) in which matched chemistry and biological effects data were listed, followed by an evaluation of the co-occurrence of chemical concentrations with measures of effects. These reports embraced controlled laboratory studies of effects of sediments spiked with individual chemicals, calculations of unacceptable concentrations based upon theoretical equilibrium partitioning principles, and evaluations of data from field studies in which matching chemical and biological measures were performed on subsamples of sediments. Among the reports reviewed, only those that met certain criteria were selected for further use. Chapman *et al.*, 1987 compared the estimated sediment quality values for three chemicals based upon four approaches, and noted that the values from the approaches were consistent.

The second step included screening the data by examining the degree of concordance between the biological and chemical data, sorting the remaining data in ascending order, and determining consensus ranges in values associated with adverse effects. A key element of the second step was the determination of the chemical concentrations above which adverse effects may be first expected and the concentrations above which adverse effects always or almost always may be expected. The intent was not to identify only the lowest concentration of contaminants at which an adverse effect had been observed or predicted for any organism.

The third step involved comparing the ambient sediment chemistry data from the NS&T Program with the respective ranges in chemical concentrations apparently associated with observations of effects. A comparison of proposed or preliminary sediment quality values and ambient concentrations of chemicals in United States sediments was previously conducted by Bolton *et al.*, 1985 and Lyman *et al.*, 1987 for the United States Environmental Protection Agency (U. S. EPA). Both reports involved a relatively small number of chemicals and sediment quality values derived from only one approach. The approach followed in this report is similar to the approach used in those two reports, but includes sediment quality values derived from many methods and evaluates data for 12 trace metals, 18 petroleum hydrocarbons, and 11 synthetic organic compounds or classes.

### Approaches for Determining Effects-Based Sediment Quality Criteria

Since the purpose of this report is not to critique or evaluate the relative strengths and weaknesses of the various approaches that have been used to develop effects-based sediment quality values, only a brief description of each will be presented here. Chapman (1989) reviewed and compared the approaches currently being pursued to develop sediment quality values, but did not compare the concentrations resulting from those approaches. That report and the other documents cited herein should be consulted for more information on each of the respective approaches.

Effects-based sediment quality values derived from different numbers and types of approaches are available for some of the NS&T Program analytes. The values from some approaches are region-specific and those from other approaches are available for only a minority of the NS&T Program analytes. Because of the complementary strengths of each of the approaches, it was decided to determine if a consensus value in concentrations for each chemical was apparent and to use those consensus values in evaluating the NS&T Program data. Conversely, because of the apparent weaknesses of each method alone, it was decided that values based upon a consensus of multiple approaches and multiple applications of each approach would have more credibility than values based upon only one approach.

**Background Approach.** Criteria have been established in various geographic areas of the United States and other countries based upon an approach involving the use of reference or background values in sediments. In this approach, the data from a pristine area have been used as the standard and concentrations in sediments from target areas that exceed these background values by some specified amount are considered unacceptable. In some cases the criteria were set at some value above the background concentration, say, at 125 percent of background or two standard deviations above the mean background concentration. This approach does not involve any determination or estimation of effects, but the criteria based upon this approach were included in this report for the purpose of comparing them with the criteria developed from the effects-based approaches. These criteria were listed in this report as presented in the cited documents without any modifications, however, they were not used to determine consensus ranges in concentrations associated with effects. Many had been listed and compared by Pavlou and Weston (1983).

**Sediment-Water Equilibrium Partitioning (EP) Approach.** In this approach the criteria are established for single chemicals at concentrations in sediment that ensure that the concentrations in interstitial water do not exceed the applicable U. S. EPA water quality criteria (Bolton *et al.*, 1985; JRB Associates, 1984). It is assumed that water quality criteria, when applied to the interstitial water of sediments, would protect infaunal organisms. Physical/chemical principles are used to predict the chemical concentrations that would occur in the interstitial water in equilibrium with those concentrations of the chemicals sorbed to particulates in the sediments, recognizing that the distribution of the chemicals between the two phases is highly influenced by the amount of organic carbon or acid volatile sulfides (AVS) present in the sediments. Tessier and Campbell (1987) reviewed many of the chemical and physical factors in sediments that can strongly influence the partitioning of trace metals between aqueous- and particle-bound phases of sediments and observed that, because of these factors, bulk chemical concentrations of trace metals were poor predictors of the bioavailability of these toxicants. Where criteria were listed in cited documents in units dry weight, they were used in this report without any modifications. Where criteria were listed in units of organic carbon, they were converted to units dry weight, assuming a stated organic carbon concentration (usually 1% total organic carbon [TOC]). Where the criteria were listed in the cited documents in units dry weight assuming a reported TOC concentration other than 1 percent (*e.g.*, 4%), those reported values were used in this report without modification.

Most of the EP-derived criteria listed herein were reported by the U. S. EPA, 1988. Since that report was published, new information has become available that strongly suggests that AVS are important in controlling availability of trace metals. The interim criteria reported by the U. S. EPA (1988) did not account for AVS. Nevertheless, these criteria were used in the present document as reported.

Also, some of the sediment/water partitioning coefficients used to calculate the criteria have changed as new data have been developed for some analytes. Although more recent EP-derived criteria are probably more accurate, some of the earlier values were also included in the present document as reported. In addition, some inaccuracy may be possible in the EP-derived values due to the methods used to determine the TOC content of the sediments. The organic carbon normalized partition coefficients ($K_{OC}$) used to calculate the criteria may differ by factors of 2 to 4 times depending upon whether percent volatile solids or percent organic carbon are determined (Dr. Peter Landrum, NOAA, personal communication).

**Spiked-Sediment Bioassay (SSB) Approach.** This approach involves exposing organisms to pristine sediments spiked in the laboratory with known amounts of single chemicals (or mixtures), observing either mortality and/or sublethal effects and determining dose-response relationships (*e.g.*, Swartz *et al.*, 1988). Usually the criteria were reported as LC50 or EC50 values, the lethal concentrations or effective concentrations resulting in 50 percent mortality or 50 percent change in some sublethal end-point relative to controls. Where the bioassays were performed specifically for the purpose of determining sediment quality criteria, the values were listed in this report without modification and the species used and the exposure duration were noted. Where the bioassays were performed to determine the relative toxicity of various chemicals, the resulting values were also listed here without modification. Where bioassays of prospective dredge material or other sediments were performed to determine the potential for bioaccumulation and the authors noted their observations on mortality during the tests, those observations were included in this report.

**Screening Level Concentrations (SLC) Approach.** Field-collected data are used in this approach and patterns in co-occurrence in sediment concentrations of chemicals and matching analyses of benthic infaunal composition are determined. The SLC are the estimated highest concentration of selected nonpolar organic chemicals that co-occur with approximately 95 percent of the infauna. A cumulative frequency distribution of all stations at which a particular species of infaunal invertebrate is present is plotted against the organic carbon-normalized concentration in sediment of the selected contaminant. The concentration of the contaminant at the locus representing the 90th percentile of the total number of stations at which the species was present is estimated by interpolation and established as the species screening level concentration (SSLC). Next, the SSLCs for a large number of species are plotted as a frequency distribution, and the concentration above which 95 percent of the SSLCs are found is determined as the SLC (Neff *et al.*, 1986). The SLC were calculated based upon data from many areas of the United States (Neff *et al.*, 1986; 1987). It is assumed that the contaminants occur in mixtures. The criteria reported in units organic carbon were converted to units dry weight in this document, assuming a TOC content of 1 percent.

**Apparent Effects Threshold (AET) Approach.** This approach also involves use of data from matched sediment chemistry and effects measures performed with field-collected sediment samples. Similar to the SLC approach, it is assumed that the chemicals occur in mixtures. An AET concentration is the sediment concentration of a selected chemical above which statistically significant ($P \leq 0.05$) biological effects (*e.g.*, depressions in the abundance of benthic infauna or elevated incidence of mortality in sediment toxicity tests) always occur and, therefore, are always expected (PTI Environmental Services, 1988). The AET values reported for Puget Sound were based upon the evaluation of data from many surveys of various portions of that region and were used in this document without modifications. Values reported in 1986 were based primarily upon data from studies performed in the waterways of Commencement Bay and were updated with additional data from other areas in Puget Sound in 1988. In addition, AET values were calculated by the present authors for data from Mississippi Sound generated by Lytle and Lytle, 1985 and for data from San Francisco Bay generated by many investigators in independent surveys (Long and Buchman, 1989; Chapman *et al.*, 1986; U.S. Navy, 1987; Word *et al.*, 1988). These latter values were calculated using the SedQual version 1.1 software developed by PTI Environmental Services, Inc. (1988) for U. S. EPA Region 10 and a sorting procedure, using Microsoft Excel software on a Macintosh computer.

Both the 1986 and the 1988 Puget Sound AET values were used in the present document. The 1988 values were based upon a larger data base than those determined in 1986, they may be more accurate than the former values, and they are being used in management decisions regarding Puget Sound. However, the 1986 concentrations also were used in this document since they were derived with methods equivalent to those used in 1988, with knowledge and data available at that time, and reflect another independent attempt to determine an unacceptable level of sediment contamination. However, whenever a 1988 AET value was exactly the same as a 1986 value, that concentration was only used once during the present data evaluation.

The Puget Sound Dredge Disposal Analysis (PSDDA) prepared screening level and maximum level values based upon the AET concentrations for Puget Sound. These values were listed in the present document without modification.

**Bioeffects/Contaminant Co-Occurrence Analyses (COA) Approach.** Similar to the SLC and AET approaches, this method also involves use of field-collected data in which chemical mixtures occur. It involves calculation of statistics of central tendency (*i.e.*, means, standard deviations, maxima, minima) in chemical concentrations associated with matching samples determined to have high, intermediate, and low indications of effects. For example, DeWitt *et al.*, 1988 listed means and standard deviations in concentrations of selected chemicals found to be nontoxic, intermediate in toxicity, and significantly toxic to the amphipod *Rhepoxynius abronius* in tests of Puget Sound sediments. Long (1989) listed the means, standard deviations, maxima, and minima in concentrations of nine physical and chemical parameters in sediments from the Commencement Bay waterways determined to be least, intermediate, and most toxic to *R. abronius*. Data from DeWitt *et al.*, 1988 were used in this report without modifications. The format used by Long (1989) was used and expanded to accommodate many more chemicals quantified in Commencement Bay sediments and the co-occurrence values are reported herein. In addition, many reports in which matching sediment chemistry and sediment toxicity and/or benthic data were listed were evaluated, co-occurrence analyses were performed and the results reported herein.

The COA data from these reports, were collected for purposes other than determining sediment effects thresholds, but, nevertheless, were used here to determine patterns in co-occurrence of effects and contamination. Only those data sets in which chemical concentrations of one or more analytes differed among sampling stations by over an order of magnitude were considered in these analyses. Measures of "effects" observed in studies with a smaller range in chemical concentrations may have been caused solely or in part by other factors. Given the different degrees of variability in analytical procedures among laboratories, orders-of-magnitude differences in chemical concentrations are likely representative of real differences among sites. Where some chemical concentrations were reported as less than the detection limits, one-half of the detection limits were used in the calculations of means and standard deviation. In those reports in which the authors identified statistically significant effects ("hits"), two categories of bioeffects response (hits and non-hits) were established and the means, standard deviation maxima, and minima in chemical concentrations associated with those categories were calculated. In those reports in which the authors did not identify statistically significant effects, a frequency distribution of the bioeffects data was examined, either two or three categories of severity of effects were determined where two or three modes, respectively, in response were evident, and the means, standard deviation, maxima, and minima in chemical concentrations were calculated for each category in bioeffects response. With regard to the latter reports, the determination of these categories of degree of effects was subjective and somewhat arbitrary. Only data from published reports were used in the COA; unpublished data from the numerous pre-dredging assessments that have been performed recently in the United States were not used.

This approach suffers from the same weaknesses as all of the others that involve the use of matching biological and chemical data collected in the field. The assumption must be made that the toxic chemicals have an influence on the biological responses that are measured that outweighs the influence of natural physicochemical factors. The assumption is also made that the chemicals that are quantified were those that were responsible for the measured effects, although co-varying chemicals not quantified may have had an influence upon the biological tests. Although the chemicals likely act together (*e.g.*, synergistically) as mixtures to influence the biological tests, their patterns in co-occurrence are estimated singly in the co-occurrence data analyses. Recognizing these weaknesses in the use of field-collected data, data from many geographic areas were evaluated and used in an attempt to evaluate co-occurrence patterns under different pollution conditions. For example, in the analyses of copper data, those data from areas known to be relatively highly contaminated with copper were given more credibility than those from areas known to be contaminated with other chemicals.

**Evaluation of the Sediment Values from the Different Approaches.**

Tessier and Campbell (1987) summarized the complexities of determining the significance of particulate trace metals contamination in aquatic environments. Uptake (and therefore, effects) of sediment-associated contaminants is largely a function of bioavailability. Bioavailability is strongly influenced by a complex suite of physical, chemical, and biological factors in the sediments. Trace metals can be adsorbed at particle surfaces, carbonate-bound, occluded in iron and/or manganese oxyhydroxides, bound to organic matter, sulphide-bound, matrix-bound, or dissolved in the interstitial water (Tessier and Campbell, 1987). The relative bioavailability of trace metals associated with these phases has the effect of hindering the prediction of effects, based upon bulk sediment chemical analyses. The oxidation-reduction potential and the concentration of sulphides in the sediments can strongly influence the concentration of trace metals and their availability. Possibly as a result of these complex phase associations, Lee and Mariani (1977) observed very little concordance between measures of bulk sediment chemical concentrations and measures of toxicity, using the shrimp *Palaemonetes pugio*, in surveys performed nationwide. They concluded, "These bioassays clearly demonstrate the lack of validity of bulk chemical criteria for judging the significance of contaminants associated with dredged sediments." The present evaluation was performed with knowledge of the complexities and uncertainties involved with attempting to associate bulk chemical data with various measures of biological effects. DiToro (1988) argued that it is essential to understand the reasons for varying bioavailability before broadly applicable criteria can be established. His argument was based upon the observation that the concentration-response curve for toxicity could be correlated with the chemical concentration in the pore water and not the total (bulk) sediment. However, with no nationally adopted, official, final effects-based standards available, the use of a preponderance of evidence derived from many approaches was judged by the present authors to be the best method for developing guidance for interpreting the NS&T Program sediment data. Furthermore, in order to develop a preponderance of evidence, many data sets were used in the present document that did not include measures, such as TOC content, that could have been used to explain varying toxicity. In addition, data derived in freshwater and saltwater were merged and treated equally, despite the possibility that bioavailability may differ between the two regimes and the concentration levels may affect the two different ecosystems in much different ways.

Approximately 150 reports were reviewed for possible use in this document. In about one-half of those reports, there was either no biological data to accompany the sediment chemistry data or vice versa, there was no discernible gradient in contamination for any of the analytes among samples (less than a ten-fold difference), the biological or chemical analytical methods were poorly documented, or the biological and chemical data were not derived from the same sampling locations. The reports in which the data did not satisfy these criteria were not used.

The data from the remaining 85 reports were assembled and listed for each of the NS&T Program analytes according to the categorical type of approach that was used. Then, they were subjected to a screening step. In this step, the data for each analyte were evaluated with consideration given to the methods that were used, the type and magnitude of biological end-point measured, and the degree of concordance between the chemical and biological data. Using these evaluation factors, professional judgment was used to eliminate and disregard some values for some of the chemicals where it appeared that the chemical under consideration was not likely a contributor to the gradient in biological effects. For example, if in a field study in which the investigators expressed the observation that one or more selected chemicals were known to be highly concentrated in their study area, but they also measured other analytes during their chemical analyses, the latter data were included in the data tables, but were excluded from further consideration. If matching chemical and biological data from field studies showed no concordance, the data were listed in the tables, but not given further consideration. If no gradient (generally, less than a two-fold difference) in chemical concentrations was reported between samples that indicated adverse effects and those that did not indicate effects, the data for that particular chemical also were not given further consideration. If no definitive AET concentration could be determined, the "greater-than" value reported was excluded during this screening step. The screening step was not performed to force consensus where none existed. It was performed before the data were sorted (the next step), so it was not possible to have *a priori* knowledge of the consensus range. No other quality assurance screening steps were performed with the data.

The data that remained following this screening step were from studies in which effects were either predicted or observed in association with increasing concentrations of the respective analyte. Then, they were sorted in ascending order and listed in Appendix tables for each chemical. Next, usually two values were determined from these remaining data for each chemical: an ER-L, a concentration at the low end of the range in which effects had been observed; and an ER-M, a concentration approximately midway in the range of reported values associated with biological effects. These two values were determined using a method similar to that used by Klapow and Lewis (1979) in establishing marine water quality standards for the State of California. For each chemical of interest, they assembled available data from spiked-water bioassays, examined the distribution of the reported LC50 values, and determined the lower 10- and 50-percentile concentrations among the ranges of values. In the present document, the ER-L values were concentrations equivalent to the lower 10 percentile of the screened available data, and indicated the low end of the range of concentrations in which effects were observed or predicted. They were used in the document as the concentrations above which adverse effects may begin or are predicted among sensitive life stages and/or species or as determined in sublethal tests. The ER-M values for the chemicals were the concentrations equivalent to the 50 percentile point in the screened available data. They were used in the document as the concentration above which effects were frequently or always observed or predicted among most species. The methods of Byrkit (1975) were used to determine the percentile values.

Except for the benthic community data, most of the biological measurements made in the different approaches involved the determination of mortality as the end-point. Some contaminants, such as PCB and some aromatic hydrocarbons, may be mutagenic or teratogenic, and not very toxic in acute tests of mortality. Mutagenicity and other chronic effects may occur at levels lower than those listed in this document in association with acute mortality.

Klapow and Lewis (1979) examined data collected from only one approach, spiked-water bioassays, and assumed that the data from different investigators and studies were equivalent and comparable. The methods commonly used in spiked-water bioassays are relatively standardized. However, they evaluated data derived from tests of different species, which, presumably, had different sensitivities. In the present case, the data were assembled from more than one approach and often from different methods used in any one approach. They included data from studies that involved species with different contaminant sensitivities; therefore, they are less likely to be equivalent and comparable. Nevertheless, following the screening step, they were used as if they were equivalent and comparable in the estimation of ER-L and ER-M values.

In addition to the objectively determined ER-L and ER-M values, overall apparent effects thresholds were subjectively identified for some chemicals. These thresholds were the concentrations above which effects usually or always occurred in association with increasing concentrations of the chemical. They were determined independently of the ER-L and ER-M values by visually examining the sorted data. They are not to be confused with the AET values reported for Puget Sound, San Francisco Bay, and Mississippi Sound. They were identified as an aid in evaluating the accuracy of the ER-L and ER-M values and were not used in ranking the NS&T Program sites.

Data compilation and analysis was as inclusive as possible and no weighting was given to data derived from one approach or another. As Klapow and Lewis (1979) pointed out, the use of the inclusive approach and the calculation of percentiles of the data help eliminate the undue influence of a single (possibly outlier) data point upon the establishment of consensus ranges in concentrations associated with effects. In the present evaluation, the assumption was made that patterns established between effects and chemical concentrations would be more credible if based upon data from several sediment quality criteria than if based upon data from only one approach or experiment.

The ER-L and ER-M values were established objectively by determining the lower 10 and 50 percentiles in the data. No other more rigorous statistical procedures were used, since the consensus ER-L and ER-M values were intended only for use by NOAA as general guidance in evaluating the NS&T Program data.

The relative degrees of confidence in the accuracy of the ER-L and ER-M values are described for each analyte. Values for which we had relatively high confidence were those that were supported by clusters of data with similar concentrations, by data derived from more than one approach, by a data set that included more than results from the use of the COA approach, by data derived from multiple geographic areas, and for which the overall apparent effects threshold was similar to or within the range of the ER-L and ER-M values. Values for which we had relatively low confidence were those that were supported by data with either a small cluster or no cluster of similar concentrations, by data derived from only one approach and/or from one geographic area, results derived only from the COA approach, and for which the overall apparent effects threshold was dissimilar to or outside the range of the ER-L and ER-M values.

**Although the consensus ER-L and ER-M concentrations may be used by others as guidance in evaluating sediment contamination data, there is no intent expressed or implied that these values represent official NOAA standards.**

**Evaluation of Sediment Effects Values and NS&T Program Data.**

Following the determination of the ER-L and ER-M values for each of the analytes, these values were compared with the NS&T Program data to determine which sites had sediments that exceeded these values. The averages of the concentrations of each NS&T Program analyte were calculated for each site, usually based upon 2 adjoining years of data (i.e., n = 3 samples x 2 years = 6 samples). Sites at which the average ambient concentrations exceeded the ER-L and ER-M values were listed for each analyte.

The potential for biological effects was assumed to be highest for those sites in which the sediments exceeded the most ER-M values. This potential was assumed to be lower for sites that exceeded many of the ER-L values, but not the ER-M values. Biological effects were assumed to be least likely at sites that exceeded none of these values. The sites were ranked accordingly.

RESULTS

Three data tables are presented for most NS&T Program analytes. The first appears in the text and lists all of the data from the various approaches that were assembled for each analyte: the type of biological test or measure that was performed or predicted, the geographic area in which the data were collected (if applicable), the chemical concentration associated with that observed or predicted measure of effects, and a reference citation keyed to the reference section of each table. The second appears in Appendix B and, again, lists all of the data. However, in these tables, the data have been sorted in ascending order with remarks regarding whether or not each data point was used to determine the ER-L and ER-M values. The third appears in the text and lists, in ascending order, only those concentrations that remained following examination and screening of the data and includes the ER-L and ER-M values with respect to the data that were used to derive them. The ER-L and ER-M values often were rounded to the nearest full integer as appropriate.

In the third table for each analyte, the type of approach was noted with a shorthand descriptor: EP for equilibrium partitioning, SSB for spiked-sediment bioassay, SLC for screening level concentration, AET for apparent effects threshold, and COA for co-occurrence analyses. Data available for some chemical analytes were judged to be insufficient to warrant the determination of ER-L and ER-M values.

<u>Trace Metals</u>:

**Antimony**

Acute and chronic toxicity of antimony to freshwater aquatic life occur at water concentrations as low as 9,000 and 1,600 parts per billion (ppb)✔, respectively; toxicity to algal species occurs at concentrations as low as 610 ppb✔; no saltwater criteria are available (EPA, 1986).

The data evaluated for sediment antimony are from measures of effects performed in Puget Sound and San Francisco Bay (Table 1), and the values available are from AET and co-occurrence calculations. The Puget Sound AET values range from 3.2 ppm to 200 ppm. The AET values for the amphipod bioassay and benthic community composition differed considerably between 1986 and 1988. AET values calculated by the present authors for San

Francisco Bay are 1.9 and 2.9 ppm for bivalve (*Crassostrea gigas, Mytilus edulis*) larvae and *R. abronius* amphipod bioassays, respectively. The data from Commencement Bay, Washington indicate that toxicity to both *R. abronius* and the larvae of the oyster *C. gigas* increased with increasing antimony concentrations in the sediments. Sediments that caused moderate bioassay toxicity to both species had a mean of 2.0 ± 5.5 ppm antimony, whereas sediments that were most highly toxic had means of 91.5 ± 184.3 and 27.5 ± 101.5 ppm antimony, respectively.

In San Francisco Bay, there was no concordance between sediment toxicity to amphipods and antimony concentration. Sediments that were least toxic or not toxic had higher mean antimony concentrations than those that were most toxic or significantly toxic. For example, samples in which *R. abronius* mortality was highest (67 ± 12%) had antimony concentrations below the detection limits, while those in which mortality was lowest (18 ± 6.6%) had a higher mean concentration. This lack of concordance suggests that some other sediment characteristic(s) had a greater influence upon the toxic response than antimony; therefore, the San Francisco Bay amphipod bioassay data were not considered in the estimations of ER-L and ER-M (Table B-1).

Biological effects were noted in San Francisco Bay and Commencement Bay sediments with mean antimony concentrations as low as about 2 ppm (Table 2). The data suggest an ER-L of about 2 ppm, equivalent to the lower 10 percentile of the data (Table 2). Commencement Bay sediments that were moderately toxic to both amphipods and bivalve larvae had a mean concentration of 2 ppm; the PSDDA screening level concentration was 2.6; and the lowest Puget Sound AET value was 3.2 ppm. The data suggest an ER-M of about 25 ppm, roughly equivalent to the 50 percentile of the data (Table 2). This value is supported by observations of high toxicity to bivalve larvae exposed to San Francisco Bay sediments (mean of 25 ppm) and Puget Sound AET from two different biological tests (both 26 ppm). With one exception, effects were always associated with antimony concentrations of 25 ppm or greater (Table B-1).

Data were available from only two approaches and from only two geographic regions. The degree of confidence in both the ER-L and ER-M values for antimony should be considered as moderate. Both values were supported by clusters of similar data, and the overall apparent effects threshold was equivalent to the ER-M value. The determination of the relationships between antimony concentrations and measures of biological effects is hindered by the the lack of data from the predictive EP approach and from single-chemical, SSBs

**Table 1. Summary of sediment effects data available for antimony.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 5.3 |
| | - oyster larvae bioassay | 26.0 |
| | - benthic community composition | 3.2 |
| | - Microtox™ bioassay | 26.0 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 200.0 |
| | - benthic community composition | 150.0 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 2.6 |
| | - maximum level criterion | 26.0 |

**Table 1. Antimony (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >1.9 |
| | - *R. abronius* amphipod bioassay | >2.9 |
| **Co-occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic to *R. abronius* (15.7 ± 3.9 dead/20) | 91.5 ± 184 |
| | - moderately toxic to *R. abronius* (5.2 ± 1.1 dead/20) | 2.0 ± 5 |
| | - least toxic to R. abronius (2.5 ± 0.9 dead/20) | 0.9 ± 1.0 |
| | - highly toxic (44.5 ± 19.0% abnormal) to oyster larvae | 27.5 ± 101.5 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 2.0 ± 5.5 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 1.0 ± 1.4 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67.0 ± 11.8% mortality) to *R. abronius* | na |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 2.7 ± 6.7 |
| | - least toxic (18.4 ± 6.8% mortality) to *R. abronius* | 9.0 ± 11.6 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 2.3 ± 6.3 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 9.9 ± 11.8 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 25 ± 0 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 6.6 ± 1 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 5 ± 11.2 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 8.6 ± 11.9 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 6.7 ± 12.3 |

| Reference | Background Approach | Concentrations (ppm) |
|---|---|---|
| 12 | EPA Region VI proposed guideline | 500.0 |

na - not available

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
12. Pavlou and Weston, 1983
20. U.S. ACOE, 1988
80. Tetra Tech, 1985
* Various, please see text

**Table 2. Effects range--low and effects range--median values for antimony and 13 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 2.0 | Commencement Bay, Washington bioassay COA |
| **2.0** | **ER-L** |
| 2.0 | Commencement Bay, Washington bioassay COA |
| 3.2 | Puget Sound, Washington AET - benthic |
| 5.3 | Puget Sound, Washington AET - amphipod |
| 6.6 | San Francisco Bay, California bioassay COA |
| 8.6 | San Francisco Bay, California bioassay COA |
| **25.0** | **ER-M** |
| 25.0 | San Francisco Bay, California bioassay COA |
| 26.0 | Puget Sound, Washington AET - oyster |
| 26.0 | Puget Sound, Washington AET - Microtox™ |
| 27.5 | Commencement Bay, Washington bioassay COA |
| 91.5 | Commencement Bay, Washington bioassay COA |
| 150.0 | Puget Sound, Washington AET - benthic |
| 200.0 | Puget Sound, Washington AET - amphipod |

## Arsenic

Arsenic is carcinogenic and teratogenic in humans and other mammals. Acute toxicity, as well as sublethal effects, have been observed in fish and invertebrates. Acute toxicity can be highly different among species, including those that are taxonomically related, and can be highly influenced by temperature, pH, speciation, and many other factors. Inorganic arsenicals are generally more toxic than organic forms (Eisler, 1988a). Inorganic arsenic (V) is acutely toxic to freshwater aquatic animals at concentrations as low as 850 ppb✔ in water, and can affect marine plants at concentrations as low as 13 to 56 ppb✔ in water and marine animals at 2,319 ppb✔ in water (EPA, 1986). Klapow and Lewis (1979) proposed a marine water quality standard of 8 ppb✔ for total arsenic.

The data available for effects of arsenic in sediment are from three approaches: EP and field studies in which AET values and/or co-occurrence values have been calculated (Tables 3 and 4). Both acute and chronic marine values based upon EP principles are available. AETs for both Puget Sound and San Francisco Bay are available and vary from 54 ppm arsenic to 700 ppm. COA were performed with data from Puget Sound, Commencement Bay, San Francisco Bay, Waukegan Harbor, Black Rock Harbor, southern California, Sheboygan River, Trinity River, Baltimore Harbor, DuPage River, Kishwaukee River, and a dump site off Georgetown, South Carolina.

Data from many of the studies were not used in estimating the ER-L and ER-M values (Table B-2). The chemical data from San Francisco Bay indicated a pattern of concordance with the bivalve embryo bioassay data, but not with the amphipod bioassay. Thus, the latter were not considered in the estimation of ER-L and ER-M values. The arsenic concentration reported for Waukegan Harbor was below detection limits and was not considered further. The data from Southern California, Trinity River, DuPage River, and Kishwaukee River indicated relatively small ranges in arsenic concentrations and were not considered further. The Black Rock Harbor data were from a bioavailability/uptake experiment in which the concentrations of other metals were substantially higher than that of arsenic. No effects upon benthic communities were reported at arsenic concentrations up to 1.4 ppm at the Georgetown, South Carolina dumpsite. The bioassay data from Los Angeles Harbor were from a small sample size (two) and the ranges in concentrations for some of the other chemicals in the sediments were much higher than that for arsenic. The Sheboygan River data were from a small sample size (three), from an experiment whose objective was to determine uptake (mainly of PCBs), and where the range in arsenic values was very small.

The remaining data suggest an ER-L of about 33 ppm, the lower 10 percentile value of the data (Table 4). San Francisco Bay sediments that were moderately toxic to bivalve larvae had a mean concentration of 22.1 ppm, and the chronic marine value derived from EP is 33 ppm (assuming a 4% TOC content). In addition, two values based upon the background approach are consistent with this value: the New England class III level (>20 ppm) and The Netherlands Harbor moderately polluted level (23 to 32 ppm).

The ER-M suggested by the data (Table 4) is about 85 ppm; supported by the acute marine threshold predicted by EP methods (64 ppm), high toxicity in Baltimore Harbor samples (mean of 91.9 ppm) and Puget Sound AET for benthic community effects and amphipod bioassays (85 and 93 ppm , respectively). With one exception, effects were always observed in association with arsenic concentrations of 50 ppm or greater, an apparent effects threshold for arsenic (Table B-2). Many values calculated from data collected in Commencement Bay and nearby southern Puget Sound indicate very high arsenic concentrations (690 to 2257 ppm) in sediments associated with observed effects. This area was highly impacted by the atmospheric and aqueous discharge of arsenic from an industrial point source for many years and high arsenic concentrations have been frequently observed there.

The arsenic data are from three approaches and from several geographic areas, but do not include observations made in single-chemical, laboratory, SSBs. There appears to be relatively poor consistency and clustering among the available values at the low end of the range. Therefore, the degree of confidence in the ER-L should be considered as relatively poor. The ER-M value is supported by several observations and is roughly equivalent to an overall apparent effects threshold, and the degree of confidence in it should be considered as moderate.

**Table 3. Summary of sediment effects data available for arsenic.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Thresholds** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 93 |
| | - oyster larvae (*C. gigas*) bioassay | 700 |
| | - benthic community composition | 85 |
| | - Microtox™ bioassay | 700 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 93 |
| | - oyster larvae (*C. gigas*) bioassay | 700 |
| | - benthic community composition | 57 |
| | - Microtox™ bioassay | 700 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 70 |
| | - maximum level criterion | 700 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - oyster/mussel larvae bioassay | 54 |
| | - amphipod bioassay | 70 |

Table 3. Arsenic (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9% dead/20) to *R. abronius* | 2257.1 ± 4213.7 |
| | - moderately toxic (5.2 ± 1.1% dead/20) to *R. abronius* | 63.2 ± 148 |
| | - least toxic (2.5 ± 0.9% dead/20) to *R. abronius* | 28.3 ± 26.6 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 689.9 ± 2350.9 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 58.7 ± 148.1 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 27.8 ± 30.8 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic samples (95%LPL) to *R. abronius* | 1005 ± 2777 |
| | - moderately toxic (<87.5 to >95% LPL) to *R. abronius* | 25.1 ± 23.1 |
| | - non-toxic (>87.5% survival) to *R. abronius* | 22.6 ± 28.1 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8%) to *R. abronius* | 17.5 ± 14.2 |
| | - moderately toxic (33.8 ± 4.7%) to *R. abronius* | 10.4 ± 13.4 |
| | - least toxic (18 ± 6.6%) to *R. abronius* | 28 ± 21.5 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 14.65 ± 13.9 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 30.3 ± 22.4 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 50.7 ± 29.3 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 22.1 ± 19.4 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 13.7 ± 14.8 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 22.8 ± 22.1 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 22 ± 18.7 |
| 72 | WAUKEGAN HARBOR, WISCONSIN highly toxic (66.3 ± 4.25 % survival✓) to *H. azteca* | <47.2 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to *N. virens* | 1.88 |
| 56 | SOUTHERN CALIFORNIA | |
| | - Mean concordance with significant mortality (51.7%) to *G. japonica* | 8.3 |
| | - Mean concordancenot signicantly toxic (23.2% mortality) to *G. japonica* | 5.8 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to *M. rosenbergii* | 2.7 ± 0.2 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0 to 10% mortality to *P. pugio* in 96-h bioassays | 1.3 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* in 96-h elutriate bioassays | 2.8 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P.pugio* in 96-h elutriate bioassays | 1.0 |

Table 3. Arsenic (continued).

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 39 | NORWALK RIVER, CONNECTICUT<br>- 0% mortality to *P. pugio* in 96-h elutriate bioassays | 3.4 |
| 39 | LOS ANGELES, CALIFORNIA<br>- >50% mortality to *P. pugio* in 96-h 20% elutriate bioassays | 12.8 |
| 75 | TRINITY RIVER, TEXAS<br>- significant mortality to *Daphnia magna*<br>- non-toxic to *D. magna* | <br>3.4 ± 1.8<br>2.2 ± 1.2 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA<br>- no effects on benthic community abundance or species richness | 1.36 |
| 62 | BALTIMORE HARBOR, MARYLAND<br>- most toxic to mummichogs and spot in 48-hour bioassays<br>- least toxic to mummichogs and spot in 48-hour bioassays | <br>91.9 ± 78.6<br>32 ± 14.3 |
| 60 | DUPAGE RIVER, ILLINOIS<br>- low number of taxa (6.7 ± 2.5)<br>- high number of taxa (15.8 ± 2) | <br>7.4 ± 2.2<br>5.9 ± 1.1 |
| 61 | KISHWAUKEE RIVER, ILLINOIS<br>- low number of taxa (8.4 ± 0.5)<br>- high number of taxa (16.3 ± 4.6) | <br>3.7 ± 1.0<br>5.0 ± 1.8 |
| **Equilibrium Partitioning Approach** | | |
| 17 | EPA acute marine EP threshold (@4% TOC) | 64 |
| | EPA chronic marine EP threshold (@4% TOC) | 33 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes harbors sediments<br>- classification of non-polluted sediment<br>- classification of moderately polluted sediment<br>- classification of heavily polluted sediment | <br><3<br>3.0-8.0<br>>8 |
| 43 | New England interim high contamination level for dredge material | >20 |
| 12 | EPA Region V guideline for pollution classification of sediments<br>USGS alert levels to flag 15 to 20% of samples analyzed<br>Ontario Ministry of the Environment Dredge Spoil Guidelines<br>EPA Region VI proposed guideline | 3<br>200<br>8<br>5 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 12.5 |

Table 3. Arsenic (continued).

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | >23 |
| | - Class 2 (moderately contaminated) | 23-32 |
| | - Class 3 (contaminated) | 32-110 |
| | - Class 4 (heavily contaminated) | >220 |

References:


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
12. Pavlou and Weston, 1983
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
23. Jansen, 1987
26. DeWitt *et al.*, 1988
39. Lee and Mariani, 1977
43. NERBC, 1980
56. Anderson *et al.*, 1988
60. llinois EPA, 1988a
61. Illinois EPA, 1988b
62. Tsai *et al.*, 1979
64. VanDolah *et al.*, 1984
68. Bahnick *et al.*, 1981
71 Simmers *et al.*, 1984
72. Ingersoll and Nelson, in press
74. Tatem, 1986
75. Qasim *et al.*, 1980
80. Tetra Tech, 1985


**Table 4. Effects range--low and efects range--median values for arsenic and 16 concentrations used to determine these values arranged in ascending order.**

| Concentration (ppm) | End Point |
|---|---|
| 22.1 | San Francisco Bay, California bioassay COA |
| **33.0** | **ER-L** |
| 33.0 | EP chronic @4% TOC |
| 50.7 | San Francisco Bay, California bioassay COA |
| 54.0 | San Francisco Bay, California AET |
| 57.0 | Puget Sound, Washington AET - benthic |
| 58.7 | Commencement Bay, Washington bioassay COA |
| 63.2 | Commencement Bay, Washington bioassay COA |
| 64.0 | EP Acute @4% TOC |
| **85.0** | **ER-M** |
| 85.0 | Puget Sound, Washington AET - benthic |
| 91.9 | Baltimore Harbor, Maryland bioassay COA |
| 93.0 | Puget Sound, Washington AET - amphipod |
| 689.9 | Commencement Bay, Washington bioassay COA |
| 700.0 | Puget Sound, Washington AET - oyster |
| 700.0 | Puget Sound, Washington AET - Microtox™ |
| 1005.0 | Puget Sound, Washington bioassay COA |
| 2257.1 | Commencement Bay, Washington bioassay COA |

## Cadmium

Eisler (1985) summarized available toxicological data for cadmium and concluded that concentrations in freshwater exceeding 10 ppb are associated with high mortality, reduced growth, inhibited reproduction, and other adverse effects. He also concluded that resistance to cadmium was higher among marine species than among freshwater species; the LC50s for some marine organisms ranged from 320 to 430 ppb. Klapow and Lewis (1979) proposed a marine water quality standard of 3 ppb✓. Effects have been observed at concentrations as low as 1 ppb✓ among freshwater animals in water, 2 ppb✓ among freshwater plants in water, and 15.5 ppb✓ among marine animals in water (EPA, 1986). The 96-h LC50 for *Mysidopsis bahia* is 16 µg/L $Cd\,Cl^{2}$ (U.S. EPA, 1987).

A relatively large amount of data exists for cadmium in sediments (Tables 5 and 6). AET values have been calculated with data from Puget Sound (range: 5.1 to 9.6 ppm) and San Francisco Bay (1.2 to 1.7 ppm). Acute and chronic marine threshold values (96 and 31 ppm, respectively, assuming 4 percent TOC content) based upon EP are available. Spiked-sediment bioassays have been performed with the amphipod *R. abronius* (range in LC 50s of 1.01 -20.8 ppm), the fish *Pimepheles affinis* (LC50 of 11 ppm), and the polychaete *Nereis virens* (no effects in 40 ppm cadmium). The *R. abronius* bioassays have been performed with 4-d and 10-d exposure periods and with lethality and sublethal end-points. Matching chemical and biological data from field-collected samples are available from many geographic areas including Commencement Bay, San Francisco Bay, Southern California Bight, San Diego Bay, Hudson-Raritan Bay, Black Rock Harbor, Massachusetts Bay, and Baltimore Harbor; patterns in co-occurrence were determined for all of these and other data sets. In most cases, the chemical analyses determined that the sediments had contaminants other than cadmium that could have influenced the biological measures.

Either no measurable effects or very small apparent effects were observed in the data from bioassays of sediments from the Duwamish River (<0.5 ppm), Newport (<0.5 ppm), Stamford (2.8 ppm), Norwalk (4.1 ppm), New York Harbor (38.6 ppm), and in analyses of benthos at the Georgetown disposal site (<0.1 ppm). Mean cadmium concentrations differed very little between samples from Massachusetts Bay that had high, moderate, and low species richness (0.4 to 1.1 ppm). Relatively high survival in a suite of bioassays of San Diego Harbor was observed over a relatively large range in cadmium concentrations (0.9 to 32.5 ppm). Bioassay data from San Francisco Bay either lacked concordance with cadmium concentrations or indicated very little difference in mean concentration between the highly, moderately, or least toxic samples. Similarly, the AET values from San Francisco Bay are likely of limited value, since it appears other factors influenced the toxic responses. The Lake Union data indicated that only one site was significantly toxic and it was highly contaminated with petroleum hydrocarbons. Total species abundance in Southern California Bight sediments lacked concordance with the mean concentration of cadmium. Los Angeles Harbor sediments were more contaminated with chemicals other than cadmium (mean = 3.0 ppm). The data from bioassays of Waukegan Harbor were from a very small sample size (n=4) and those sediments had relatively high levels of many other contaminants. The Black Rock Harbor sediments were tested in an uptake/bioavailability study and had higher concentrations of metals other than cadmium. The data from the Sheboygan River bioassays were from an uptake study with a sample size of three and in sediments in which PCBs and other chemicals were highly elevated. Various tests with the clam *Macoma balthica* in Fraser River estuary sediments indicated a small gradient in cadmium concentrations among samples and a high proportion of the samples had cadmium concentrations below the detection limits (0.4 ppm). All of the data above were not used in the estimation of ER-L and ER-M values (Table B-3).

DuPage River sediments indicated no concordance between benthic taxa richness and mean cadmium concentrations. Most of the sediments sampled in the Kishwaukee River had cadmium concentrations below the detection limits of 1 ppm. An LC50 of 1.01 ppm developed from a *R. abronius* bioassay of foundry sands spiked with cadmium was, in effect, a bioassay of aqueous cadmium since no or very little fine-grained particles were available. Keweenaw Waterway sediments that were toxic to *Daphnia magna* contained higher concentrations of copper compared to cadmium. Sediments from Phillips Chain of Lakes, Torch Lake, and

Little Grizzly Creek were highly contaminated with copper; cadmium differed little between toxic and non-toxic sampling stations. Sediments from Cubatao River, Brazil were highly contaminated with chemicals other than cadmium All of the data described above were not considered further in the estimation of ER-L and ER-M values (Table B-3).

The remaining data suggest an ER-L of about 5 ppm (5.3 rounded to 5.0 ppm) (Table 6). Puget Sound AET values based upon different biological indicators ranged from 5.1 to 6.7 ppm. Significant mortality occurred among the amphipod *Grandidierella japonica* in bioassays of southern California sediments that had a mean cadmium concentration of 5.3 ppm. Lowest species richness and lowest abundance of arthropods and echinoderms in southern California sediments occurred in samples with mean cadmium concentrations of 4.7, 4.3, and 6.2 ppm, respectively. The amphipod *R. abronius* avoided sediments spiked with 5.6 and 5.8 ppm cadmium; and in other *R. abronius* bioassays of cadmium-spiked sediments, LC50s as low as 6.9 ppm were observed. Effects were usually observed at cadmium concentrations of 5 ppm or greater, but there were many exceptions to this overall apparent effects threshold (Table B-3).

The data also suggest an ER-M of about 9 ppm (9.1 rounded to 9.0 ppm) (Table 6). Many LC50 and EC50 concentrations for SSBs performed with *R. abronius* are in the range of 8.2 to 11.5 ppm cadmium. The Puget Sound AET values based upon oyster embryo and Microtox™ bioassays are 9.6 ppm. Significant mortality to *Daphnia magna* exposed to Trinity River, Texas sediments occurred in samples with a mean cadmium concentration of 10.6 ppm. Significant reduction in survival of *P. affinis* occurred in sediments spiked with 11 ppm.

The degree of confidence in the ER-L and ER-M values for cadmium should be considered as very high. Data are available from many approaches, from multiple methods for some approaches, and they are relatively consistent. An overall apparent effects threshold coincided with the ER-L value.

**Table 5. Summary of sediment effects data available for cadmium.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 6.7 |
| | - oyster larvae (*C. gigas*) bioassay | 9.6 |
| | - benthic community composition | 5.8 |
| | - Microtox™ bioassay | 9.6 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 6.7 |
| | - oyster larvae (*C. gigas*) bioassay | 9.6 |
| | - benthic community composition | 5.1 |
| | - Microtox™ bioassay | 9.6 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 0.96 |
| | - maximum level criterion | 9.6 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 1.7 |
| | - amphipod bioassay | 1.2 |

**Table 5. Cadmium (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 41.6 ± 79.8 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 2.9 ± 2.3 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 2.3 ± 1.3 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 15.3 ± 45.1 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 2.7 ± 2.0 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 1.9 ± 1.1 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 1.98 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | <0.5 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of *M. balthica* | 1.2 ± 1 |
| | - sediment populated by *M. balthica* | <0.04 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 0.4 |
| | - significant 24-h avoidance behavior among *M. balthica* | 1.4 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ±1 1.8% mortality) to *R. abronius* | 0.8 ± 0.5 |
| | - moderately toxic (33.8 ±4 .7% mortality) to *R. abronius* | 0.5 ± 0.3 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 0.6 ± 0.3 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 0.6 ± 0.4 |
| | - not toxic (18.4 ± 6.8% mortality) to R. abronius | 0.6 ± 0.3 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 0.7 ± 0.3 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 0.7 ± 0.5 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 0.4 ± 0.1 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 0.6 ± 0.4 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 0.6 ± 0.3 |
| 49 | PALOS VERDES SHELF, CALIFORNIA | |
| | - significantly toxic to *R. abronius* | 28.7 ± 3.1 |
| | - not toxic to *R. abronius* | 8.9 ± 9.2 |
| 50 | - major degradation to macrobenthos (20.2sp./0.1m. sq.) | 28.7 ± 3.1 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 5.3 |
| | - not toxic (23.2% mortality) to *G. japonica* | 3.2 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 0.4 ± 0.3 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 0.5 ± 0.3 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 6.2 ± 13.1 |

Table 5. Cadmium (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - high arthropod abundance (148 ±5 8/0.1 sq. m.) | 0.9 ± 1 |
| | - moderate arthropod abundance (72.6 ± 6.8/0.1 sq. m.) | 0.7 ± 0.7 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 4.3 ± 11.4 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m) | 1.5 ± 4 |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 0.6 ± 0.7 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 4.7 ± 12.2 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 9.4 ± 17.3 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 0.8 ± 1.1 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 1.1 ± 2 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 3.0 |
| 48 | SAN DIEGO BAY, CALIFORNIA | |
| | - >97% survival of *P. staminea* | 32.5 |
| | - >97% survival of *M. elongata* | 28.0 |
| | - >97% survival of *N. arenaceodentata* | 22.7 |
| | - >97% survival of *C. stigmaeus* and *M. elongata* | 32.5 |
| 66 | - ≥82% survival of *C. stigmaeus, A. sculpta,* and *A. tonsa* | 0.9 |
| | - ≥86% survival of *N. arenaceeodentata,* and *M. nasuta* | 0.9 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* | 1.2 ± 0.3 |
| 72 | WAUKEGAN HARBOR, ILLLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✔) to *H. azteca* | 2.5 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in nematode, *C.germanica* | 18.6 ± 8.9 |
| | - positive rate of growth in nematode, *C.germanica* | 11.8 ± 6.6 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to polychaete, *N. virens* | 1.6 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (93.6 ± 9.4/0.1 sq. m.) | 0.4 ± 0.1 |
| | - moderate benthos species richness (58.2 ±1 0.5/0.1 sq. m.) | 0.7 ± 0.6 |
| | - low benthos species richness (31 ± 6.5/0.1 sq. m.) | 1.1 ± 1.0 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 2.8 ± 0.5 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | <0.5 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 2.8 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 4.1 |

Table 5. Cadmium (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 40 | CUBATAO RIVER, BRAZIL | |
| | - 24-hour EC-50 with *D. simillis* | 0.2 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 1.7 ± 0.3 |
| | - not toxic to *D. magna* | 0.6 ± 0.3 |
| | - mean conc. in highly toxic (northern) sediments to *D. magna* | 1.5 ± 0.2✔ |
| | - mean conc. in least toxic (southern) sediments to *D. magna* | 0.5 ± 0.4✔ |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortality to *D. magna* | 4.9 |
| | - low mortality (0-5%) to *D. magna* | 3.1 ± 0.6 |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *Hexagenia* sp. | 2.5 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 10.6 ± 8.7 |
| | - low mortality to *D. magna* | 4.8 ± 5.6 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <0.1 |
| 44 | NEW YORK HARBOR, NEW YORK | |
| | - <10% mortality in adult *N. virens*, *M. mercenaria*, and *P. pugio* | 38.6 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (5.1 ± 3.5 TLm) spot (5.9 ± 3.4 TLm) | 22.8 ± 19.8 |
| | - least toxic to mummichogs (43.2 ± 31.1 TLm) spot (24 ± 5.6 TLm) | 2.0 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 1.3 ± 0.6 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 1.5 ± 0.9 |
| 60 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | .05 ± 0 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± .6/site) | 0.3 ± 0.8 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@4%TOC) | 96 |
| 4 | EPA chronic marine EP threshold (@4%TOC) | 31 |
| **Spiked-sediment Bioassays** | | |
| 70 | Significant reduction in survival of *P. affinis* in 446- d bioassay | 11 |
| 8 | LC50 of *R. abronius* in 10-d bioassay (n=25) | 9.81 |
| | EC50 of *R. abronius* emergence in 10-d bioassay | 9.72 |
| | EC50 of *R. abronius* reburial in 10-d bioassay | 9.07 |

Table 5. Cadmium (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Spiked-sediment Bioassays** | | |
| 28 | LC50 for *R. abronius* in 10-d bioassay (Yaquina Bay) | 8.8 |
| | LC50 for *R. abronius* in 10-d bioassay (Whidbey Island) | 10 |
| 45 | LC50 ± 95% C.L. for *R. abronius* (fresh) 10-d bioassay | 8.7 (8.1 - 9.4) |
| | LC50 ± 95% C.L. for *R. abronius* juveniles | 8.2 (7.6 - 8.9) |
| | LC50 ± 95% C.L. for *R. abronius* adults | 11.5 (10.6 - 12.4) |
| 9 | LC50 for *R. abronius* survival, 10-d (n = 5 x 11 dilutions) | 6.9 |
| | EC50 for *R. abronius* reburial, 10-d (n = 5 x 11 dilutions) | 6.5 |
| | EC50 for *R. abronius* reburial, 4-d (n = 5 x 6 dilutions) | 20.8 |
| | LC50 for R. *abronius* survival, 4-d (n = 5 x 6 dilutions) | 25.9 |
| 22 | No observable mortality or behavioral effects to *N. virens* in 28 days | 40 |
| 11 | 23.2% dead and 86% avoidance, 56 *R. abronius*, 72-h, 2-choice exeriment. | 5.8 |
| | 44.4% avoidance, 45 *R. abronius*, 72-h, 2-choice experiment | 5.6 |
| 27 | LC76 for *R. abronius* in 72-h bioassay | 8.5 |
| | LC98 for *E. sencillus* in 72-h bioassay | 8.4 |
| 73 | LC50 for *R. abronius* exposed to foundry sands, 10-d bioassay | 1.0 ± 1.1 |
| | Overall LC50 for *R. abronius* exposed to sand (MS-1) | 8.9 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes harbors classification of non-polluted sediment | 6 |
| 43 | New England interim high contamination level for dredge material | >7 |
| 12 | EPA Region V guideline for pollution classification of sediments | 6 |
| | USGS alert levels to flag 15 to 20% of samples analyzed | 20 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 1 |
| | EPA Region VI proposed guidelines | 2 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 0.7 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <6 |
| | - Class 2 (moderately contaminated) | 6-19 |
| | - Class 3 (contaminated) | 19-32 |
| | - Class 4 (heavily contaminated) | >32 |

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2. PTI Environmental Services, 1988
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43. NERBC, 1980
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**Table 5. Cadmium (continued)**

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72. Ingersoll and Nelson, 1989
73. Ott, 1986
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75. Qasim *et al.*, 1980
77. McGreer, 1982
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82. Gilbert *et al.*, 1976
83. Word and Mearns, 1979

**Table 6. Effects range-low and effects range-median values for cadmium and 36 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 4.3 | Southern California arthropods COA |
| 4.7 | Southern California species richness COA |
| **5.0** | **ER-L** |
| 5.1 | Puget Sound, Washington AET - benthic |
| 5.3 | Southern California bioassay COA |
| 5.6 | SSB with *R. abronius* |
| 8.4 | SSB with *R. abronius* |
| 5.8 | Puget Sound, Washington AET - benthic |
| 5.8 | SSB with *R. abronius* |
| 6.2 | Southern California echinoderms COA |
| 6.5 | SSB with *R. abronius* |
| 6.7 | Puget Sound, Washington AET - amphipod |
| 6.9 | SSB with *R. abronius* |
| 8.2 | SSB with *E. sencillus* |
| 8.5 | SSB with *R. abronius* |
| 8.7 | SSB with *R. abronius* |
| 8.8 | SSB with *R. abronius* |
| 8.9 | SSB with *R. abronius* |
| **9.0** | **ER-M** |
| 9.1 | SSB with *R. abronius* |
| 9.6 | Puget Sound, Washington AET - oyster |
| 9.6 | Puget Sound, Washington AET - Microtox™ |
| 9.7 | SSB with *R. abronius* |
| 9.8 | SSB with *R. abronius* |
| 10.0 | SSB with *R. abronius* |
| 10.6 | Trinity River, Texas bioassay COA |
| 11.0 | SSB with *P. affinis* |
| 11.5 | SSB with *R. abronius* |
| 15.3 | Commencement Bay, Washington bioassay COA |
| 18.6 | Hudson-Raritan, New York bioassay COA |
| 20.8 | SSB with *R. abronius* (4-day) |
| 22.8 | Baltimore Harbor, Maryland bioassay COA |
| 25.9 | SSB with *R. abronius* (4-day) |
| 28.7 | Palos Verdes Shelf, California bioassay COA |
| 28.7 | Palos Verdes Shelf, California benthos COA |
| 31.0 | EP chronic marine @4% TOC |
| 41.6 | Commencement Bay, Washington bioassay COA |
| 96.0 | EP acute marine @4% TOC |

**Chromium**

The toxicity of chromium is highly influenced by speciation; acute and chronic toxicity to aquatic and marine organisms has been tested with chromium (III) and chromium (VI). Acute toxicity of chromium (VI) to saltwater animals occurs at concentrations ranging from 2,000 to 105,000 ppb✓. Acute toxicity of chromium (III) has been observed at concentrations of 10,300 to 31,500 ppb✓ (U. S. EPA, 1986). Eisler (1986) also observed a wide range in concentrations in water that caused effects: 445 to 2,000 ppb for chromium (VI) and 2,000 to 3,200 ppb✓for chromium (III). Klapow and Lewis (1979) proposed a marine water quality standard of 2 ppb✓ for total chromium.

A relatively large amount of data exists for chromium in sediments (Table 7). AET values were available for Puget Sound and were calculated from data available from several studies in San Francisco Bay. No single-chemical, SSB data were available and no SLC or EP data for chromium were available. Co-occurrence analyses were performed with data from studies performed with benthic community composition and toxicity tests. These studies had been performed in many areas, including Commencement Bay, Strait of Georgia, San Francisco Bay, off various areas of southern California, Hudson-Raritan Bay estuary, Massachusetts Bay, Trinity River, Baltimore Harbor, DuPage River, Kishwaukee River, and Phillips Chain of Lakes.

No effects among the benthos at the Georgetown, South Carolina disposal site were observed at up to 2.5 ppm chromium. Most of the bioassays of San Diego Bay sediments indicated high survival. Only one sample from Lake Union indicated toxicity and it was overwhelmingly dominated by PAH. Very little concordance between chromium and toxicity was observed in Commencement Bay samples. Southern California sediments that had moderate densities of echinoderms had mean concentrations of chromium similar to those that had high densities. Waukegan Waterway sediments toxic to *Hyalella azteca* were tested with only three samples. Kishwaukee sediments were more highly contaminated with PCBs than with chromium. Southern California sediments with moderate arthropod densities had chromium concentrations similar to those that had high densities of arthropods. Los Angeles Harbor sediments toxic to *P. pugio* were not highly contaminated with chromium. Three stations in the DuPage River had low numbers of benthic macroinvertebrate taxa, but only one had a high chromium concentration. Burrowing time for *Macoma balthica* exposed to Fraser River sediments was increased relative to controls, but most of the variance in the data was explained by the high concentrations of other chemicals. None of the data from these studies was used further in the estimation of ER-L and ER-M values (Table B-4).

The remaining data (Table 8) suggest an ER-L of about 80 ppm chromium, roughly the lower 10 percentile of the data. Massachusetts Bay sediments with low species richness had a mean chromium content of 81 ppm, as compared to a mean of 27 ppm in samples that had high species richness. Trinity River sediments that were significantly toxic to *Daphnia magna* had a mean of 72.6 ppm, as compared to samples that were not toxic that had a mean of 18.1 ppm. Southern California samples that were significantly toxic to *Grandidierella japonica* had a mean of 81.4 ppm, as compared to non-toxic samples with a mean of 73 ppm.

The data suggest an ER-M value of about 145 ppm, the 50 percentile value of the data (Table 8). This value is supported by significant toxicity of Sheboygan River sediments (128 ppm) and low southern California arthropod abundance (145.8 ppm).

The degree of confidence in the ER-L and ER-M values for chromium should be considered as moderate. There are no data from single-chemical, spiked-sediment bioassays and from EP principles. All of the available data are field collections of matching biological and chemical data and are, therefore, subject to the weaknesses described previously regarding co-occurrence analyses. Furthermore, there appears to be relatively little convergence, or consistency in the values reported from the various studies. Some of the poor consistency may be due to a lack of speciation data for chromium; all of the data were reported as total chromium, whereas the hexavalent form has been reported as the most toxic. No overall effects threshold is apparent from the available data.

Table 7. Summary of sediment effects data available for chromium.

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 270 |
| | - benthic community composition | 260 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 280 |
| | - *R. abronius* amphipod bioassay | 370 |
| **Co-occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic to *R. abronius* (15.7 ± 3.9 dead/20) | 19.7 ± 11.3 |
| | - moderately toxic to *R. abronius* (5.2 ± 1.1 dead/20) | 17.7 ± 7.3 |
| | - least toxic to *R. abronius* (2.5 ± 0.9 dead/20) | 16.2 ± 8.1 |
| | - highly toxic (44.5 ± 19.0% abnormal) to oyster larvae | 22.2 ± 9 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 17.7 ± 7.3 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 11.8 ± 3.7 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 20 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 15.3 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 60 |
| | - significant 24-h avoidance behavior among *M. balthica* | 90 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 87.3 ± 22.1 |
| | - sediment populated by feral *M. balthica* | 42 ± 11 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67.0 ± 11.8% mortality to *R. abronius* | 141.8 ± 86.5 |
| | - moderately toxic (33.8 ± 4.7% mortality) to. *R. abronius* | 163.3 ± 116.7 |
| | - least toxic (18.4 ± 6.8% mortality) to *R. abronius* | 195 ± 93.9 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 154.9 ± 102.1 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 202.6 ± 97.3 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 97.5 ± 66.7 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 164 ± 91.4 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 88.2 ± 82.7 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 133.7 ± 94.2 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 150.2 ± 85.9 |
| 50 | PALOS VERDES SHELF , CALIFORNIA | |
| | - "major degradation" to macrobenthos (20.2sp/0.1m. sq.) | 669.3 ± 172.9 |

Table 7. Chromium (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-occurrence Analyses** | | |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 81.4 ± 88.5 |
| | - not toxic (23.2% mortality) to *G. japonica* | 73 ± 124.4 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 29.6 ± 15.6 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 32.3 ± 17.5 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 201.3 ± 349 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 40.7 ± 30.9 |
| | - moderate arthropod abundance (72.6 ± 6.8/0.1 sq. m.) | 46.3 ± 43.3 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 145.8 ± 307.9 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m.) | 62.3 ± 139.2 |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 38.1 ± 36.3 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 156.6 ± 320.9 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 292.6 ± 459.3 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 42 ± 39.8 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 54 ± 83.5 |
| 39 | LOS ANGELES HARBOR , CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 47.6 |
| 48 | SAN DIEGO BAY, CALIFORNIA | |
| | - >97% survival of clam, *P. staminea* | 299.5 |
| | - >97% survival of shrimp, *M. elongata* | 254.8 |
| | - >97% survival of polychaete, *N. arenaceodentata* | 299.5 |
| | - >97% survival of sanddab, *C. stigmaeus*, and *M. elongata* | 299.5 |
| 66 | - ≥82% survival of *C. stigmaeus*, *A. sculpta*, and *A. tonsa* | 26 |
| | - ≥86% survival of *N. arenaceaodentata* and *M. nasuta* | 26 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* | 87 ± 47 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✓) to *H. azteca* | 38.5 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5) | 59.7 ± 28.7 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2) | 34 ± 5.9 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5) | 43.4 ± 22.5 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6) | 29.2 ± 9.1 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 108.8 ± 19.6 |
| | - not toxic to *D. magna* | 36.3 ± 21.9 |
| | - mean concentration in highly toxic (northern) sediments (to *D. magna*) | 101.6 ± 23✓ |
| | - mean concentration in least toxic (southern) sediments (to *D. magna*) | 29 ± 14✓ |

**Table 7. Chromium (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-occurrence Analyses** | | |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *Hexagenia* sp. | 180 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortality to *D. magna* | 980 |
| | - low mortality to *D. magna* | 315.4 ± 236 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 128 ± 4 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in nematode, *C. germanica* | 160.3 ± 85.4 |
| | - positive rate of growth in nematode, *C. germanica* | 144.6 ± 88.6 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to polychaete, *N. virens* | 369.2 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (mean = 93.6 ± 9.4) | 27 ± 11.1 |
| | - moderate benthos species richness (mean = 58.2 ± 10.5) | 60.9 ± 27.5 |
| | - low benthos species richness (mean = 31 ± 6.5) | 81 ± 29.3 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | 19.9 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 86 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 67.5 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 2.46 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 72.6 ± 60.6 |
| | - low mortality to *D. magna* | 18.1 ± 16.8 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (5.1 ± 3.5) and spot (5.9 ± 3.4) | 1646 ± 1628 |
| | - least toxic to mummichogs (43.2 ± 31.1) and spot (24 ± 5.6) | 335 ± 179.7 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes harbors classification of non-polluted sediment | <25 |
| | Great Lakes harbors classification of moderately polluted sediment | 25-75 |
| | Great Lakes harbors classification of heavily polluted sediment | >75 |
| 43 | New England interim high contamination level for dredged material | >300 |

**Table 7. Chromium (continued)**

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 12 | EPA Region V guideline for pollution classification of sediments | 25 |
| | USGS alert levels to flag 15-20% of samples analyzed | 200 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 25 |
| | EPA Region VI proposed guidelines | 100 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <190 |
| | - Class 2 (moderately contaminated) | 190-220 |
| | - Class 3 (contaminated) | 220-550 |
| | - Class 3 (heavily contaminated) | >550 |

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79. Tietjen and Lee, 1984
80. Tetra Tech, 1985
82. Gilbert *et al.*, 1976
83. Word and Mearns, 1979
* Various, please see text

**Table 8. Effects range-low and effects range-median values for chromium and 21 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 60.9 | Massachusetts Bay benthos COA |
| 72.6 | Trinity River, Texas bioassay COA |
| **80.0** | **ER-L** |
| 81.0 | Massachusetts Bay benthos COA |
| 81.4 | Southern California bioassay COA |
| 87.0 | Little Grizzly Creek, California bioassay COA |
| 87.3 | Fraser River, B.C. bivalves COA |
| 90.0 | Fraser River, B.C. bioassay COA |
| 101.6 | Keweenaw Waterway, Michigan bioassay COA |
| 108.8 | Keweenaw Waterway, Michigan bioassay COA |
| 128.0 | Sheboygan River, Wisconsin bioassay COA |
| **145.0** | **ER-M** |
| 145.8 | Southern California arthropod abundance COA |
| 156.6 | Southern California benthos COA |
| 160.3 | Hudson-Raritan Bay, New York estuary toxicity COA |
| 180.0 | Torch Lake, Michigan bioassay COA |
| 201.3 | Southern California echinoderm abundance COA |
| 260.0 | Puget Sound, Washington, AET - benthic |
| 270.0 | Puget Sound, Washington, AET - amphipod |
| 369.2 | Black Rock Harbor, Connecticut, bioassay COA |

Table 8. (continued)

| Concentrations (ppm) | End Point |
|---|---|
| 669.3 | Palos Verdes Shelf, California, benthos COA |
| 980.0 | Phillips Chain of Lakes, Wisconsin, bioassay COA |
| 1646.0 | Baltimore Harbor, Maryland, bioassay COA |

## Copper

Saltwater animals are acutely sensitive to copper in water at concentrations ranging from 5.8 ppb✓ to 600 ppb✓, mysids indicate sensitivity in chronic life-cycle studies at 77 ppb✓, and freshwater animals are sensitive at concentrations as low at 16.7 ppb✓ (EPA, 1986). Klapow and Lewis (1979) proposed a marine water quality standard of 5 ppb✓.

A considerable amount of data exist in which the concentration of copper in sediments can be associated with measures of effects (Table 9). EP values are available for acute and chronic marine conditions. Apparent effects threshold values for Puget Sound and San Francisco Bay are listed. Spiked-sediment bioassays have been performed with sediment collected in Puget Sound and Oregon. Matching sediment chemistry and biological data are available for many areas and the results of analyses of co-occurrence are listed in Table 9.

Several field studies are noteworthy as regards copper concentrations and measures of effects in sediments. Malueg *et al.* (1984a) sampled sites along the north and south reaches of the Keweenaw Waterway. Copper concentrations were very high in the north reaches and much lower in the southern part. The minimal concentration above which toxicity always occurred (equivalent to an AET) was 480 ppm. Kraft and Sypniewski (1981) also sampled benthos in the north and south reaches of the Keweenaw Waterway. The average copper concentration in the northern sampling stations was 589 ppm and was associated with a depressed average number of benthic taxa relative to the southern stations. Rygg (1985) reported that above 200 ppm copper, benthic community diversity was invariably depressed in Norwegian fjords. The lowest copper concentration in Little Grizzly Creek sediments above which toxicity was always observed by Malueg *et al.* (1984b) was 550 ppm.

In one of only two reports in which results of SSBs with copper were performed, Phelps *et al.* (1983) reported that the burrowing time for the littleneck clam *Protothaca staminea* was significantly decreased at sediment concentrations exceeding 17.8 ppm. There appeared to be a threshold between 14.7 and 17.8 ppm copper in this burrowing response. The sediments used in the tests had a background concentration of 12 ppm before spiking was performed. However, other field-collected sediments with ambient concentrations of 23 ppm caused no increase in burrowing time and sediments spiked with 10,240 ppm copper and Chelex 100 chelating agent also caused no increase in burrowing time. Therefore, it appears that copper concentrations of about 20 ppm may begin to induce sublethal behavioral effects when the copper is not tightly chelated or otherwise bound to the sediments. The data from toxicity tests of four samples from Waukegan Waterway (Ingersoll and Nelson, in press) indicate that copper concentrations in sediments and toxicity to *Hyalella azteca* were positively correlated, whereas there was poor concordance between the toxicity data and the concentrations of other chemicals. The minimum copper concentration associated with a significantly toxic sample was 19.5 ppm, similar to the 17.8 ppm value determined in the spiked bioassays.

The data from two studies (Massachusetts Bay benthos and Puget Sound spiked sediments) suggest that effects may begin at concentrations as low as 15 to 18 ppm, but very little other data provide confirmatory evidence that effects are commonly associated with concentrations this low (Table B-5). The lower 10 percentile of the data is equivalent to about 70 ppm (68.2 rounded to 70 ppm). This ER-L value is supported by bioassay data from a *Macoma* burrowing experiment with British Columbia sediments (67 ppm copper), significantly toxic sediments from the Trinity River (mean 68.4) and San Francisco Bay bioassay data (means of 68.2 and 76 ppm). An ER-M value (50 percentile) of about 390 ppm is supported by two Puget Sound AETs (390 ppm). With the exception of bioassays of San Diego Bay sediments performed with relatively resistant species, effects were always observed in association with copper concentrations of 300 ppm or greater (Table B-5).

It is noteworthy that LC50 values from six different bioassay series with copper-spiked sediments ranged from 681 to 2,296 ppm (Cairns *et al.*, 1984) as compared to the previously described ET50 of 17.8 ppm for a burrowing bivalve. Effects have been associated with copper concentrations ranging from 17.8 to 2820 ppm. However, the degree of confidence in the ER-L and ER-M values must be considered relatively high. A relatively large amount of data is available and they are from all of the major approaches. Both values are supported by clusters of data. The overall apparent effects threshold is similar to the ER-M value.

**Table 9. Summary of sediment effects data available for copper.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 810 |
| | - oyster larvae (*C. gigas*) bioassay | 390 |
| | - benthic community composition | 310 |
| | - Microtox™ bioassay | 390 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 1300 |
| | - oyster larvae (*C gigas*) bioassay | 390 |
| | - benthic community composition | 530 |
| | - Microtox™ bioassay | 390 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 81 |
| | - maximum level criteria | 810 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 110 |
| | - *R. abronius* amphipod bioassay | 180 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 2820 ± 4881 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 118 ± 98 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 85.1 ± 69 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 918 ± 2750 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 106 ± 93 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 73 ± 75 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic to *R. abronius* (95% LPL) | 1260 ± 3251 |
| | - moderately toxic to *R. abronius* (<87.5% survival to >95% LPL) | 138 ± 124 |
| | - least toxic to *R. abronius* (>87.5% survival) | 98 ± 90 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 156 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 43 |

**Table 9. Copper (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 67 |
| | - significant 24-h avoidance behavior among *M. balthica* | 150 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 135 ± 57 |
| | - sediment populated by feral *M. balthica* | 28 ± 16 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 85 ± 63 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 64 ± 40 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 72 ± 41 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 70 ± 47 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 75 ± 43 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 88 ± 33 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 76 ± 51 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 35 ± 17 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 68 ± 48 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 47 ± 26 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* and *Hexagenia* sp. | 1374 ± 809 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 181 |
| | - not toxic (23.2% mortality) to *G. japonica* | 62 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 12 ± 6 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 13 ± 14 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 97 ± 177 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 16 ± 14 |
| | - moderate arthropod abundance (72 ± 3.3/0.1 sq. m.) | 15 ± 18 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 71 ± 155 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m.) | 31 ± 60 |
| | - moderate species richness ( 72 ± 3.3/0.1 sq. m.) | 15 ± 15 |
| | - low species richness ( 51.2 ± 8.6/0.1 sq. m.) | 73 ± 166 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 147 ± 232 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 20 ± 22 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 21 ± 39 |
| 49 | PALOS VERDES, CALIFORNIA | |
| | - significantly toxic to *R. abronius* | 592 ± 126 |
| | - not toxic to *R. abronius* | 251 ± 227 |
| | - major degradation to macrobenthos (20.2 sp/0.1 m. sq.) | 592 ± 126 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 147 |

Table 9. Copper (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 48 | SAN DIEGO BAY, CALIFORNIA | |
| | - >97% survival of clam, *P. staminea* | 995 |
| | - >97% survival of mysid, *M. elongata* | 312 |
| | - >97% survival of polychaete, *N. arenaceodentata* | 995 |
| | - >97% survival of sanddab, *C. stigmaeus* and mysid, *M. elongata* | 995 |
| 66 | - ≥82% survival of *C. stigmaeus*, *A. sculpta*, and *A. tonsa* | 210 |
| | - ≥86% survival of *N. arenaceaodentata* and *M. nasuta* | 210 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✔) to *H. azteca* | 19.5 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 77 ± 39 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 62 ± 25 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | 45 ± 53 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 19.5 ± 6 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 145 ± 2 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortaliity to *D. magna* (n = 1) | 540 |
| | - low mortality to *D. magna* (n = 5) | 135 ± 118 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 730 ± 205 |
| | - not toxic to *D. magna* | 43 ± 49 |
| | - mean concentration in highly toxic (northern) sediments (to *D. magna*) | 612 ± 318✔ |
| | - mean concentration in least toxic (southern) sediments (to *D. magna*) | 24 ± 11✔ |
| 78 | - significantly depressed macrobenthos taxa richness | 589 |
| | - high macrobenthos taxa richness | 33 |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *Hexagenia* sp. | 1800 |
| 69 | MISSISSIPPI RIVER | |
| | - 80-100% survival (92 ± 6.3) of *G. pseudolimnaeus*, 4-d bioassay | 17.8 |
| | - 25% (n = 1) survival of mayfly (*Hexagenia* sp.), 4-d bioassay | 2.2 |
| | - 80-100% survival (90 ± 7.5) of mayfly (*Hexagenia* sp), 4-d bioassay | 8 ± 5 |
| | - 55% ± 10% survival of midges (*C. tentans*), 4-d bioassay | 4 ± 3 |
| | - 90% ± 5.8% survival of midges (*C. tentans*), 4-d bioassay | 9 ± 4 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (93.6 ± 9.4) | 5 ± 2 |
| | - moderate benthos species richness (58.2 ± 10.5) | 15 ± 7 |
| | - low benthos species richness (31 ± 6.5) | 16 ± 7 |

Table 9. Copper (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in *C. germanica* | 453 ± 311 |
| | - positive rate of growth in *C. germanica* | 251 ± 232 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to *N. virens* | 612 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 218 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 224 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | 12 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (TLm 5.1 ± 3.5) and spot (TLm5.9 ± 3.4) | 1071 ± 948 |
| | - least toxic to mummichogs (TLm 43.2 ± 31.1) and spot (TLm 24 ± 5.6) | 158 ± 29 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 1 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 68 ± 62 |
| | - low mortality to *D. magna* | 18 ± 15 |
| 41 | NORWEGIAN FJORDS, NORWAY | |
| | - 50% reduction from maximum in Hurlbert's benthic species diversity index | 200 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@4% TOC) | 216 |
| 4 | EPA chronic marine EP threshold (@4% TOC) | 136 |
| **Spiked-Sediment Bioassays** | | |
| 53 | TUALATIN RIVER, OREGON | |
| | - LC50 of midge, *C. tentans* in 10-d bioassay | 2296 |
| | - LC50 of cladoceran, *D. magna* in 48-h bioassay | 937 |
| | SOAP CREEK POND, OREGON | |
| | - LC50 of midge, *C. tentans* in 10-d bioassay | 857 |
| | - LC50 of cladoceran, *D. magna* in 48-h bioassay | 681 |
| | - LC50 of amphipod, *G. lacustris* in 10-d bioassay | 964 |
| | - LC50 of amphipod, *H. azteca* in 10-d bioassay | 1078 |
| 32 | PUGET SOUND, WASHINGTON | |
| | - ET50 for burrowing time of clam, *P. staminea* | 17.8 |

**Table 9. Copper (continued)**

| References | Background Approaches | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes Harbors | |
| | - classification of non-polluted sediments | <25 |
| | - classification of moderately polluted sediments | 25-50 |
| | - classification of heavily polluted sediments | >50 |
| 43 | New England interim high contamination level for dredge material | >400 |
| 12 | EPA Region V guideline for pollution classification of sediments | 25 |
| | USGS alert levels to flag 15 to 20% of samples analyzed | 2000 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 25 |
| | EPA Region VI proposed guidelines | 50 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 68 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <60 |
| | - Class 2 (moderately contaminated) | 60-190 |
| | - Class 3 (contaminated) | 190-370 |
| | - Class 4. (heavily contaminated) | >370 |

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82. Gilbert *et al.*, 1976
83. Word and Mearns,1979

* -Various, please see text

**Table 10. Effects range-low and effects range-median values for copper and 51 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 15.0 | Massachusetts Bay benthos COA |
| 17.8 | Sublethal SSB with *Macoma* |
| 19.5 | Waukegan Waterway, Illinois bioassay COA |
| 45.4 | Kishwaukee River, Illinois benthos COA |
| 67.0 | *M. balthica* burrowing ET50 COA |
| 68.2 | San Francisco Bay, California bioassay COA |
| 68.4 | Trinity River, Texas bioassay COA |
| **70.0** | **ER-L** |
| 76.0 | San Francisco Bay, California bioassay COA |
| 84.6 | San Francisco Bay, California bioassay COA |
| 87.7 | San Francisco Bay, California bioassay COA |
| 96.7 | Southern California echinoderms COA |
| 106.3 | Commencement Bay, Washington bioassay COA |
| 110.0 | San Francisco Bay, California AET |
| 117.8 | Commencement Bay, Washington bioassay COA |
| 134.6 | Fraser River, B.C. benthos - *M. balthica* COA |
| 136.0 | EP chronic marine threshold |
| 138.0 | Puget Sound, Washington bioassay COA |
| 145.0 | Sheboygan River, Wisconsin bioassay COA |
| 147.0 | Los Angeles Harbor, California bioassay COA |
| 150.0 | Fraser River, B.C bioassay COA |
| 156.0 | Lake Union, Washington bioassay COA |
| 180.0 | San Francisco Bay, California AET |
| 181.3 | Southern California bioassay COA |
| 200.0 | Norway benthos COA |
| 216.0 | EP acute marine threshold |
| 310.0 | Puget Sound, Washington AET - benthic |
| **390.0** | **ER-M** |
| 390.0 | Puget Sound, Washington AET - oyster |
| 390.0 | Puget Sound, Washington AET - Microtox™ |
| 453.0 | Hudson-Raritan Bay, New york bioassay COA |
| 530.0 | Puget Sound, Washington AET - benthic |
| 540.0 | Phillips Chain of Lakes, Wisconsin bioassay COA |
| 589.0 | Keweenaw Waterway, Michigan benthos COA |
| 592.0 | Palos Verdes Shelf, California, bioassay COA |
| 592.0 | Palos Verdes Shelf, California benthos COA |
| 612.0 | Black Rock Harbor, Connecticut bioassay COA |
| 612.0 | Keweenaw Waterway, Michigan bioassay COA |
| 681.0 | SSB with *Daphnia* |
| 730.0 | Keweenaw Waterway, Michigan bioassay COA |
| 810.0 | Puget Sound, Washington AET - amphipod |
| 857.0 | SSB with midge |
| 918.0 | Commencement Bay, Washington bioassay COA |
| 937.0 | SSB with *Daphnia* |
| 964.0 | SSB with amphipod |
| 1071.0 | Baltimore Harbor, Maryland bioassay COA |
| 1078.0 | SSB with amphipod |
| 1260.0 | Puget Sound, Washington bioassay COA |
| 1300.0 | Puget Sound, Washington AET - amphipod |
| 1374.0 | Little Grizzly Creek, California bioassay COA |
| 1800.0 | Torch Lake, Michigan bioassay COA |
| 2296.0 | SSB with midge |
| 2820.0 | Commencement Bay, Washington bioassay COA |

**Lead**

Along with other adverse effects, lead can modify the function and structure of kidney, bone, the central nervous system, and the hepatopoietic system (Eisler, 1988b). Adverse effects upon daphnid reproduction has been observed at concentrations in water as low as 1 ppm, organolead compounds are generally more toxic than inorganic forms, adverse effects usually occur at concentrations ranging from 1.3 to 7.7 ppb✓ in water; and marine animals may be more resistant to effects of lead than freshwater species (Eisler, 1988b). The proposed marine water quality standard for California was 8 ppb✓ in water (Klapow and Lewis, 1979).

A relatively large amount of data exists for lead and measures of effects in sediments (Table 11). AET and EP values are available. Matching biological and chemical data from many studies performed in areas such as Puget Sound, Commencement Bay, San Francisco Bay, southern California, Hudson-Raritan estuary, and Trinity River are available. However, no single-chemical, SSB data are available.

No significant toxicity was observed in sediments from the Duwamish River, Stamford, Norwalk, and Newport at lead concentrations up to 277 ppm. San Francisco Bay sediments that were significantly toxic to amphipods had very little difference in lead concentrations compared to those that were not toxic. Total benthos abundance and some categories of other measures of benthic communities off southern California were not in concordance with lead concentrations. The minimum lead concentration associated with toxicity of Waukegan Harbor sediments was below the detection limits of 32 ppm. Lead concentrations did not differ remarkably among stations sampled in the Cubatao River, Brazil. The Little Grizzly Creek system toxicity tests suggested little concordance between toxicity and lead concentrations. These data were not considered further in the estimation of ER-L and ER-M values (Table B-6).

The minimum concentration above which effects were observed was about 27 ppm; significant toxicity to *Daphnia magna* was reported at this concentration (Table 12). Kishwaukee River macroinvertebrate taxa richness was lower in sediments with a mean lead concentration of 31 ppm, compared to a mean of 21 ppm in taxa-rich sediments. The data suggest an ER-L of about 35 ppm, equivalent to the lower 10 percentile of the data. This value is supported by increased burrowing time of *Macoma balthica* (32 ppm), depressed benthos diversity in Norwegian fjords (35 ppm), Los Angeles Harbor bioassay data (41.3 ppm), and depressed benthos species richness in Massachusetts Bay (mean 42 ppm). The 50 percentile value in the data suggests an ER-M of about 110 ppm; supported by Torch Lake and Commencement Bay bioassay data (110 ppm, mean 113 ppm, respectively), San Francisco Bay AET for amphipod bioassay (120 ppm), observations of the concentration associated with significant bioeffects in San Francisco Bay (130 ppm), and the EP chronic marine threshold of 132 ppm. Effects were usually observed at concentrations of 110 ppm or greater and always observed at concentrations of 300 ppm or greater (Table B-6).

The degree of confidence in the ER-L and ER-M values for lead should be considered as moderate and high, respectively. A relatively large amount of data exist to relate sediment concentrations with measures of effects, and both values are supported by small clusters of data. However, the chemical data are not speciated to indicate the proportion that is in organic and inorganic forms, there are no SSB data, the available data indicate a fairly wide range in concentrations associated with effects, and the overall apparent effects threshold lies outside the ER-L/ER-M range.

**Table 11. Summary of sediment effects data available for lead.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 660 |
| | - oyster larvae (*C. gigas*) bioassay | 660 |
| | - benthic community composition | 300 |
| | - Microtox™ bioassay | 530 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 660 |
| | - oyster larvae (*C gigas*) bioassay | 660 |
| | - benthic community composition | 450 |
| | - Microtox™ bioassay | 530 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 66 |
| | - maximum level criteria | 660 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 140 |
| | - *R. abronius* amphipod bioassay | 120 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 1613 ± 2628 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 171 ± 192 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 78 ± 75 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 570 ± 1489 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 113 ± 123 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 105 ± 173 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic to *R. abronius* (95%LPL) | 750 ± 1763 |
| | - mod. toxic to *R. abronius* (<87.5% survival to >95% LPL) | 137 ± 140 |
| | - least toxic to *R. abronius* (>87.5% survival) | 47 ± 31 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 300 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 27.1 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 32 |
| | - significant 24-h avoidance behavior among *M. balthica* | 74 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 82 ± 49 |
| | - sediment populated by feral *M. balthica* | 14 ± 9 |

Table 11. Lead (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 96 ± 93 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 42 ± 27 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 51 ± 34 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 58 ± 61 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 54 ± 36 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 105 ± 87 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 63 ± 63 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 25 ± 17 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 59 ± 63 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 43 ± 33 |
| 7 | - sediment quality triad minimum or no bioeffects | ≤50 |
| | - sediment quality triad significant bioeffects | ≥130 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* and *H. limbata* | 32 ± 18 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 73 ± 42 |
| | - not toxic (23.2% mortality) to *G. japonica* | 46 ± 59 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 12 ± 13 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 10 ± 9 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 64 ± 118 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 12 ± 9 |
| | - moderate arthropod abundance (72 ± 3.3/0.1 sq. m.) | 13 ± 10 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 48 ± 103 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m.) | 20 ± 34 |
| | - moderate species richness ( 72 ± 3.3/0.1 sq. m.) | 11 ± 8 |
| | - low species richness ( 51.2 ± 8.6/0.1 sq. m.) | 51 ± 111 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 95 ± 154 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 13 ± 10 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 17 ± 24 |
| 49 | PALOS VERDES, CALIFORNIA | |
| | - "major degradation" to macrobenthos (20.2 sp/0.1 m. sq.) | 312 ± 23 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 41 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✓) to *H. azteca* | <32 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 144 ± 110 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 57 ± 20 |

Table 11. Lead (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | 31 ± 26 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 21 ± 11 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 253 ± 47 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortaliity to *D. magna* (n = 1) | 160 |
| | - low mortality to *D. magna* (n = 5) | 79 ± 34 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 29 ± 8 |
| | - not toxic to *D. magna* | 11 ± 10 |
| | - mean concentration in highly toxic (northern) sediments (to *D. magna*) | 27 ± 9✔ |
| | - mean concentration in least toxic (southern) sediments (to *D. magna*) | 9.5 ± 10.3✔ |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *H. limbata* | 110 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (93.6 ± 9.4/0.1 sq. m.) | 13 ± 4 |
| | - moderate benthos species richness (58.2 ± 10.5/0.1 sq. m.) | 42 ± 26 |
| | - low benthos species richness (31 ± 6.5/0.1 sq. m.) | 47 ± 17 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in *C. germanica* | 321 ± 195 |
| | - positive rate of growth in *C. germanica* | 145 ± 132 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to *N. virens* | 90 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 123 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 277 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | <1 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (TLm 5.1 ± 3.5) and spot (TLm 5.9 ± 3.4) | 512 ± 231✔ |
| | - least toxic to mummichogs (TLm 43.2 ± 31.1) and spot (TLm 24 ± 5.6) | 213 ± 131 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <0.5 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 54 ± 27 |
| | - low mortality to *D. magna* | 35 ± 22 |

**Table 11. Lead (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 40 | CUBATAO RIVER, BRAZIL | |
| | - 24-h EC50 with *D. similis* | 18 |
| 41 | NORWEGIAN FJORDS, NORWAY | |
| | - 50% reduction from maximum in Hurlbert's benthic species diversity index | 35 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@4% TOC) | 3360 |
| 4 | EPA chronic marine EP threshold (@4% TOC) | 132 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes Harbors | |
| | - classification of non-polluted sediments | <40 |
| | - classification of moderately polluted sediments | 40-60 |
| | - classification of heavily polluted sediments | >60 |
| 43 | New England interim high contamination level for dredge material | >200 |
| 12 | EPA Region V guideline for pollution classification of sediments | 40 |
| | USGS alert levels to flag 15-20% of samples analyzed | 500 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 50 |
| | EPA Region VI proposed guidelines | 50 |
| | FWPCA Chicago Guidelines: LIGHT (no alteration to benthos) | 0-40 |
| | FWPCA Chicago Guidelines: MODERATE (pollutant tolerant benthos) | 40-60 |
| | FWPCA Chicago Guidelines: HEAVY (benthos absent or abundance reduced) | >60 |
| | EPA Jensen Criteria for open water dredge material disposal | 50 |
| 20 | EPA/ACOE Puget Sound interim criteria (central basin background) | 33 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <110 |
| | - Class 2 (moderately contaminated) | 110-460 |
| | - Class 3 (contaminated) | 460-660 |
| | - Class 4. (heavily contaminated) | >660 |

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4. Bolton *et al.*, 1985
7. Chapman *et al.*, 1987
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23. Jansen, 1987
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49. Swartz *et al.*, 1985
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75. Qasim *et al.*, 1980
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Table 11. Lead (continued)

References:

29. Yake *et al.*, 1986
39. Lee and Mariani, 1977
40. Zagatto *et al.*, 1987
62. Tsai *et al.*, 1979
64. Van Dolah *et al.*, 1984
67. McGreer, 1979
83. Word and Mearns, 1979
* -Various, please see text.

**Table 12. Effects range-low and effects range-median values for lead and 47 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 27✔ | Keweenaw Waterway, Michigan bioassay COA |
| 29.0 | Keweenaw Waterway, Michigan bioassay COA |
| 30.6 | Kishwaukee River Illinois, benthos COA |
| 32.0 | *M. balthica* burrowing ET50 COA |
| 35.0 | Norway benthos COA |
| **35.0** | **ER-L** |
| 41.3 | Los Angeles Harbor, California bioassay COA |
| 42.1 | San Francisco Bay, California bioassay COA |
| 42.4 | Massachusetts Bay, Massachusetts benthos COA |
| 46.7 | Massachusetts Bay, Massachusetts benthos COA |
| 47.8 | Southern California arthropods COA |
| ≤50.0 | San Francisco, California, triad minimum effects COA |
| 51.0 | Southern California species richness COA |
| 53.7 | Trinity River, Texas bioassay COA |
| 58.9 | San Francisco Bay, California bioassay COA |
| >60.0 | FWPCA Classification: benthos absent COA |
| 63.4 | San Francisco Bay, California bioassay COA |
| 64.4 | Southern California echinoderms COA |
| 73.1 | Southern California bioassay COA |
| 74.0 | *M balthica* bioassay avoidance COA |
| 81.7 | Fraser River B.C., Canada benthos COA |
| 89.6 | Black Rock Harbor, Connecticut bioassay COA |
| 95.7 | San Francisco Bay, California bioassay COA |
| 104.5 | San Francisco Bay, California bioassay COA |
| **110.0** | **ER-M** |
| 110.0 | Torch Lake, Michigan bioassay COA |
| 113.1 | Commencement Bay, Washington bioassay COA |
| 120.0 | San Francisco Bay, California AET |
| ≥130.0 | San Francisco Bay, California triad significant effects COA |
| 132.0 | EP chronic marine @4% TOC |
| 136.6 | Puget Sound, Washington bioassay COA |
| 140.0 | San Francisco Bay, California AET |
| 143.7 | DuPage River, Illinois benthos COA |
| 160.0 | Phillips Chain of Lakes, Wisconsin bioassay COA |
| 170.8 | Commencement Bay, Washington bioassay COA |
| 253.0 | Sheboygan River, Wisconsin bioassay COA |
| 300.0 | Puget Sound, Washington AET - benthic |
| 300.0 | Lake Union, Washington bioassay COA |
| 312.3 | Palos Verdes Shelf, California benthos COA |
| 320.9 | Hudson-Raritan Bay, New York bioassay COA |
| 450.0 | Puget Sound, Washington AET - benthic |
| 512.0 | Baltimore Harbor, Maryland bioassay COA |
| 530.0 | Puget Sound, Washington AET - Microtox™ |
| 570.1 | Commencement Bay, Washington bioassay COA |
| 660.0 | Puget Sound, Washington AET - amphipod |

**Table 12. (continued)**

| Concentrations (ppm) | End Point |
|---|---|
| 660.0 | Puget Sound, Washington AET - oyster |
| 750.2 | Puget Sound, Washington bioassay COA |
| 1613.0 | Commencement Bay, Washington bioassay COA |
| 3360.0 | EP acute marine @4% TOC |

**Mercury**

Acute toxicity of mercury (II) to freshwater invertebrates ranges from 2.2 to 2,000 ppb✓ and from 3.5 to 1678 ppb✓ for marine organisms (U.S. EPA, 1986). Klapow and Lewis (1979) proposed a marine water quality standard of 0.14 ppb✓ mercury. Eisler (1987) reported that organomercury compounds--especially methylmercury--were more toxic than inorganic forms; lethal concentrations of total mercury to sensitive organisms varied from 0.1 to 2.0 ppb✓ for aquatic fauna; mercury was the most toxic trace metal to aquatic organisms; and that toxicity was increased in the presence of zinc and lead.

A moderate amount of sediment data exist for mercury (Table 13). AET values for Puget Sound and San Francisco Bay are available. Matching chemistry and biological data for Puget Sound, San Francisco Bay, DuPage River, Phillips Chain of Lakes, Baltimore Harbor, and Trinity River are listed in Table 13 along with those from other areas. EP threshold values and data from two SSB experiments are available.

No toxicity was observed in bioassays of sediments from the Duwamish River, Stamford, Norwalk, and Newport with mercury concentrations up to 0.3 ppm. Very small gradients in mercury concentrations were observed in data from San Francisco Bay, southern California, Kishwaukee River, Keweenaw Waterway, Massachusetts Bay, and Trinity River. These data were not considered in the estimation of ER-L and ER-M values (Table B-7).

The remaining data suggest an ER-L value of about 0.15 ppm (0.17 rounded to 0.15 ppm), equivalent to the lower 10 percentile of the data (Table 14). This value is supported by bioassay data from Los Angeles Harbor (0.15 ppm), Lake Union (0.17 ppm), and *Macoma* burrowing bioassays of Fraser River sediments (0.18 ppm). Chronic effects are predicted by EP principles to occur at 0.032 ppm.

The data suggest an ER-M of about 1.3 ppm mercury, the 50 percentile value in the data. This value is supported by two San Francisco Bay AETs (1.3 and 1.5 ppm), moderate toxicity of Puget Sound sediments to amphipods (mean of 1.38 ppm), and significant toxicity of Little Grizzly Creek sediments to *Daphnia* (mean of 1.5 ppm). With several exceptions (principally data from San Diego Bay), effects were usually observed at concentrations of 1.0 ppm or greater (Table B-7).

The degree of confidence in the ER-L and ER-M estimates should be considered as moderate and high, respectively. There are clusters of data around the 0.15 and 1.3 ppm values, suggesting that these values are supported by a preponderance of evidence and an apparent effects threshold within the ER-L/ER-M range. However, the predicted chronic marine value (0.032 ppm) is considerably lower than the ER-L, the majority of the available data are from field studies, there are relatively little data from SSBs, and the available data from bioassays with *R. abronius* and *Pontoporeia affinis* were not consistent.

**Table 13. Summary of sediment effects data available for mercury.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2.1 |
| | - oyster larvae (*C. gigas*) bioassay | 0.6 |
| | - benthic community composition | 0.9 |
| | - Microtox™ bioassay | 0.4 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2.1 |
| | - oyster larvae (*C gigas*) bioassay | 0.6 |
| | - benthic community composition | 2.1 |
| | - Microtox™ bioassay | 0.4 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 0.2 |
| | - maximum level criteria | 2.0 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 1.5 |
| | - *R. abronius* amphipod bioassay | 1.3 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 11.2 ± 22.8 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 0.3 ± 0.2 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 0.2 ± 0.1 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 3.5 ± 12.5 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 0.2 ± 0.1 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 0.2 ± 0.1 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic to *R. abronius* (95%LPL) | 5 ± 14.8 |
| | - mod. toxic to *R. abronius* (<87.5% survival to >95% LPL) | 1.4 ± 4.6 |
| | - least toxic to *R. abronius* (>87.5% survival) | 0.5 ± 0.5 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 0.2 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 0.1 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 0.2 |
| | - significant 24-h avoidance behavior among *M. balthica* | 0.5 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 0.4 ± 0.2 |
| | - sediment populated by feral *M. balthica* | 0.1 ± 0.1 |

Table 13. Mercury (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 1 ± 1 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 0.7 ± 0.8 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 0.5 ± 0.4 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 0.7 ± 0.8 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 0.6 ± 0.4 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 0.6 ± 0.4 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 0.9 ± 1 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 0.3 ± 0.2 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 0.7 ± 0.9 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 0.5 ± 0.3 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* and *Hexagenia* sp. | 1.5 ± 0.9 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 0.3 ± 0.1 |
| | - not toxic (23.2% mortality) to *G. japonica* | 0.3 ± 0.02 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 0.15 |
| 48 | SAN DIEGO BAY, CALIFORNIA | |
| | - >97% survival of clam, *P. staminea* | 66.5 |
| | - >97% survival of mysid, *M. elongata* | 58.2 |
| | - >97% survival of *C. stigmaeus*, and *M. elongata* | 254.4 |
| 66 | - ≥82% survival of *C. stigmaeus*, *A. sculpta*,, and *A. tonsa* | 2.7 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✔) to *H. azteca* | 0.1 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 1.6 ± 2 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 0.3 ± 0.2 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | 0.1 ± 0.1 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 0.1 ± 0.1 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | <0.1 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortaliity to *D. magna* (n = 1) | 9.4 |
| | - low mortality to *D. magna* (n = 5) | 1 ± 1.3 |

Table 13. Mercury (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 0.2 ± 0.1 |
| | - not toxic to *D. magna* | 0.1 ± 0.1 |
| | - mean concentration in highly toxic (northern) sediments (to *D. magna*) | 0.2 ± 0.8✔ |
| | - mean concentration in least toxic (southern) sediments (to *D. magna*) | 0.1 ± 0.1✔ |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and Hexagenia sp. | 0.3 |
| 69 | MISSISSIPPI RIVER | |
| | - 80-100% survival (92 ± 6.3) of *G. pseudolimnaeus*, 4-d bioassay | 0.04 |
| | - 25% (n=1) survival of mayfly (*Hexagenia* sp.) 4-d bioassay | <0.01 |
| | - 80-100% survival (90 ± 7.5) of mayfly (*Hexagenia* sp), 4-d bioassay | <0.01 ± 0✔ |
| | - 55%±10% survival of midges (*C. tentans*) , 4-d bioassay | 0.01 ± 0 |
| | - 90%±5.8% survival of midges (*C. tentans*), 4-d bioassay | <0.01 ± 0✔ |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness(93.6 ± 9.4) | 0.06 ± 0.04 |
| | - moderate benthos species richness (58.2 ± 10.5) | 0.2 ± 0.1 |
| | - low benthos species richness (31 ± 6.5) | 0.1 ± 0.02 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in *C. germanica* | 8.9 ± 7.5 |
| | - positive rate of growth in *C. germanica* | 5 ± 6.7 |
| 44 | NEW YORK HARBOR, NEW YORK | |
| | - <10% mortality to *N. virens, M. mercenaria* and *P. pugio*; 100-d exposures | 34.9 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 0.2 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 0.3 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | 0.03 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (TLm 5.1 ± 3.5) and spot (TLm 5.9 ± 3.4) | 1.6 ± 1.1 |
| | - least toxic to mummichogs (TLm 43.2 ± 31.1) and spot (TLm 24 ± 5.6) | 0.4 ± 0.1 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 0.6 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 0.3 ± 0.1 |
| | - low mortality to *D. magna* | 0.6 ± 0.7 |
| 40 | CUBATAO RIVER, BRAZIL | |
| | - 24-h EC50 with *D. similis* | 0.9 |

Table 13. Mercury (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@4% TOC) | 0.6 |
| 4 | EPA chronic marine EP threshold (@4% TOC) | 0.03 |
| **Spiked-Sediment Bioassays** | | |
| 63 | No reduction in the activity behavior of *P. affinis*, 2-d experiment | 0.65 - 1.15 |
| | Significant reduction in the activity behavior of *P. affinis*, 5-d experiment | 2.15 - 3.35 |
| 18 | LC50 of *R. abronius* in 10-d bioassay | 13.1 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes Harbors | |
| | - classification of non-polluted sediments | <1 |
| | - classification of heavily polluted sediments | ≥1 |
| 43 | New England interim high contamination level for dredge material | >1.5 |
| 12 | EPA Region V guideline for pollution classification of sediments | 1 |
| | USGS alert levels to flag 15 to 20% of samples analyzed | 20 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 0.3 |
| | EPA Region VI proposed guidelines | 1 |
| | EPA Jensen Criteria for open water dredge material disposal | 1 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 0.15 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <1.5 |
| | - Class 2 (moderately contaminated) | 1.5-9 |
| | - Class 3 (contaminated) | 9-16 |
| | - Class 4 (heavily contaminated) | >16 |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
12. Pavlou and Weston, 1983
17. Lyman *et al.*, 1987
18. Swartz *et al.*, 1988
20. U.S. ACOE, 1988
23. Jansen, 1987
26. DeWitt *et al.*, 1988
29. Yake *et al.*, 1986
39. Lee and Mariani, 1977
40. Zagatto *et al.*, 1987
43. NERBC, 1980
44. Rubinstein *et al.*, 1983
48. Salazar *et al.*, 1980
54. Maleug *et al.*, 1984a
55. Maleug *et al.*, 1984b
56. Anderson *et al.*, 1988
60. Illinois EPA, 1988a
61. Illinois EPA, 1988b
62. Tsai *et al.*, 1979
63. Magnuson *et al.*, 1976
64. Van Dolah *et al.*, 1984
66. Salazar and Salazar, 1985
67. McGreer, 1979
68. Bahnick *et al.*, 1981
69. Marking *et al.*, 1981
72. Ingersoll and Nelson, in press
74. Tatem, 1986
75. Qasim *et al.*, 1980
77. McGreer, 1982
79. Tietjen and Lee, 1984
80. Tetra Tech, 1985
82. Gilbert *et al.*, 1976

* -Various, please see text.

**Table 14. Effects range-low and effects range-median values for mercury and 30 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 0.032 | EP Chronic Marine @4% TOC |
| 0.08 | Waukegan Harbor, Illinois bioassay COA |
| **0.15** | **ER-L** |
| 0.15 | Los Angeles Harbor, California bioassay COA |
| 0.17 | Lake Union, Washington bioassay COA |
| 0.18 | *M. balthica* burrowing bioassay COA |
| 0.29 | Torch Lake, Michigan bioassay COA |
| 0.41 | Puget Sound, Washington bioassay AET - Microtox™ |
| 0.42 | Fraser River, B.C., Canada *M. balthica* bioassay COA |
| 0.48 | *M. balthica* avoidance bioassay COA |
| 0.59 | Puget Sound, Washington AET - oyster |
| 0.6 | EP acute marine @4% TOC |
| 0.88 | Puget Sound, Washington AET - benthic |
| 0.9 | San Francisco Bay, California bioassay COA |
| 0.9 | Cubatao River, Brazil bioassay COA |
| 0.96 | San Francisco Bay, California bioassay COA |
| **1.3** | **ER-M** |
| 1.3 | San Francisco Bay, California AET |
| 1.38 | Puget Sound, Washington bioassay COA |
| 1.5 | San Francisco Bay, California AET |
| 1.5 | Little Grizzly Creek, California bioassay COA |
| 1.6 | Baltimore Harbor, Maryland bioassay COA |
| 1.6 | DuPage River, Illinois benthos COA |
| 2.1 | Puget Sound, Washington AET - amphipod |
| 2.1 | Puget Sound, Washington AET - benthic |
| 2.15-3.35 | SSB with *Pontoporeia* |
| 3.5 | Commencement Bay, Washington bioassay COA |
| 5.04 | Puget Sound, Washington bioassay COA |
| 8.9 | Hudson-Raritan Bay, New York bioassay COA |
| 9.4 | Phillips Chain of Lakes, Wisconsin bioassay COA |
| 11.2 | Commencement Bay, Washington bioassay COA |
| 13.1 | SSB with *R. abronius* |

## Nickel

Acute toxicity to organisms occurs at nickel concentrations as low as 1101 ppb✔ in freshwater and as low as 151.7 ppb✔ in saltwater; chronic effects can occur at concentrations of 141 ppb✔ or greater in saltwater; and toxicity is influenced greatly by water hardness and salinity (U.S. EPA, 1986). The 96-h LC50s for two species of estuarine fish were 38 and 70 mg/L nickel chloride (Mayer, 1987). The proposed California marine water quality standard for nickel is 20 ppb✔ (Klapow and Lewis, 1979).

A moderate amount of data are available for sediments to estimate effects thresholds (Table 15), however all of the data are from matching biological and chemical analyses performed with field samples. AET values for Puget Sound are available and were calculated for San Francisco Bay and matching biological and chemical data are available from San Francisco Bay, Commencement Bay, the Keweenaw River, southern California, Massachusetts Bay, Baltimore Harbor, and other areas.

Data from the Cubatao River, Brazil lacked concordance between the biological measure and nickel concentrations. Very small gradients in nickel concentrations were reported in results from San Francisco Bay, Trinity Bay, Fraser River, and some categories of effects from Commencement Bay. The nickel concentration was below the detection limits of 31.8 ppm in a Waukegan Harbor sample that was toxic. Several of the Puget Sound AETs were not definitive. All of these data were not used in the determination of ER-L and ER-M values (Table B-8).

Effects were not observed in association with mean nickel concentrations below 21 ppm in sediments (Table B-8). Benthic species richness was moderate in Massachusetts Bay sediments with a mean nickel concentration of 21 ppm (Table 16). The lower 10 percentile value of the data suggest an ER-L of about 30 ppm (28 rounded to 30 ppm). This value is supported by a Puget Sound AET of 28 ppm, high oyster larvae toxicity in Commencement Bay sediments with a mean nickel concentration of 30 ppm, high toxicity in a Los Angeles Harbor sediment with 31 ppm, and low benthic species richness in Massachusetts Bay sediments with a mean of 33 ppm (Table 16). The 50 percentile value of the data suggests an ER-M of about 50 ppm (52 rounded to 50 ppm), supported by a 1986 Puget Sound AET (49 ppm) and 100 percent mortality in Black Rock Harbor sediments (52 ppm). No overall effects threshold was apparent.

The degree of confidence in the ER-L and ER-M values for nickel should be considered as moderate. The available data indicate relatively high consistency and clustering at or between the two values, but the data are only from field studies, include no SSBs or thresholds derived from the EP approach, and no overall effects threshold is apparent.

**Table 15. Summary of sediment effects data available for nickel.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | >120 |
| | - oyster larvae (*C. gigas*) bioassay | 39 |
| | - benthic community composition | 49 |
| | - Microtox™ bioassay | 28 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | >140 |
| | - benthic community composition | >140 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 28 |
| | - maximum level criteria | 120 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >170 |
| | - *R. abronius* amphipod bioassay | >170 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 41 ± 32 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 20 ± 13 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 16 ± 7 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 30 ± 22 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 17 ± 8 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 12 ± 3 |

Table 15. Nickel (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 88 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 17.5 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 44 ± 3 |
| | - sediment populated by feral *M. balthica* | 34 ± 4 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 113 ± 42 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 99 ± 35 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 108 ± 25 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 105 ± 36 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 108 ± 27 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 93 ± 3 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 112 ± 31 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 78 ± 42 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 100 ± 35 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 102 ± 44 |
| 49 | PALOS VERDES, CALIFORNIA | |
| | - "major degradation" to macrobenthos (20.2 sp/0.1 m. sq.) | 94 ± 5 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* and *H. limbata* | 40 ± 16 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 24 ± 22 |
| | - not toxic (23.2% mortality) to *G. japonica* | 20 ± 15 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 31 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✔) to *H. azteca* | <13.8 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 110 ± 0 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortaliity to *D. magna* (n = 1) | 350 |
| | - low mortality to *D. magna* (n = 5) | 106 ± 74 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 109 ± 19 |
| | - not toxic to *D. magna* | 35 ± 14 |
| | - mean concentration in highly toxic (northern) sediments (to *D. magna*) | 100 ± 26✔ |
| | - mean concentration in least toxic (southern) sediments (to *D. magna*) | 29 ± 3.6✔ |

**Table 15. Nickel (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *H. limbata* | 150 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (93.6 ± 9.4/0.1 sq. m.) | 10 ± 3 |
| | - moderate benthos species richness (58.2 ± 10.5/0.1 sq. m.) | 21 ± 11 |
| | - low benthos species richness (31 ± 6.5/0.1 sq. m.) | 33 ± 12 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to *N. virens* | 52 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 38 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 43 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | 10 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (TLm 5.1 ± 3.5) and spot (TLm5.9 ± 3.4) | 97 ± 53 |
| | - least toxic to mummichogs (TLm 43.2 ± 31.1) and spot (TLm 24 ± 5.6) | 70 ± 14 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 6 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 29 ± 26 |
| | - low mortality to *D. magna* | 36 ± 29 |
| 40 | CUBATAO RIVER, BRAZIL | |
| | - 24-h EC50 with *D. similis* | 3 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes Harbor | |
| | - classification of non-poluted sediments | <20 |
| | - classification of modertely polluted sediments | 20-50 |
| | - classification of heavilypolluted sediments | >50 |
| 43 | New England interim hih contamination level for dredge material | >100 |
| 12 | EPA Region V guideline or pollution classification of sediments | 20 |
| | USGS alert levels to fla 15-20% of samples analyzed | 2000 |
| | Ontario Ministry of the Evironment Dredge Spoil Guidelines | 25 |
| | EPA Region VI proposedguidelines | 50 |

**Table 15. Nickel (continued)**

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <35 |
| | - Class 2 (moderately contaminated) | 35-65 |
| | - Class 3 (contaminated) | 65-80 |
| | - Class 4 (heavily contaminated) | >80 |

**References:**

1. Beller *et al* 1986
2. PTI Environmental Services, 1988
12. Pavlou and Weston, 1983
20. U.S. ACOE, 1988
23. Jansen, 1987
29. Yake *et al.*, 1986
39. Lee and Mariani, 1977
40. Zagatto *et al.*, 1987
43. NERBC, 1980
49. Swartz *et al.*, 1985
54. Maleug *et al.*, 1984a
55. Maleug *et al.*, 1984b
56. Anderson *et al.*, 1988
62. Tsai *et al.*, 1979
64. Van Dolah *et al.* 1984
68. Bahnick *et al.*, 1981
71. Simmers *et al.*, 1984
72. Ingersoll and Nelson, In press
74. Tatem, 1986
75. Qasim *et al.*, 1980
77. McGreer, 1982
80. Tetra Tech, 1985
82. Gilbert *et al.*, 1976

* -Various, please see text

**Table 16. Effects range-low and effects range-median values for nickel and 18 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 21 | Massachusetts Bay benthos COA |
| 28 | Puget Sound, Washington, AET - Microtox™ |
| 30 | **ER-L** |
| 30 | Commencement Bay, Washington, bioassay COA |
| 31 | Los Angeles Harbor, California, bioassay COA |
| 33 | Massachusetts Bay benthos COA |
| 39 | Puget Sound, Washington, AET - oyster |
| 40 | Little Grizzly Creek, California, bioassay COA |
| 41 | Commencement Bay, Washington bioassay COA |
| 49 | Puget Sound, Washington, AET - benthic |
| 50 | **ER-M** |
| 52 | Black Rock Harbor, Connecticut, bioassay COA |
| 88 | Lake Union, Washington, bioassay COA |
| 94 | Palos Verdes Shelf, California, benthos COA |
| 97 | Baltimore Harbor, Maryland, bioassay COA |
| 100 | Keweenaw River, Michigan, bioassay COA |
| 109 | Keweenaw River, Michigan, bioassay COA |
| 110 | Sheboygan River, Wisconsin, bioassay COA |
| 150 | Torch Lake, Michigan, bioassay COA |
| 350 | Phillips Chain of Lakes, Wisconsin, bioassay COA |

**Silver**

Available data indicate that chronic toxicity to freshwater organisms may occur at concentrations in water as low as 0.12 ppb✔ and that concentrations in seawater should not exceed 2.3 ppb✔ at any time (U.S. EPA, 1986). The proposed California marine water standard is 0.45 ppb✔ (Klapow and Lewis, 1979).

A relatively small amount of data exist for relating the concentrations of silver in sediments to measures of effects (Table 17). Definitive AETs for Puget Sound could not be calculated for many of the biological end-points and, therefore, are reported as greater-than values. Co-occurrence analyses were performed with data from Commencement Bay, San Francisco Bay, and southern California. Sublethal tests of sediments from the Strait of Georgia were performed with *Macoma balthica*.

There was little or no concordance between measures of toxicity to either amphipods or oyster larvae and silver concentrations in Commencement Bay. Also, amphipod bioassay data from San Francisco Bay and southern California indicated little concordance with respective silver concentrations. In addition, total benthic community abundance and silver concentrations on the southern California shelf indicated little concordance. San Diego Bay sediments with up to 0.8 ppm silver were not toxic in a variety of bioassays. Several of the Puget Sound AETs were not definitive. These data were not considered during the determination of ER-L and ER-M values (Table B-9).

From the remaining data, it appears that effects were not observed in association with silver concentrations of less than about 0.6 ppm (Table 18). The data suggest an ER-L of about 1.0 ppm, the lower 10 percentile value of the available data. This value is supported by results of an avoidance bioassay performed with *M. balthica* (1.0 ppm), San Francisco Bay bioassay data (1.0 ppm), and a San Francisco Bay AET (1.1 ppm). The ER-M suggested by the data is 2.2 ppm, the 50 percentile value of the available data. This value is supported by the absence of feral *M. balthica* in Fraser River sediments (2.1 ± 1.3 ppm), low arthropod abundance in southern California benthos (2.2 ± 3.9 ppm), low species richness in southern California benthos (2.5±4.1 ppm), and increased burrowing time of *M. balthica* exposed to Strait of Georgia sediments (2.6 ppm). With several exceptions, effects were observed at silver concentrations of 1.7 ppm or greater (Table B-9).

The degree of confidence in the silver ER-L and ER-M values should be considered as moderate. There is consistency in the clusters of data around the ER-L and ER-M values and a weak apparent effects threshold lies within ER-L/ER-M range. However, these values are based upon a relatively small amount of data and there are no data from SSBs, nor from EP approaches.

Table 17. Summary of sediment effects data available for silver.

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | >3.7 |
| | - oyster larvae (*C. gigas*) bioassay | >0.6 |
| | - benthic community composition | 5.2 |
| | - Microtox™ bioassay | >0.6 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 6.1 |
| | - benthic community composition | >6.1 |
| | - oyster larvae (*C. gigas*) bioassay | >0.6 |
| | - Microtox™ bioassay | >0.6 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 1.2 |
| | - maximum level criteria | 5.2 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 1.1 |
| | - *R. abronius* amphipod bioassay | >8.6 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 0.2 ± 0.1 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 0.3 ± 0.1 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 0.3 ± 0.1 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 0.3 ± 0.1 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 0.3 ± 0.1 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 0.3 ± 0.1 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic to *R. abronius* (95% LPL) | 0.6 ± 1.0 |
| | - moderately toxic to *R. abronius* (<87.5% survival to >95% LPL) | 0.6 ± 0.6 |
| | - least toxic to *R. abronius* (>87.5% survival) | 0.3 ± 0.1 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 2.6 |
| | - significant 24-h avoidance behavior among *M. balthica* | 1 |
| 77 | FRASER RIVER, B.C., CANADA | |
| | - sediment devoid of feral *M. balthica* | 2.1 ± 1.3 |
| | - sediment populated by feral *M. balthica* | 0.8 ± 0.6 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 1.7 ± 2.6 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 0.9 ± 0.9 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 1.3 ± 1.8 |
| | - significantly toxic (42.9 ± 19.2% mortality to *R. abronius* | 1.2 ± 1.7 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 1.4 ± 1.9 |

Table 17. Silver (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 6.9 ± 2.5 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 1 ± 0.6 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 0.5 ± 0.4 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 1.7 ± 2.2 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 0.6 ± 0.5 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 1.3 ± 1.4 |
| | - not toxic (23.2% mortality) to *G. japonica* | 1.1 ± 1.9 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 0.6 ± 0.8 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 0.6 ± 0.7 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 3.1 ± 4.5 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 0.9 ± 1.6 |
| | - moderate arthropod abundance (73 ± 6.8/0.1 sq. m.) | 0.7 ± 1 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 2.2 ± 3.9 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m.) | 0.9 ± 2.1 |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 0.7 ± 0.8 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 2.5 ± 4.1 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 3.2 ± 5.6 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 1 ± 2 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 1.3 ± 1.8 |
| 66 | SAN DIEGO BAY, CALIFORNIA | |
| | - ≥82% survival of sanddab *C. stigmaeus, A. sculpta,* and *A. tonsa* | 0.8 |
| | - ≥86% survival of *A. sculpta, N. arenacaedentata;,* and *M. nasuta* | 0.8 |

| Reference | Background Approach | Concentrations (ppm) |
|---|---|---|
| 12 | USGS alert levels to flag 15-20% of samples analyzed | 1000 |

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
12. Pavlou and Weston, 1983
20. U.S. ACOE, 1988
26. DeWitt *et al.*, 1988
56. Anderson *et al.*, 1988
66. Salazar and Salazar, 1985
67. McGreer, 1979
77. McGreer, 1982
80. Tetra Tech, 1985
83. Word and Mearns, 1979

* -Various, please see text

**Table 18. Effects range-low and effects range-median values for silver and 13 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 0.6 | Puget Sound, Washington, bioassay COA |
| 1.0 | *M. balthica* avoidance bioassay COA |
| 1.0 | San Francisco Bay, California Bioassay COA |
| **1.0** | **ER-L** |
| 1.1 | San Francisco Bay, California AET |
| 1.7 | San Francisco Bay, California bioassay COA |
| 2.1 | Feral Fraser River *M. balthica* absent COA |
| 2.2 | Southern California arthropod abundance COA |
| **2.2** | **ER-M** |
| 2.5 | Southern California species richness COA |
| 2.6 | *M. balthica* burrowing time bioassay COA |
| 3.1 | Southern California echinoderm abundance COA |
| 5.2 | Puget Sound, Washington AET - benthic |
| 6.1 | Puget Sound, Washington AET - amphipod |
| 6.9 | San Francisco Bay, California bioassays COA |

### Tin

No data were found with which total tin concentrations could be related to effects in sediments. However, organotin concentrations in sediments can be related to toxicity with data from two small studies (Word *et al.*, 1988; Salazar and Salazar, 1985). Significant percent mortality among amphipods (*R. abronius*) was observed inconsistently (*i.e.*, some samples were toxic, some others were not) over a range of tributyltin concentrations of 18.7 to 2,214 ppm dry weight and over a range of total butyltin concentrations of 30 to 3,011 ppm dry weight in tests of Oakland Inner Harbor sediments (Word *et al.*, 1988). Over 86 percent survival of mysids (*Acanthomysis sculpta*) was observed in bioassays of San Diego Bay sediments with a range of tributyltin concentrations of 155 to 780 ppm wet weight (no moisture content data provided) (Salazar and Salazar, 1985).

Because of a lack of data, no consensus values can be determined for the concentrations of tin in sediments that are associated with biological effects.

### Zinc

Freshwater daphnids are sensitive to zinc at concentrations as low as 51 ppb✔ in water; chronic effects in daphnids have been observed at concentrations as low as 47 ppb✔; LC50s for saltwater animals✔ range from 192 ppb✔ to 320,400 ppb✔; and chronic effects among marine mysids occur as low as 120 ppb✔ (U.S. EPA, 1986). The proposed marine water quality standard for California is 20 ppb✔ (Klapow and Lewis, 1979).

A relatively large amount of data are available to use in relating measures of effects to zinc concentrations in sediments (Table 19). They are available from all of the major approaches to the development of sediment quality standards. AET values for Puget Sound and San Francisco Bay are listed in Table 19. Co-occurrence analyses were performed with data from Commencement Bay, San Francisco Bay, Puget Sound, southern California, DuPage River, Kishwaukee River, Keweenaw Waterway, Trinity River, Massachusetts Bay, Hudson-Raritan Estuary, Baltimore Harbor, and other areas. Chronic and acute EP thresholds are available, assuming a 4 percent TOC content. Data from SSB performed with *R. abronius* and *Ponotoporeia affinis* are available.

No effects to the benthos were observed at the Georgetown, South Carolina disposal site. No concordance between toxicity and zinc concentrations was apparent in tests of Cubatao River sediments. No concordance between total abundance of benthos and zinc concentrations was apparent for southern California. A relatively poor correlation between species diversity and zinc concentrations in Norwegian fjords was reported. A relatively small gradient in zinc concentrations was reported for sediments from the Kishwaukee River, Illinois. A relatively poor correlation between *M. balthica* burrowing time and zinc concentrations was reported. Relatively poor concordance between toxicity to amphipods and zinc concentrations was apparent in the data from San Francisco Bay. These data were not considered in the estimation of ER-L and ER-M values (Table B-10).

From the remaining data, it appears that biological effects have not been observed in association with zinc concentrations of about 50 ppm or less in sediments (Table 20). Behavioral effects upon the amphipod *R. abronius* and the shrimp *P. affinis* have been observed at zinc concentrations of 51 to 124 ppm. The data suggest an ER-L value of about 120 ppm, the lower 10 percentile value of the available data. This value is supported by observations of low species richness among Massachusetts Bay benthos (117 ± 42 ppm), significant mortality among *Daphnia magna* exposed to Trinity River sediments (121 ± 20 ppm), high mortality among *H. azteca* exposed to Waukegan Harbor sediments (127 ppm), and a San Francisco Bay AET based upon bivalve larvae bioassays (130 ppm). With a few exceptions, biological effects were usually observed at zinc concentrations of 260 ppm or greater (Table B-10). Also, the 50 percentile of the available data is equivalent to about 270 ppm, the ER-M suggested by the data. This value is supported by bioassay data from the Hudson-Raritan estuary (245 ± 201 ppm) and Little Grizzly Creek (267 ± 298 ppm), a Puget Sound AET (260 ppm), and an LC50 for a SSB with *R. abronius* (276 ppm).

The degree of confidence in the ER-L and ER-M values for zinc should be considered as relatively high. Both of the values are supported by a consistent cluster of data derived from more than one data set and/or approach. The available data strongly suggest that sublethal and other sensitive measures of effects occur at zinc concentrations of about 50 to 125 ppm and that effects almost always occur at or above zinc concentrations of 260 ppm. However, several of the Puget Sound AET values and the two EP thresholds suggest that thresholds for effects occur at concentrations much higher than the ER-L and ER-M values.

**Table 19. Summary of sediment effects data available for zinc.**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 870 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 260 |
| | - Microtox™ bioassay | 1600 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 960 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 410 |
| | - Microtox™ bioassay | 1600 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 160 |
| | - maximum level criterion | 1600 |

Table 19. Zinc (continued)

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 130 |
| | - *R. abronius* amphipod bioassay | 230 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 941 ± 1373 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 211 ± 342 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 108 ± 79 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 387 ± 783 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 185 ± 335 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 107 ± 122 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - non-toxic (>87.5% survival of *R. abronius*) | 114 ± 52 |
| | - moderately toxic (<87.5% to >95% LPL to *R. abronius*) | 195 ± 166 |
| | - highly toxic (95% LPL to *R. abronius*) | 707 ± 955 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 320 |
| 39 | DUWAMISH RIVER, WASHINGTON | |
| | - 0-10% mortality to *P. pugio* | 72 |
| 77 | FRASER RIVER, B.C.,CANADA | |
| | - sediment devoid of *M. balthica* | 169 ± 53 |
| | - sediment populated by *M. balthica* | 65 ± 19 |
| 67 | STRAIT OF GEORGIA, B.C., CANADA | |
| | - significant increase in burrowing time (ET50) of *M. balthica* | 109 |
| | - significant 24-h avoidance behavior among *M. balthica* | 172 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality to *R. abronius* | 187 ± 115 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 146 ± 73 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 171 ± 91 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 158 ± 87 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 177 ± 96 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 205 ± 90 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 172 ± 92 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 89 ± 41 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 154 ± 91 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 136 ± 78 |
| 50 | PALOS VERDES SHELF, CALIFORNIA | |
| | - "major degradation" to macrobenthos (20.2sp./0.1m. sq.) | 739 ± 139 |

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 348 ± 234 |
| | - not toxic (23.2% mortality) to *G. japonica* | 212 ± 243 |
| 83 | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 50 ± 13 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 55 ± 34 |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 230 ± 444 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 51 ± 24 |
| | - moderate arthropod abundance (72.6 ± 6.8/0.1 sq. m.) | 52 ± 28 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 182 ± 384 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m) | 71 ± 106 |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 50 ± 22 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 197 ± 415 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 347 ± 592 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 53 ± 28 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 73 ± 81 |
| 39 | LOS ANGELES HARBOR, CALIFORNIA | |
| | - >50% mortality to *P. pugio* (20% elutriate bioassay) | 223 |
| 55 | LITTLE GRIZZLY CREEK, CALIFORNIA | |
| | - significant mortality to *D. magna* | 267 ± 298 |
| 55 | PHILLIPS CHAIN OF LAKES, WISCONSIN | |
| | - significant mortality to *D. magna* | 570 |
| | - low mortality (0-5%) to *D. magna* | 216 ± 213 |
| 74 | SHEBOYGAN RIVER, WISCONSIN | |
| | - significant mortality to prawn, *M. rosenbergii* | 290 ± 10 |
| 72 | WAUKEGAN HARBOR, ILLINOIS | |
| | - highly toxic (66.3 ± 4.25% survival✔) to *H. azteca* | 127 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 327 ± 162 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 182 ± 56 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | 107 ± 31 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 96 ± 52 |
| 54 | KEWEENAW WATERWAY, MICHIGAN | |
| | - significantly toxic to *D. magna* | 168 ± 52 |
| | - not toxic to *D. magna* | 69 ± 24 |
| | - mean concentration in highly toxic (northern) sediments to *D. magna* | 154 ± 54✔ |
| | - mean concentration in least toxic (southern) sediments to *D. magna* | 62 ± 20✔ |

**Table 19. Zinc (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 55 | TORCH LAKE, MICHIGAN | |
| | - significant mortality to *D. magna* and *H. limbata*. | 310 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 121 ± 100 |
| | - low mortality to *D. magna* | 58 ± 41 |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - high benthos species richness (93.6 ± 9.4/0.1 sq. m.) | 32 ± 7 |
| | - moderate benthos species richness (58.2 ± 10.5/0.1 sq. m.) | 98 ± 64 |
| | - low benthos species richness (31 ± 6.5/0.1 sq. m.) | 117 ± 42 |
| 39 | NEWPORT, RHODE ISLAND | |
| | - 0% mortality to *P. pugio* | 55 |
| 71 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - 100% mortality to polychaete, *N. virens* | 334 |
| 39 | STAMFORD, CONNECTICUT | |
| | - 10% mortality to *P. pugio* | 340 |
| 39 | NORWALK, CONNECTICUT | |
| | - 0% mortality to *P. pugio* | 636 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in nematode, *C.germanica* | 449 ± 252 |
| | - positive rate of growth in nematode, *C.germanica* | 245 ± 201 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (5.1 ± 3.5 TLm) spot (5.9 ± 3.4 TLm) | 1804 ± 2098 |
| | - least toxic to mummichogs (43.2 ± 31.1 TLm) spot (24 ± 5.6 TLm) | 738 ± 394 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 11 |
| 40 | CUBATAO RIVER, BRAZIL | |
| | - 24-h EC-50 with *D. simillis* | 20 |
| 41 | NORWEGIAN FJORDS, NORWAY | |
| | - 50% reduction from max in Hurlbert's benthic species diversity index | 80 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@4%TOC) | 2240 |
| 4 | EPA chronic marine EP threshold (@4%TOC) | 760 |
| **Spiked-Sediment Bioassays** | | |
| 11 | 54.7% dead out of 53 *R. abronius* in 72-h bioassay | 613 |
| | 70%✔ avoidance, out of 59 *R. abronius* in 72-h, 2-choice experiment | 51 |
| | 66.7% avoidance, out of 45 *R. abronius*, in 72-h, 2-choice experiment | 188 |

**Table 19. Zinc (continued)**

| References | Biological Approaches | Concentrations (ppm) |
|---|---|---|
| **Spiked-Sediment Bioassays** | | |
| 18 | LC50 for *R. abronius* in 10-d bioassay | 276 |
| 63 | Activity behavior of *Pontoporeia* significantly decreased, 5-day exposure | 59-124 |
| 27 | LC05 for Zn and LC76 for Cd, *R. abronius*, 72-h bioassay | 79 |
| | LC08 for Zn and LC98 for Cd, *R. abronius*, 72-h bioassay | 76 |

| References | Background Approach | Concentrations (ppm) |
|---|---|---|
| 68 | Great Lakes Harbors | |
| | - Classification of non-polluted sediments | <90 |
| | - Classification of moderately polluted sediments | 90-200 |
| | - Classification of heavily polluted sediments | >200 |
| 43 | New England interim high contamination level for dredge material | >400 |
| 12 | EPA Region V guideline for pollution classification of sediments | 90 |
| | USGS alert levels to flag 15-20% of samples analyzed | 5000 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 100 |
| | EPA Region VI proposed guidelines | 75 |
| | FWPCA Chicago Guidelines: | |
| | - LIGHT (no alteration to benthos) | 0-90 |
| | - MODERATE: (predominance of pollutant-tolerant benthos) | 90-200 |
| | - HEAVY: (benthos absent or abundance reduced) | >200 |
| | EPA Jensen Criteria for open water dredge material disposal | 50 |
| | EPA Region VI proposed guidelines for sediment disposal | 75 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 105 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <370 |
| | - Class 2 (moderately contaminated) | 370-1160 |
| | - Class 3 (contaminated) | 1160-2330 |
| | - Class 4 (heavily contaminated) | >2330 |

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* Various, Please see text

**Table 20. Effects range-low and effects range-median values for zinc and 46 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppm) | End Point |
|---|---|
| 51 | Sublethal SSB with *R. abronius* |
| 59 - 124 | Sublethal SSB with *P. affinis* |
| 98 | Massachusetts Bay, Massachusetts benthos COA |
| 117 | Massachusetts Bay, Massachusetts benthos COA |
| **120** | **ER-L** |
| 121 | Trinity River, Texas bioassays COA |
| 127 | Waukegan Harbor, Illinois bioassays COA |
| 130 | San Francisco Bay, California AET |
| 154 | Keweenaw Waterway, Michigan bioassays COA |
| 168 | Keweenaw Waterway, Michigan bioassays COA |
| 169 | Feral Fraser River *M. balthica* absent COA |
| 172 | *M. balthica* avoidance bioassay COA |
| 172 | San Francisco Bay, California bioassays COA |
| 182 | Southern California arthropod abundance COA |
| 185 | Commencement Bay, Washington bioassays COA |
| 188 | Sublethal SSB with *R. abronius* |
| 195 | Puget Sound, Washington bioassays COA |
| 197 | Southern California species richness COA |
| 205 | San Francisco Bay, California bioassays COA |
| 211 | Commencement Bay, Washington bioassays COA |
| 223 | Los Angeles Harbor, California bioassays COA |
| 230 | San Francisco Bay, California AET |
| 230 | Southern California echinoderm abundance COA |
| 260 | Puget Sound, Washington AET - benthic |
| 267 | Little Grizzly Creek, California bioassays COA |
| **270** | **ER-M** |
| 276 | SSB with *R. abronius* LC50 |
| 290 | Sheboygan River, Wisconsin bioassays COA |
| 310 | Torch Lake, Michigan bioassays COA |
| 320 | Lake Union, Washington bioassays COA |
| 327 | DuPage River, Illinois species richness COA |
| 334 | Black Rock Harbor, Connecticut bioassays COA |
| 348 | Southern California bioassays COA |
| 387 | Commencement Bay, Washington bioassays COA |
| 410 | Puget Sound, Washington AET - benthic |
| 449 | Hudson-Raritan Bay, New York bioassays COA |
| 570 | Phillips Chain of Lakes, Wisconsin bioassays COA |
| 613 | SSB with *R. abronius* |
| 707 | Puget Sound, Washington bioassays COA |
| 739 | Palos Verdes Shelf, California "major degradation" COA |
| 760 | EP marine chronic threshold @ 4% TOC |
| 870 | Puget Sound, Washington AET - amphipod |
| 941 | Commencement Bay, Washington bioassays COA |
| 960 | Puget Sound, Washington AET - amphipod |
| 1600 | Puget Sound, Washington AET - oyster |
| 1600 | Puget Sound, Washington AET - Microtox™ |
| 1804 | Baltimore Harbor, Maryland bioassays COA |
| 2240 | EP marine acute threshold @ 4% TOC |

## Other Major and Trace Elements

Data with which measures of biological effects could be related to the concentrations of aluminum, iron, manganese, silicon, thallium, and selenium were not found. Therefore, no ER-L or ER-M values were determined for these analytes that are quantified in sediments by the NS&T Program.

## PCBs

Acute toxicity of PCBs in water to freshwater aquatic organisms probably occurs at concentrations above 2.0 ppm and above 10 ppm for saltwater species (U.S. EPA, 1986). LC50s for Aroclor 1242 tested in 96-h bioassays with *Palaemonetes pugio* ranged from 15 to 57 ppm (Mayer, 1987)

A considerable amount of data exist with which PCB concentrations in sediments and measures of biological effects can be related (Table 21). Most of these data are from field studies and were evaluated with co-occurrence analyses. Matching biological and chemical data are available from Puget Sound, Commencement Bay, San Francisco Bay, southern California, San Diego Bay, DuPage River, Kishwaukee River, Waukegan Harbor, Mississippi River, Trinity River, Massachusetts Bay, Baltimore Harbor, Hudson-Raritan estuary, and other areas. AET were listed for Puget Sound and San Francisco Bay. An EP chronic marine threshold was available, along with marine and freshwater SLCs and results of two sSSB experiments.

Data from the Trinity River indicated no gradient in PCB concentrations among stations. Most of the Mississippi River data indicated no concordance between toxicity and PCB concentrations. No gradient in PCB concentrations among Massachusetts Bay stations was apparent. There was very little concordance between bivalve larvae bioassay results and PCB concentrations in San Francisco Bay. Data from southern California indicated no concordance between total abundance of benthos and PCB concentrations. There was no concordance between moderately and highly toxic samples and PCB concentrations in data from Commencement Bay. There was very little difference in PCB concentrations in samples from Puget Sound that were moderately toxic versus those that were highly toxic. No concordance was apparent between toxicity and PCB concentrations in tests of southern California sediments. San Diego Bay sediments were not highly toxic. These data were not considered in the estimation of ER-L and ER-M values (Table B-11).

It appears that biological effects may begin in association with PCB concentrations above about 3 ppb (Table 22). The ER-L suggested by the data is 50 ppb PCB (54 rounded to 50 ppm), equivalent to the lower 10 percentile value of the available data. This value is supported only by the two marine SLCs (36.6 and 42.6 ppb) and a San Francisco Bay AET for bivalve larvae (based upon data that indicated weak concordance--54 ppb). The data suggest an ER-M of about 400 ppb; a value supported by Commencement Bay samples highly toxic to oyster larvae (mean 368 ppb) and the mean concentration in southern California sediments with moderate species richness (400 ppb). With very few exceptions, effects were almost always associated with PCB concentrations of 370 ppb or more (Table B-11).

The degree of confidence in these values should be considered as moderate. There are data from all of the major approaches, the overall apparent effects threshold is roughly equivalent to the ER-M concentration, and consistent clusters of data support the ER-L and ER-M values. However, much of the data available from the various approaches are not consistent. The highest and lowest Puget Sound AETs differ by over an order of magnitude; the data from the only single-chemical, SSB indicate relatively low acute toxicity and a value (LC50 of 10,800 ppb) inconsistent with much of the other data; PCB concentrations in Waukegan Harbor sediments determined to be toxic in Microtox™ tests differed by four orders of magnitude from those determined to be toxic in Puget Sound with the same test; and the marine and freshwater SLCs are much lower than the concentrations associated with benthic effects in other studies. Since the only data from a SSB unexpectedly indicated an LC50 much higher than the PCB concentrations associated with measures of effects in the field, PCBs in field-collected sediments may be highly particle-bound and not bioavailable and/or they may have a relatively minor role in causing biological effects such as acute mortality relative to other co-occurring contaminants.

**Table 21. Summary of sediment effects data available for PCBs.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2500 |
| | - oyster larvae (*C. gigas*) bioassay | 1100 |
| | - benthic community composition | 1100 |
| | - Microtox™ bioassay | 130 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 3100 |
| | - oyster larvae (*C. gigas*) bioassay | 1100 |
| | - benthic community composition | 1000 |
| | - Microtox™ bioassay | 130 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET | |
| | - screening level concentration | 130 |
| | - maximum level criterion | 2500 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 54 |
| | - *R. abronius* amphipod bioassay | 260 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7±3.9 dead/20) to *R. abronius* | 38 ± 32 |
| | - moderately toxic (5.2±1.1 dead/20) to *R. abronius* | 251 ± 556 |
| | - least toxic (2.5±0.9 dead/20) to *R. abronius* | 61 ± 88 |
| | - highly toxic (44.5±19% abnormal) to oyster larvae | 368 ± 695 |
| | - moderately toxic (23±2.3% abnormal) to oyster larvae | 140 ± 262 |
| | - least toxic (15.1±3.1% abnormal) to oyster larvae | 28 ± 27 |
| 26 | PUGET SOUND, WASHINGTON | |
| | - highly toxic (<95% LPL to *R. abronius*) | 276 ± 365 |
| | - moderately toxic (<87.5% to >95% LPL to *R. abronius*) | 259 ± 407 |
| | - non-toxic (≥87.5% survival of *R. abronius*) | 99 ± 120 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 4300 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 169 ± 171 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 151 ± 260 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 94 ± 147 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 146 ± 218 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 101 ± 153 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 164 ± 100 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 165 ± 232 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 26 ± 16 |

Table 21. PCBs (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 127 ± 171 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 216 ± 376 |
| 7 | - sediment quality triad minimum or no bioeffects | ≤100 |
| | - sediment quality triad significant bioeffects | ≥160 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 272 ± 217 |
| | - not toxic (23.2% mortality) to *G. japonica* | 480 ± 724 |
| 83 | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 1300 ± 2700 |
| | - moderate echinoderm abundance (56.2 ± 23/0.1 sq. m.) | 30 ± 50 |
| | - high echinoderm abundance (191.3 ± 70.1/0.1 sq. m.) | 20 ± 20 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 1000 ± 2400 |
| | - moderate arthropod abundance (72.6 ± 6.8/0.1 sq. m.) | 60 ± 70 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 80 ± 100 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 1110 ± 2610 |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 400 ± 600 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m) | 220 ± 540 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 160 ± 430 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 80 ± 140 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 2260 ± 3530 |
| 66 | SAN DIEGO BAY, CALIFORNIA | |
| | - ≥82% survival of *C. stigmaeus, A. sculpta, A. tonsa* | 25 |
| | - ≥86% survival of *A. sculpta, N. arenacaedentata, M. nasuta* | 25 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 190 ± 214 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 31 ± 19 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (8.4 ± 0.5/site) | 128 ± 264 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 7 ± 6 |
| 24 | WAUKEGAN HARBOR, ILLINOIS | |
| | - high Microtox™ toxicity (average EC50 of 47.7 ± 15.2) | 3,550,050 ± 6,598,300✔ |
| | - moderate Microtox™ toxicity (average EC50 of 128.7 ± 49.3) | 1,141,300 ± 2,229,700 |
| | - low Microtox™ toxicity (average EC50 of 368.1 ± 101.7) | ND-174,000✔ |
| 69 | MISSISSIPPI RIVER | |
| | - 80 to 100% survival (92 ± 6.3) of *G. pseudolimnaeus* | 60 |
| | - 25% survival of mayfly (*Hexagenia* sp.; n = 1) | <1.13 |
| | - 80-100% survival of mayfly (*Hexagenia* sp.) | 12 ± 20 |
| | - 55% ± 10% survival of midges (*C. tentans*) | 0.7 ± 0.3 |
| | - 90% ± 5.8% survival of midges (*C. tentans*) | 15 ± 22 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 0.005 ± 0 |
| | - low mortality to *D. magna* | 0.005 ± 0 |

Table 21. PCBs (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - low benthos species richness (31 ± 6.5/0.1 sq. m.) | 5 ± 5 |
| | - moderate benthos species richness (58.2 ± 10.5/0.1 sq. m.) | 5 ± 5 |
| | - high benthos species richness (93.6 ± 9.4/0.1 sq. m.) | 2 ± 1 |
| 58 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - significant toxicity to *A. abdita* in 10-day bioassay | 1700 |
| 79 | HUDSON-RARITAN BAY, NEW YORK | |
| | - negative rate of growth in nematode, *C.germanica* | 638 ± 512 |
| | - positive rate of growth in nematode, *C.germanica* | 290 ± 502 |
| 44 | NEW YORK HARBOR | |
| | - <10% mortality to *N. virens*, *M. mercenaria*, *P. pugio* | 7280 |
| 62 | BALTIMORE HARBOR, MARYLAND | |
| | - most toxic to mummichogs (TLm5.1 ± 3.5), spot (TLm5.9 ± 3.4) | 1100 ± 800 |
| | - least toxic to mummichogs (TLm43.2 ± 31.1), spot (TLm24 ± 5.6) | 180 ± 160 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | 50 |
| **National Screening Level Concentrations** | | |
| 5 | Freshwater sediments @ 1% TOC | 2.9 |
| | Marine sediments @ 1% TOC | 42.6 |
| 14 | Marine sediments @ 1% TOC | 36.6 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@4%TOC) (hexa-CB) | 280 |
| **Spiked Sediment Bioassays** | | |
| 18 | LC50 for *R. abronius* in 10-d bioassay | 10800 |
| 65 | significant toxicity to *R. abronius* in 10-d bioassay | 1000 ± 300 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 68 | Great Lakes Harbors | |
| | - Classification of heavily polluted sediments | ≥10000 |
| 43 | New England interim high contamination level for dredge material | 1000 |
| 12 | EPA Region V guideline for pollution classification of sediments | 1000-10000 |
| | USGS alert levels to flag 15-20% of samples analyzed | 20 |
| | Ontario Ministry of the Environment Dredge Spoil Guidelines | 50 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 380 |

Table 21. PCBs (continued)

| References | Background Approaches | Concentrations (ppb) |
|---|---|---|
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <100 |
| | - Class 2 (moderately contaminated) | 100-250 |
| | - Class 3 (contaminated) | 250-500 |
| | - Class 4 (heavily contaminated) | >500 |

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
7. Chapman *et al.*, 1987
12. Pavlou and Weston, 1983
14. Neff *et al.*, 1987
18. Swartz *et al.*, 1988
20. U.S. ACOE, 1988
23. Jansen, 1987
24. Ross *et al.*, 1988
26. DeWitt *et al.*, 1988
29. Yake *et al.*, 1986
43. NERBC, 1980
44. Rubenstein *et al.*, 1983
56. Anderson *et al.*, 1988
58. Rogerson *et al.*, 1985
60. Illinois EPA, 1988a
61. Illinois EPA, 1988b
62. Tsai *et al.*, 1979
64. Van Dolah *et al.*, 1984
65. Plesha *et al.*, 1988
66. Salazar and Salazar, 1985
68. Bahnick *et al.*, 1981
69. Marking *et al.*, 1981
75. Qasim *et al.*, 1980
79. Tietjen and Lee, 1984
80. Tetra Tech, 1985
82. Gilbert *et al.*, 1976
83. Word and Mearns, 1979

* -Various, please see text

**Table 22. Effects range-low and effects range-median values for PCBs and 34 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 2.9 | Freshwater SLC |
| 36.6 | Marine SLC |
| 42.6 | Marine SLC |
| **50** | **ER-L** |
| 54 | San Francisco Bay, California AET |
| ≤100 | San Francisco Bay, California triad minimum bioeffects COA |
| 128 | Kishwaukee River, Illinois benthos COA |
| 130 | Puget Sound, Washington AET - Microtox™ |
| 140 | Commencement Bay, Washington bioassay COA |
| 146 | San Francisco Bay, California, bioassay COA |
| 151 | San Francisco Bay, California bioassay COA |
| ≥160 | San Francisco Bay, California triad significant bioeffects COA |
| 165 | San Francisco Bay, California bioassay COA |
| 190 | DuPage River, Illinois benthos COA |
| 259 | Puget Sound, Washington bioassay COA |
| 260 | San Francisco Bay, California AET |
| 280 | EP chronic marine @ 4% TOC |
| 368 | Commencement Bay, Washington bioassay COA |
| **400** | **ER-M** |
| 400 | Southern California benthos COA |
| 638 | Hudson-Raritan Bay, New York bioassay COA |
| 1000 | Puget Sound, Washington AET - benthic |
| 1000 | Southern California arthropod abundance COA |

**Table 22. (continued)**

| Concentrations (ppb) | End Point |
|---|---|
| 1000 | SSB with *R. abronius* (PCBs mixed with hydrocarbons) |
| 1100 | Puget Sound, Washington AET - oyster |
| 1100 | Puget Sound, Washington AET - benthic |
| 1110 | Baltimore Harbor, Maryland bioassay COA |
| 1100 | Southern California species richness COA |
| 1300 | Southern California echinoderm abundance COA |
| 1700 | Black Rock Harbor, Connecticut bioassay COA |
| 2500 | Puget Sound, Washington AET - amphipod |
| 3100 | Puget Sound, Washington AET - amphipod |
| 4300 | Lake Union, Washington toxicity COA |
| 10800 | SSB with *R. abronius* LC50 |
| 1,141,300 | Waukegan Harbor, Illinois bioassay COA |
| 3,550,050✔ | Waukegan Harbor, Illinois bioassay COA |

## Pesticides:

### DDT and Metabolites

Data and estimates of threshold concentrations have been reported as the concentrations for each of the six isomers (p,p-DDT, o,p-DDT, p,p-DDD, o,p,-DDD, p,p-DDE, o,p-DDE); as the total of the two isomers each of DDT, DDD, and DDE; and as the concentration for the total of all six of these isomers of DDT. Therefore, within the limits of data availability, the data are treated separately here for each of the isomers and for the total. However, this approach has the unfortunate effect of reducing the amount of data available for any one of the isomers and for the total of the isomers.

The criterion to protect freshwater aquatic organisms is 0.001 ppm as a 24-h average and the concentration should not exceed 1.1 ppm at any time; the criterion to protect saltwater species is also 0.001 ppm as a 24-h average and the concentration should not exceed 0.13 ppm at any time (U.S. EPA, 1986). Available data indicate that acute toxicity of DDE occurs at concentrations as low as 1,050 ppm in freshwater and 14 ppm in saltwater (U.S. EPA, 1986). The LC50s for p,p'-DDT, p,p'-DDD, and p,p'-DDE were 0.45 ppm for a mysid (96-h test); 20 ppm for spot (48-h test); and over 100 ppm for spot (48-h test), respectively.

Data are available for either p,p'-DDT or the sum of o,p'-DDT and p,p'-DDT from Puget Sound AET, San Francisco Bay bioassays, Palos Verdes bioassays (with very small sample sizes), benthic effects at the Georgetown disposal site, SSB with *R. abronius*, and various applications of EP approaches (Table 23). The seven LC50s determined in the spiked bioassays averaged 49.5 ppb and ranged from 11.2 to 125.1 ppb, assuming 1 percent TOC content. The data for p,p'-DDT and the sum of the two isomers were treated as equivalent, since o,p'-DDT was rarely reported at high concentrations. There was no concordance between DDT concentrations in San Francisco Bay sediments and effects to bivalve larvae exposed to the sediments; neither the co-occurrence nor the AET data were used further. Likewise, there was no appreciable gradient in DDT concentration between samples least toxic to amphipods versus those moderately toxic to amphipods among San Francisco Bay sediments. Two of the Puget Sound AETs were not definitive. These data and the small amount of Palos Verdes data were not used to estimate ER-L and ER-M values (Table B-12). The remaining data suggest an ER-L of about 1.0 ppb DDT, the lower 10 percentile of the data (Table 24). This value is supported by EP-based thresholds of 0.7 and 1.6 ppb (assuming 1% TOC content). The data suggest an ER-M of about 7 ppb, roughly equivalent to the 50 percentile value of the data. This value is supported by moderate toxicity to bivalve larvae (6.6 ppb) and significant toxicity to amphipods (7.5 ppb) exposed to San Francisco Bay sediments. With several exceptions, effects were usually observed at concentrations of about 6 ppb or greater (Table B-12).

The degree of confidence in the p,p'-DDT ER-L and ER-M values should be considered as low. The data points do not cluster about the ER-L or ER-M values, especially at the upper end of the bioeffects range. Also, the values are based upon data from a few areas rather than over a broad range of areas. However, except for the EP-derived values, the highest and lowest threshold values differ by about an order of magnitude (3.9 to 49.5 ppb).

**Table 23. Summary of sediment effects data available for p,p'-DDT.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 3.9 |
| | - oyster larvae (*C. gigas*) bioassay | >6 |
| | - benthic community composition | 11 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | >270 |
| | - oyster larvae (*C. gigas*) bioassay | >6 |
| | - benthic community composition | 34 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 9.6 |
| | - *R. abronius* amphipod bioassay | 9.6 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 12 ± 25 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 2 ± 2 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 1 ± 3 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 8 ± 18 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 1 ± 3 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 0.6 ± 0.2 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 7 ± 18 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 2 ± 4 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 5 ± 15 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 3 ± 6 |
| 49 | PALOS VERDES, CALIFORNIA | |
| | - significantly toxic to *R. abronius* (n = 2) | 83 |
| | - not toxic to *R. abronius* (n = 1) | 74 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 840 |
| | EPA chronic marine EP threshold (@ 4% TOC) | 6.4 |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 6 |

**Table 23. p,p'-DDT (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 25 | Sediment safe level based upon sediment/water partitioning coefficient and acute water quality criteria (@ 1% TOC) | 210 |
| | Sediment safe level based upon sediment/water partitioning coefficient and chronic water quality criteria (@ 1% TOC) | 1.6 |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 0.7 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 0.4 |
| **Spiked Sediment Bioassays** | | |
| 16 | Overall mean LC50 for *R. abronius* in Puget Sound, Washington sediments (@ 1% TOC) (LC50s ranged from 11.2 to 125.1 ppb) | 49.5 |

**References:**

1. Beller et al., 1986
2. PTI Environmental Services, 1988
4. Bolton et al., 1985
9. Swartz et al., 198516.
16. Word et al., 1987
17. Lyman et al., 1987
25. Pavlou, 1987
64. Van Dolah et al., 1984

* -Various, please see text

**Table 24. Effects range-low and effects range-median values for p,p'-DDT and 15 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 0.4 | EP 99 percentile chronic marine |
| 0.7 | EP 95 percentile chronic marine |
| **1.0** | **ER-L** |
| 1.6 | EP chronic safe level @ 1% TOC |
| 3.9 | Puget Sound, Washington, AET - amphipod |
| 6.0 | EP chronic marine @ 4% TOC |
| 6.4 | EP chronic marine @ 4% TOC |
| 6.6 | San Francisco Bay, California, bioassay COA |
| **7.0** | **ER-M** |
| 7.5 | San Francisco Bay, California, bioassay COA |
| 9.6 | San Francisco Bay, California, AET |
| 11.0 | Puget Sound, Washington, AET - benthic |
| 12.2 | San Francisco Bay, California, bioassay COA |
| 34.0 | Puget Sound, Washington, AET - benthic |
| 49.5 | SSB with *R. abronius*: overall mean LC50 |
| 210.0 | EP acute safe level @ 1% TOC |
| 840.0 | EP acute marine @ 4% TOC |

For the p,p'-DDE isomer or total DDE, data are available from Puget Sound AET, San Francisco Bay bioassays and AET, Palos Verdes bioassays and benthic community analyses, Mississippi River bioassays, benthic community analyses at the Georgetown disposal site, and various uses of the EP approaches (Table 25). No effects upon benthos at the Georgetown site were observed at concentrations below the limits of detection of 50 ppb; there was no concordance between DDE concentrations in San Francisco Bay and significantly toxic versus non-toxic samples tested with bivalve larvae; nor for sediments that were highly versus moderately toxic to bivalves or moderately versus least toxic to amphipods. Low survival of *Hexagenia* sp. exposed to Mississippi River sediment was observed in only one sample and there was a very small gradient in DDE concentration among samples; therefore, these data were not used in estimating ER-L and ER-M values (Table B-13). The remaining data (Table 26) suggest an ER-L of about 2 ppb, the lower 10 percentile value of the available data. This value is supported by AET and bioassay data from San Francisco Bay sediments tested with *R. abronius* amphipods and bivalve larvae (2.2., 2.2, 2.1, 2.2 ppb). Effects were almost always seen in association with concentrations exceeding 2 ppb (Table B-13). The 50 percentile value of the data suggest an ER-M of about 15 ppb, a value supported by relatively few data points: Puget Sound AETs of 9 and 15 ppb.

The degree of confidence in the p,p'-DDE ER-L and ER-M values should be considered as moderate and low, respectively. There are few data points available and no measures of effects based upon SSBs. An apparent effects threshold could not be determined due to the lack of sufficient data. The ER-L value is supported by a small cluster of data from San Francisco Bay.

**Table 25. Summary of sediment effects data available for DDE.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 15 |
| | - benthic community composition | 9 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 15 |
| | - benthic community composition | 9 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 2.2 |
| | - *R. abronius* amphipod bioassay | 2.2 |
| **Co-occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 3 ± 5 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 1 ± 1 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 1 ± 1 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 2 ± 4 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 1 ± 1 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 1 ± 1 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 2 ± 4 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 1 ± 1 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 2 ± 3 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 1 ± 1 |

Table 25. DDE (continued).

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-occurrence Analyses** | | |
| 49 | PALOS VERDES, CALIFORNIA | |
| | - significantly toxic to *R. abronius* | 5157 ± 1065 |
| | - not toxic to *R. abronius* | 3374 ± 3153 |
| | - major degradation" of macrobenthos (20.2 sp./0.1 m. sq.) | 5157 ± 1065 |
| 69 | MISSISSIPPI RIVER | |
| | - 80-100% survival (92 ± 6.3) of *G. pseudolimnaeus*, 4-d bioassay | 0.28 |
| | - 25% (n = 1) survival of mayfly (*Hexagenia* sp.), 4-d bioassay | <0.2 |
| | - 80-100% survival (90 ± 7.5) of mayfly (*Hexagenia* sp.) 4-d bioassay | <0.21✔ |
| | - 55% ± 10% survival of midges (*C. tentans*), 4-d bioassay | 0.1 ± 0 |
| | - 90% ± 5.8% survival of midges (*C. tentans*), 4-d bioassay | <0.21✔ |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@4% TOC) | 28000 |
| 17 | EPA acute marine EP threshold (@4% TOC) | 28000 |
| 25 | Safe level based on sediment/water partitioning coefficient, acute water quality criteria | 7000 |
| 13 | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 27 |
| | 95 percentile chronic marine permissable (sediment/water partition coefficent) | 60 |


**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
13. Pavlou *et al.*, 1987
17. Lyman *et al.*, 1987
25. Pavlou, 1987
49. Swartz *et al.*, 1985
50. Swartz *et al.*, 1986
69. Marking *et al.*, 1981
64. Van Dolah *et al.*, 1984
* -Various, please see text

**Table 26. Effects range-low and effects range-median values for p,p'-DDE and 13 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| **2.0** | **ER-L** |
| 2.1 | San Francisco Bay, California, bioassay COA |
| 2.2 | San Francisco Bay, California, AET |
| 2.2 | San Francisco Bay, California, bioassay COA |
| 2.2 | San Francisco Bay, California, AET |
| 3.4 | San Francisco Bay, California, bioassay COA |
| 9.0 | Puget Sound, Washington, AET - benthic |
| **15.0** | **ER-M** |
| 15.0 | Puget Sound, Washington, AET - amphipod |
| 27.0 | EP 99 percentile chronic marine @ 1% TOC |
| 60.0 | EP 95 percentile chronic marine @ 1% TOC |
| 5157.0 | Palos Verdes, California, bioassay COA |
| 5157.0 | Palos Verdes, California, major benthic degradation COA |
| 7000.0 | EP acute safe level @ 1% TOC |
| 28000.0 | EP acute marine @ 1% TOC |

Puget Sound and San Francisco Bay AET, San Francisco Bay bioassay data, Palos Verdes bioassay data, and EP-based thresholds are available for p,p'-DDD (Table 27). There were very small differences in DDD concentration in San Francisco Bay samples that were significantly toxic to bivalve larvae versus those that were not toxic, so these data were not used to estimate ER-L and ER-M values (Table B-14). Also, there was no concordance between DDD concentration and toxicity with the sediments that were highly and moderately toxic to bivalve larvae--these data were not used further (Table B-14). The Palos Verdes data were from a relatively small number of samples (n=6) and were not used to estimate ER-L/ER-M values, although they indicated no toxicity at a mean concentration two orders of magnitude higher than the concentrations in Puget Sound and San Francisco Bay. Lyman *et al.* (1987) listed the EP criterion for DDD as 13,000 ppb for acute effects. Bolton *et al.*, (1985) also listed the EP-based DDD threshold as 13 mg/kg (equivalent to 13,000 ppb dry weight), but did not identify this as a threshold for acute or chronic effects (the text implied that it was for chronic effects). The concentration identified by Lyman *et al.* (1987) was used to determine the ER-L and ER-M values. The lower 10 percentile value of the remaining data (Table 28) suggest an ER-L of about 2 ppb; a value also supported by a Puget Sound AET of 2 ppb. The data suggest an ER-M of about 20 ppb; a value supported by a Puget Sound AET (16 ppb). There were too little data to justify the identification of an apparent effects threshold. A small amount of data were available for o,p'-DDD and indicated no relationship with measures of biological effects, thereby precluding estimation of ER-L and ER-M values. Thus, the degree of confidence in the p,p'-DDD ER-L and ER-M values should be considered as low. A small amount of data are available from only two areas. There are no SSB data.

**Table 27. Summary of sediment effects data available for DDD.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 43 |
| | - benthic community composition | 2 |

**Table 27. DDD (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 43 |
| | - benthic community composition | 16 |
| * | SAN FRANCISCO BAY, CALIFORNIA, AET | |
| | - bivalve larvae bioassay | 16 |
| | - *R. abronius* amphipod bioassay | 16 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 1 ± 2 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 1 ± 1 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 1 ± 1 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 1 ± 2 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 2 ± 0.1 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 1 ± 0.3 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 16 ± 23 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 10 ± 7 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 13 ± 21 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 13 ± 9 |
| 49 | PALOS VERDES SHELF, CALIFORNIA | |
| | - significantly toxic to *R. abronius* (n = 3) | 1090.7 ± 573 |
| | - not toxic to *R. abronius* | 324 ± 387.3 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 13000 |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 13000 |
| 13 | 99 percentile chronic marine permissable (@ 1% TOC) | 6 |
| | 95 percentile chronic marine permissable (@ 1% TOC) | 22 |
| 25 | Sediment safe level based upon sediment/water partitioning coefficients and acute water quality criteria (@ 1% TOC) | 3250 |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
13. Pavlou *et al.*, 1987
17. Lyman *et al.*, 1987
25. Pavlou, 1987
49. Swartz *et al.*, 1985
64. Van Dolah *et al.*, 1984

* -Various, please see text.

**Table 28. Effects range-low and effects range-median values for p,p'-DDD and 7 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| **2.0** | **ER-L** |
| 2.0 | Puget Sound, Washington, AET - benthic |
| 6.0 | EP 99 percentile chronic marine @ 1% TOC |
| 16.0 | Puget Sound, Washington, AET - benthic |
| **20.0** | **ER-M** |
| 22.0 | EP 95 percentile chronic marine @ 1% TOC |
| 43.0 | Puget Sound, Washington, AET - amphipod |
| 3250.0 | EP Acute Safe Level @ 1% TOC |
| 13000.0 | EP Acute Marine @ 1% TOC |

Data available with which to evaluate total DDT (a summation of all the quantified isomers) include those from southern California bioassays and benthic communities; DuPage River benthic communities; Trinity River bioassays; SSBs performed with *Nereis virens*, *Crangon septemspinosa*, *Hyallella azteca*, and *R. abronius*; and various applications of EP approaches (Table 29). The DDT LC50 for the *C. septemspinosa* sediment bioassays was reported as ug/L in the data table and ug/kg in the text (McLeese and Metcalfe, 1980); it was assumed that the units of ug/kg were correct and they were used in the present document. There was no concordance between mean DDT concentrations and both high and moderate total abundance and high and moderate species richness among southern California benthic communities, so these data were not used in the estimation of ER-L and ER-M values (Table B-15). The lower 10 percentile of the remaining data (Table 30) suggest an ER-L value of about 3 ppb, a value poorly supported by two EP-derived thresholds (1.58 and 3.29 ppb) and a freshwater SLC (1.9 ppb). The ER-M value equivalent to the 50 percentile of the available data is about 350 ppb, a value supported by observations of moderate abundances of anthropods in southern California sediments (mean 350 ppb) and low taxa richness in DuPage River macrobenthos (mean 222 ppb). The series of SSBs with *H. azteca* demonstrate the importance of organic carbon in regulating bioavailability, and, therefore, toxicity of sediment-associated DDT. There was no overall apparent threshold in concentration of total DDT above which effects were usually or always observed (Table B-15). The degree of confidence in the ER-L and ER-M values should be considered as moderate. A moderate amount of data are available and they are from all the major approaches, however, there is very little clustering of the data.

**Table 29. Summary of sediment effects data available for total DDT.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 6.9 |
| | - maximum level criterion | 69 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 68±72 |
| | - not toxic (23.2% mortality) to *G. japonica* (includes Palos Verdes sample) | 1018±2424 |
| | - not toxic (21.3% mortality) to *G. japonica* (excludes Palos Verdes sample) | 28.6 |

Table 29. DDT (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 83 | - high echinoderm abundance (191.3±70.1/0.1 sq. m.) | 50 ± 60 |
| | - moderate echinoderm abundance (56.2±23/0.1 sq. m.) | 79 ± 126✔ |
| | - low echinoderm abundance (6.1 ± 7.2/0.1 sq. m.) | 18260 ± 43080 |
| | - high arthropod abundance (148 ± 58/0.1 sq. m.) | 100 ± 150 |
| | - moderate arthropod abundance (72.6 ± 6.8/0.1 sq. m.) | 350 ± 710 |
| | - low arthropod abundance (35.3 ± 15.8/0.1 sq. m.) | 13420 ± 37670 |
| | - high species richness (96.3 ± 22.3/0.1 sq. m) | 1874 ± 6660✔ |
| | - moderate species richness (72 ± 3.3/0.1 sq. m.) | 250 ± 620 |
| | - low species richness (51.2 ± 8.6/0.1 sq. m.) | 14190 ± 40200 |
| | - high total abundance (88.9 ± 35.4/0.1 sq. m.) | 35300 ± 59540 |
| | - moderate total abundance (75.6 ± 12.7/0.1 sq. m.) | 210 ± 490 |
| | - low total abundance (57.6 ± 13.6/0.1 sq. m.) | 1410 ± 5440 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 222 ± 282 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 20 ± 18 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 31 ± 20 |
| | - low mortality to *D. magna* | 7 ± 10 |
| **National Screening Level Concentrations** | | |
| 5 | For freshwater sediments @ 1% TOC | 1.9 |
| | For marine sediments (@1%TOC) | 428 |
| 14 | For marine sediments (@1%TOC) | 505 |
| **Equilibrium Partitioning** | | |
| 15 | Sediment-water partitioning coefficient/marine chronic criteria (1% TOC) | 1.58 |
| | Sediment-biota partitioning coefficient/marine chronic criteria (1% TOC) | 3.29 |
| 6 | EPA interim marine sediment quality criteria based upon EP @ 1% TOC | 8.28 |
| 35 | Lethal threshold in freshwater based on Koc coefficients | 45.9 |
| **Spiked-Sediment Bioassays** | | |
| 42 | LD50 for cricket nymph, *G. pennsylvanicus* in 18-h bioassay | 67232 |
| 34 | LC50 for *N. virens* in 288-h bioassay (no deaths) | 16500 |
| 35 | LC50 for *C. septemspinosa* in 97-h bioassay | 31 |
| | Lethal threshold for *C. septemspinosa* | 20 |

**Table 29. DDT (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Spiked-Sediment Bioassays** | | |
| 89 | LC50 for *Hyallella azteca* @ 3% organic carbon | 11,000 |
| | LC50 for *Hyallella azteca* @ 7.2% organic carbon | 19,600 |
| | LC50 for *Hyallella azteca* @ 10.5% organic carbon | 49,700 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 12 | USGS alert levels to flag 15-20% of samples analyzed | 20 |
| 20 | EPA/ACOE Puget Sound Interim Criteria (central basin background) | 5 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <200 |
| | - Class 2 (moderately contaminated) | 200-2000 |
| | - Class 3 (contaminated) | 2000-10000 |
| | - Class 4 (heavily contaminated) | >10000 |

**References:**

5. Neff *et al.*, 1986
6. EPA, 1988
12. Pavlou and Weston 1983
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
15. JRB Associates, 1984
20. U.S. ACOE, 1988
23. Jansen, 1987
34. McLeese *et al.*,1982
35. McLeese and Metcalfe, 1980
42. Harris, 1964

* -Various, please see text.

43. NERBC, 1980
56. Anderson *et al.*, 1988
75. Qasim *et al.*, 1980
83. Word and Mearns, 1979
89. Nebeker *et al.*, 1989

**Table 30. Effects range-low and effects range-median values for total DDT and 21 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 1.58 | EP marine chronic @ 1% TOC |
| 1.9 | Freshwater SLC @ 1% TOC |
| **3.0** | **ER-L** |
| 3.29 | EP marine chronic @ 1% TOC |
| 8.28 | Interim EP marine criteria @ 1% TOC |
| 20.0 | SSB lethal threshold with *Crangon* |
| 31.0 | SSB 97-h LC50 for *Crangon* bioassay |
| 31.4 | Trinity River, Texas, bioassay COA |
| 45.9 | Calculated freshwater EP threshold |
| 79.0✓ | Southern California echinoderm abundance COA |
| 221.7 | DuPage River, Illinois benthos COA |
| **350** | **ER-M** |
| 350.0 | Southern California arthropod avoidance COA |
| 428.0 | Marine SLC @ 1% TOC |
| 505.0 | Marine SLC @ 1% TOC |
| 4950.0 | Overall LC50 for *R. abronius* bioassay |
| 11000.0 | SSB LC50 *H. azteca* bioassay @ 3% TOC |

Table 30. (continued)

| Concentrations (ppb) | End Point |
|---|---|
| 13420.0 | Southern California arthropod abundance COA |
| 14190.0 | Southern California species richness COA |
| 18260.0 | Southern California echinoderm abundance COA |
| 19600.0 | SSB LC50 *H. azteca* bioassay @ 7.2% TOC |
| 49700.0 | SSB LC50 *H. azteca* bioassay @ 10.5% TOC |
| 62732.0 | SSB LD50 cricket nymph bioassay |

Some of the DDD concentrations (1 to 16 ppb) in Puget Sound and San Francisco Bay sediments associated with toxicity were at the low end of the range and relatively similar to some of the thresholds predicted by the EP approach, however, they differed considerably from the mean DDD concentrations (324 to 1090 ppb) observed off Palos Verdes, California. There are relatively large disparities among the available data for total DDT from the same and different approaches. Values derived for total DDT from EP approaches (1.58 to 45.9 ppb) differ considerably from those derived from SSBs with marine animals (31 to 16,500 ppb). No deaths were observed in *N. virens* exposed to 16,500 ppb total DDT; whereas, an LC50 of 31 ppb and a lethal threshold of 20 ppb were calculated for bioassays performed with *C. septemspinosa*. Freshwater and saltwater SLCs for total DDT differed by over two orders of magnitude. Chronic thresholds predicted by the EP approach differed by about four orders of magnitude from mean concentrations associated with low echinoderm abundance off southern California, an area well documented to be highly contaminated with DDT and metabolites (Word and Mearns, 1979). Some of the EP-derived thresholds for the DDE isomers exceed those derived for total DDT. Overall, the degree of confidence in the ER-L and ER-M values for DDT and metabolites should be considered as relatively low, mainly since there are relatively large inconsistencies in the data derived from different approaches and different uses of some of the same approaches. These differences may be largely due to differences in organic carbon content of test sediments or other physical/chemical factors.

**Lindane**

In bioassays of marine fish and macroinvertebrates, 96-h LC50s of 0.077 to 190 ug/L (ppm) have been observed for lindane in saltwater (Mayer, 1987). Data with which to associate lindane concentrations in sediments with measures of effects are restricted to predictions based upon the EP approach (Table 31). A few samples tested with amphipod and bivalve larvae bioassays in San Francisco Bay had measurable amounts of lindane (up to 1.9 ppb dry weight), but most of the samples were not tested for this pesticide or had non-detectable concentrations, precluding use of the data to determine ER-L and ER-M values. The PSDDA screening level concentration was based upon analytical capabilities, not on AET or other measures of effects. No effects among benthic communities at the Georgetown, South Carolina dumpsite were observed in samples that had less than the detection limits of 50 ppb lindane. The remaining data from the EP approach predict that effects would occur at concentrations ranging from 1.57 to 12 ppb dry weight (Table 31). These data are insufficient to determine ER-L and ER-M values.

**Table 31. Summary of sediment effects data available for lindane.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 0.6 ± 0.8 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | not detected |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | not detected |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 0.33 ± 0.65 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | not detected |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | not detected |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 0.4 ± 0.7 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | not detected |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 0.3 ± 0.7 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | not detected |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **Equilibrium Partitioning** | | |
| 6 | EPA interim marine sediment quality criteria @ 1% TOC | 1.57 |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 12 |
| 25 | Sediment safe level based upon sediment/water partitioning Coefficients and acute water quality criteria (@ 1% TOC) | 3.1 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 12 | USGS alert level to flag 15-20% of samples analyzed | 20 |
| 20 | PSDDA guidelines (based upon analytical capabilities) | 5.0 |

**References:**

4. Bolton *et al.*, 1985
6. EPA, 1988
12. Pavlou and Weston, 1983
20. U.S. ACOE, 1988
25. Pavlou, 1987
64. Van Dolah *et al.*, 1984

* -Various, please see text

## Chlordane

The chlordane water quality criteria are 0.0043 ppm as a 24-h average and not to exceed 2.4 ppm in freshwater at any time. In saltwater they are 0.004 ppm and 0.09 ppm, respectively (U.S. EPA, 1986). EC50s for estuarine organisms range from 2.4 to 260 ppm tested in 48-h bioassays (Mayer, 1987). Data with which to evaluate measures of effects and chlordane in sediments are available from EP methods, SSBs, and analyses of matching field-collected biological and chemical analyses (Table 32). The field-collected data are from San Francisco Bay, Trinity River, and DuPage River. No effects upon the benthic communities were observed at the Georgetown disposal site at chlordane concentrations below the limits of detection (<50 ppb). San Francisco Bay sediments that were highly toxic to bivalve larvae were not tested for chlordane concentrations so these data (and the AET for bivalve larvae) were not used to determine ER-L and ER-M values. Among the 20 San Francisco Bay sediments that were moderately toxic to amphipods, only 4 were tested for chlordane concentrations; no chlordane was detected in those 4 samples. Likewise, among the 22 samples that were least toxic to amphipods, 4 were tested for chlordane concentrations; and one had 2 ppb and the others had no detectable amount. These data were not considered further in the determination of ER-L and ER-M values (Table B-16). Effects are predicted by EP methods to occur at concentrations as low as 0.3 ppb (Table 33). The ER-L suggested by the data is 0.5 ppb, supported by two EP-derived concentrations (0.3, 0.6 ppb). The 50 percentile value in the available data is 6 ppb, an ER-M supported by San Francisco Bay bioassay data (means of 4.1 and 6.4 ppb). Effects were usually observed at concentrations of 2 ppb or greater (Table B-16).

The degree of confidence in these values for chlordane should be considered as low. Two of the EP-derived chronic thresholds are very low compared to the co-occurrence and SSB data; SSBs have not been performed with sensitive infaunal organisms such as amphipods; and the abundance of data from San Francisco Bay where chlordane concentrations are not particularly high may have biased the determination of the ER-L and ER-M values.

**Table 32. Summary of sediment effects data available for chlordane.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 2.0 |
| | - *R. abronius* amphipod bioassay | 2.0 |
| **Co-occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 6.4 ± 7.5 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | Not detected |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | Not detected |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 3.5 ± 6.3 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 1 ± 1.4 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | No data |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 4.1 ± 6.6 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 0.5 ± 1 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 3.5 ± 6.3 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 1 ± 1.4 |

Table 32. Chlordane (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-occurrence Analyses** | | |
| 75 | TRINITY RIVER, TEXAS. | |
| | - significant mortality to *D. magna* | 31.3 ± 29.4 |
| | - low mortality to *D. magna* | 1.7 ± 2.3 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 25 ± 22.3 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 8.3 ± 4.3 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **Equilibrium Partitioning** | | |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 0.6 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 0.3 |
| 35 | Lethal threshold in freshwater based on Koc coefficients | 17.4 |
| **Spiked Sediment Bioassays** | | |
| 34 | LC50 for *N. virens* | ≤5800 |
| 35 | LC50 for *C. septemspinosa* | 120 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 20 | PSDDA guidelines (based on analytical capability) screening level concentrations | 5.0 |
| 12 | USGS alert levels to flag 15-20% of samples analyzed | 20 |

**References:**


12. Pavlou and Weston, 1983
13. Pavlou *et al.*, 1987
20. U.S. ACOE, 1988
34. McLeese *et al.*, 1982
35. McLeese and Metcalfe, 1980
60. Illinois EPA, 1988a
64. Van Dolah *et al.*, 1984
75. Qasim *et al.*, 1980
* Various, please see text.

**Table 33. Effects range-low and effects range-median values for chlordane and 12 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 0.3 | EP 99 percentile chronic marine |
| **0.5** | **ER-L** |
| 0.6 | EP 95 percentile chronic marine |
| 2.0 | San Francisco Bay, California, AET |
| 3.5 | San Francisco Bay, California, bioassay COA |
| 3.5 | San Francisco Bay, California, bioassay COA |
| 4.1 | San Francisco Bay, California, bioassay COA |
| **6.0** | **ER-M** |
| 6.4 | San Francisco Bay, California bioassay COA |
| 17.4 | EP freshwater lethal threshold |
| 25.0 | DuPage River, Illinois, benthos COA |
| 31.3 | Trinity River, Texas, bioassay COA |
| 120.0 | SSB LC50 for C. *septemspinosa* |
| <5800.0 | SSB LC50 for N. *virens* |

## Heptachlor

The 96-h. LC50s for heptachlor in water range from 0.03 to 3.8 ug/L (ppm) for estuarine organisms (Mayer, 1987). The LC50 for heptachlor epoxide, a degradation product of heptachlor, was 0.04 ppm in a bioassay with pink shrimp (Mayer, 1987).

Sediment effects data are available only from one SLC, one SSB (with a cricket nymph), and two uses of the EP approach (Table 34). The PSDDA screening level is based upon assumed analytical capability, not an AET or some other measure of effects. The freshwater SLC (0.8 ppb dw) and the two EP thresholds (0.04, 0.06 ppb dw) are roughly within an order of magnitude of each other. The results of an 18-d bioassay of muck soil with cricket nymphs (of questionable applicability to marine and estuarine sediments) indicated an LD-50 of 4192 ppb dw, four orders of magnitude higher than the other concentrations. Because of the lack of sufficient data, ER-L and ER-M values cannot be determined.

**Table 34. Summary of sediment effects data available for heptachlor.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **National Screening Level Concentrations** | | |
| 5 | For freshwater sediments @ 1% TOC | 0.8 |
| **Equilibrium Partitioning** | | |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 0.06 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 0.04 |
| **Spiked-Sediment Bioassays** | | |
| 42 | LD50 for cricket nymph (*G. pennsylvanicus*) | 4192 |

**Table 34. Summary of sediment effects data available for heptachlor.**

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 20 | PSDDA guidelines (based on analytical capability) screening level concentrations | 5.0 |
| 12 | USGS alert levels to flag 15-20% of samples analyzed | 20 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated; ppb organic carbon) | <200 |
| | - Class 2 (moderately contaminated; ppb organic carbon) | 200-2000 |
| | - Class 3 (contaminated; ppb organic carbon) | 2000-10000 |
| | - Class 4 (heavily contaminated; ppb organic carbon) | >10000 |

**References:**

5. Neff et al., 1986
12. Pavlou and Weston, 1983
13. Pavlou *et al.*, 1987
20. U.S. ACOE, 1988
23. Jansen, 1987
42. Harris, 1964.

**Dieldrin**

The 96-h LC50s for dieldrin range from 0.7 ug/L to 10 ug/L as determined with estuarine organisms tested in water (Mayer, 1987).

Sediment-related effects data are available from San Francisco Bay bioassays, Trinity River bioassays, DuPage River benthos studies, Kishwaukee River benthos studies, a freshwater SLC, the EP approach, and SSBs with two species (Table 35). The four San Francisco Bay samples that were highly toxic to bivalve larvae were not tested for dieldrin concentrations. There was little or no gradient in dieldrin concentrations among other San Francisco Bay samples. There also was no gradient in dieldrin concentration between Trinity River sediments that were highly toxic to *Daphnia* versus those that were not toxic. These data were not considered further (Table B-17). The lower 10 percentile of the remaining data suggest an ER-L of about 0.02 ppb, a value supported by two EP thresholds (0.01 and 0.02 ppb) (Table 36). The data suggest an ER-M of about 8 ppb, a value supported by Kishwaukee River benthic data (mean 7.4 ppb), and San Francisco Bay bioassay data (mean 8.2 ppb). No overall effects threshold is apparent.

The degree of confidence in the ER-L and ER-M values for dieldrin should be considered as low. A small amount of data are available; much of the co-occurrence data are from San Francisco Bay where the range in dieldrin concentrations is low; different uses of the EP approach resulted in predicted concentrations that differ by five orders of magnitude; and two independent spiked sediment bioassays resulted in LC50s that differed by four orders of magnitude. In addition, the ER-L is supported only by theoretical EP-derived concentrations and not verified by empirical evidence.

Table 35. **Summary of sediment effects data available for dieldrin.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 6.6 |
| | - *R. abronius* amphipod bioassay | 6.6 |
| **Co-occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 10.3 ± 9.6 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 4.4 ± 2.3 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 5.2 ± 1.2 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 7.6 ± 7.5 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 6.2 ± 0.6 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | no data |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 8.2 ± 8.1 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 5.2 ± 1.2 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 7.6 ± 7.5 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 6.2 ± 0.6 |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 25.5 ± 33.2 |
| | - low mortality to *D. magna* | 25.5 ± 61.1 |
| 60 | DUPAGE RIVER, ILLINOIS | |
| | - least number of benthic macroinvertebrate taxa (6.7 ± 2.5/site) | 16 ± 12.1 |
| | - highest number of benthic macroinvertebrate taxa (15.8 ± 2/site) | 5.6 ± 2.2 |
| 61 | KISHWAUKEE RIVER, ILLINOIS | |
| | - least number of benthic macroinertebrate taxa (8.4 ± 0.5/site) | 7.4 ± 4.8 |
| | - highest number of benthic macroinvertebrate taxa (16.3 ± 4.6/site) | 4.3 ± 2.1 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50 |
| **National Screening Level Concentrations** | | |
| 5 | For freshwater sediments @ 1% TOC | 0.21 |
| **Equilibrium Partitioning** | | |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 0.02 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 0.01 |
| 35 | Lethal threshold in freshwater based on Koc coefficients | 11.9 |
| 6 | EPA interim mean marine sediment quality criteria @ 1% TOC | 57.7 |
| | EPA interim mean freshwater sediment quality criteria @ 1% TOC | 199 |

**Table 35. Dieldrin (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Spiked Sediment Bioassays** | | |
| 34 | LC50 for *N. virens* | 13000 |
| 35 | LC50 for *C. septemspinosa* | 4.1 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 20 | PSDDA guidelines (based on analytical capability) | 5.0 |
| 12 | USGS alert levels to flag 15 to 20% of samples analyzed | 20 |
| 43 | New England interim high contamination levels for dredge material | 100 |

**REFERENCES**

5. Neff *et al.*, 1986
6. EPA, 1988
12. Pavlou and Weston, 1983
13. Pavlou *et al.*, 1987
20. U.S. ACOE, 1988
34. McLeese *et al.*, 1982
35. McLeese and Metcalfe, 1980
43. NERBC, 1980
60. Illinois EPA, 1988a
61. Illinois EPA, 1988b
64. Van Dolah *et al.*, 1984
75. Qasim *et al.*, 1980

* Various, please see text

**Table 36. Effects range-low and effects range-median values for dieldrin and 14 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 0.01 | EP 99 percentile chronic marine |
| **0.02** | **ER-L** |
| 0.02 | EP 95 percentile chronic marine |
| 0.21 | Freshwater SLC @ 1% TOC |
| 4.1 | SSB LC50 for *C. septemspinosa* |
| 6.6 | San Francisco Bay, California AET |
| 6.6 | San Francisco Bay, California AET |
| 7.4 | Kishwaukee River, Illinois benthos COA |
| **8.0** | **ER-M** |
| 8.2 | San Francisco Bay, California bioassay COA |
| 10.3 | San Francisco Bay, California bioassay COA |
| 11.9 | EP freshwater lethal threshold |
| 16.0 | DuPage River, Illinois benthos COA |
| 57.7 | EP interim marine criteria |
| 199.0 | EP interim freshwater criteria |
| 13000.0 | SSB LC50 for *N. virens* |

**Aldrin**

The 48-h EC50s for aldrin tested with pink shrimp (*Penaeus duorarum*) and blue crab (*Callinectes sapidus*) were 0.32 and 23 ug/L, respectively; and the 48-h LC50s for spot (*Leiostomus xanthurus*) and mullet (*Mugil cephalus*) were 3.2 and 2 ug/L, respectively (Mayer, 1987). The criteria to protect freshwater and marine aquatic life are 3.0 and 1.3 ug/L, respectively (U.S. EPA, 1986).

A relatively small amount of data are available with which to assess the effects of aldrin in sediments (Table 37). These data are restricted to San Francisco Bay bioassay results and uses of the EP approach. Of the 53 San Francisco Bay sediments tested for toxicity with bivalve larvae, only 17 were analyzed for aldrin concentrations, and among those samples only 3 had detectable amounts (0.7, 1.1, and 1.9 ppb). Similarly, of the 39 samples tested with the amphipod bioassay, 15 were analyzed for aldrin content, and among those samples only the same 3 samples had detectable amounts. These data are insufficient to use in the determination of ER-L and ER-M values, as are the AET concentrations determined from them. The remaining data from four uses of the EP approach indicate a range of thresholds from 4.3 to 21 ppb dw. The EPA chronic marine concentration of 21 ppb would have been 5.2 ppb (equal to the concentration reported by Pavlou, 1987), if an assumption of a 1 percent TOC content had been made in the calculation. There do not appear to be any empirical data to compare with these predicted concentrations, so ER-L and ER-M values were not determined.

**Table 37. Summary of sediment effects data available for aldrin.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >1.9 |
| | - *R. abronius* amphipod bioassay | >1.9 |
| **Co-occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 0.3 ± 0.5 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | not detected |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | detected in one sample |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 0.1 ± 0.4 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 1.0 ± 1.3 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | not detected |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 0.2 ± 0.4 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 0.5 ± 1.0 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 0.1 ± 0.4 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 1.0 ± 1.3 |
| **Equilibrium Partitioning** | | |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 8.4 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 4.3 |
| 4 | EPA chronic marine EP threshold @ 4% TOC | 21.0 |

Table 37. Aldrin (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 25 | Sediment safe levels based on sediment/water partitioning coefficients and acute water quality criteria @ 1% TOC | 5.2 |

| References | Background Approach | Concentrations (ppb) |
|---|---|---|
| 20 | PSDDA guidelines (based on analytical capability) | 5.0 |
| 12 | USGS alert levels to flag 15 to 20% of samples analyzed | 20.0 |

**References:**

4. Bolton *et al.*, 1985
13. Pavlou *et al.*, 1987
* Various, please see text
20. U.S. ACOE, 1988
25. Pavlou, 1987

## Endrin

The 96-h LC50s for endrin tested with a variety of estuarine organisms ranged from 0.037 to 1.2 ug/L (Mayer, 1987). The concentration should not exceed 0.18 ug/L in freshwater or 0.037 ug/L in saltwater at any time (U.S. EPA, 1986).

A relatively small amount of data is available for this pesticide in sediments (Table 38), however there are data from most of the major approaches to the development of criteria. Matching chemical and toxicity data from the Trinity River are available. Data from various uses of the EP approaches and from two SSBs are available. None were eliminated from consideration in the determination of the ER-L and ER-M values (Table B-18). Effects are predicted at concentrations of 0.01 to 321 ppb by the EP approach. Spiked sediment bioassays performed with three species, indicated LC50s that differed by nearly three orders of magnitude. The ER-L and ER-M values are 0.02 and 45 ppb, respectively (Table 39). The ER-L value is supported by two EP-predicted concentrations, 0.01 and 0.02 ppb, and the ER-M value is supported by an LC50 for *Crangon septemspinosa* in spiked bioassays (47 ppb).

The ER-L value (0.02 ppb) is not supported by any empirical biological evidence from laboratory or field studies and the degree of confidence in the value should be considered as low. The ER-M value (45 ppb) is supported only by the LC50 from a SSB (47 ppb) and not by evidence from tests of mixtures, as would be experienced in the field; therefore, the degree of confidence in the ER-M should also be considered as low.

**Table 38. Summary of sediment effects data available for endrin.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 75 | TRINITY RIVER, TEXAS | |
| | - significant mortality to *D. magna* | 18.3 ± 2.0 |
| | - low mortality to *D. magna* | 3.8 ± 3.1 |
| 64 | GEORGETOWN OCEAN DREDGED MATERIAL DISPOSAL SITE, SOUTH CAROLINA | |
| | - no effects upon benthos species richness or abundance | <50.0 |
| **Equilibrium Partitioning** | | |
| 15 | Sediment-water partitioning coefficient/marine chronic criteria (1% TOC) | 174.0 |
| | Sediment-biota partitioning coefficient/marine chronic criteria (1% TOC) | 321.0 |
| 13 | 95 percentile chronic marine permissable (sediment/water partition coefficient) | 0.02 |
| | 99 percentile chronic marine permissable (sediment/water partition coefficient) | 0.01 |
| 6 | EPA interim marine sediment quality criteria 1% TOC | 2.15 |
| 6 | EPA interim freshwater sediment quality criteria 1% TOC | 10.4 |
| 35 | Lethal threshold in freshwater based on Koc coefficients | 15.4 |
| **Spiked-Sediment Bioassays** | | |
| 34 | LC50 for *N. virens* | 28000.0 |
| 35 | LC50 for *C. septemspinosa* | 47.0 |
| 89 | LC50 for *H. azteca* @ 3% TOC | 4400 |
| | LC50 for *H. azteca* @ 6.1% TOC | 4800 |
| | LC50 for *H. azteca* @ 11.2% TOC | 6000 |

| Reference | Background Approach | Concentrations (ppb) |
|---|---|---|
| 12 | USGS alert levels to flag 15-20% of samples analyzed | 20.0 |

**References:**


6. EPA, 1988
12. Pavlou and Weston, 1983
13. Pavlou *et al.*, 1987
15. JRB Associates, 1984
34. McLeese *et al.*, 1982
35. McLeese and Metcalfe, 1980
64. Van Dolah *et al.*, 1984
75. Qasim et al., 1980
89. Nebeker *et al.*, 1989

**Table 39. Effects range-low and effects range-median values for endrin and 13 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 0.01 | EP 99 percentile chronic marine |
| **0.02** | **ER-L** |
| 0.02 | EP 95 percentile chronic marine |
| 2.15 | EP interim marine criteria @ 1% TOC |
| 10.4 | EP interim freshwater criteria @ 1% TOC |
| 15.4 | EP freshwater lethal threshold |
| 18.3 | Trinity River, Texas, bioassay COA |
| **45.0** | **ER-M** |
| 47.0 | SSB LC50 *C. septemspinosa* |
| 174.0 | EP chronic sediment/water marine @ 1% TOC |
| 321.0 | EP chronic sediment/biota marine @ 1% TOC |
| 4400 | SSB LC50 with *H. azteca* @ 3% TOC |
| 4800 | SSB LC50 with *H. azteca* @ 6.1% TOC |
| 6000 | SSB LC50 with *H. azteca* @ 11.2% TOC |
| 28000.0 | SSB LC50 with *N. virens* |

### Mirex

Only matching bioassay and chemical data from San Francisco Bay were found for mirex. They indicated very small differences in concentrations between highly and/or significantly toxic samples versus least and/or non-toxic samples. Therefore, ER-L and ER-M values could not be determined.

## Polynuclear Aromatic Hydrocarbons:

### Acenaphthene

Puget Sound AET, several EP-derived concentrations, data from bioassays of dilution series of Black Rock Harbor and Eagle Harbor sediments, and co-occurrence concentrations are available for acenaphthene (Table 40). The co-occurrence data are from Commencement Bay, Eagle Harbor (an area with documented high PAH concentrations), San Francisco Bay, and southern California. The bioassay data from San Francisco Bay indicated very little concordance with acenaphthene concentrations or a small gradient in concentrations, so neither the co-occurrence analysis data nor the AET concentrations were used in the determination of ER-L and ER-M values (Table B-19). Also, the southern California bioassay data showed no concordance with the acenaphthene concentrations. Because of a small gradient in the acenapthene concentrations in Black Rock Harbor sediments, those data also were not used further. The samples from both Commencement Bay and Eagle Harbor that were moderately toxic to amphipods indicated a small elevation in acenaphthene concentrations over those that were least toxic; thus the data were not used for ER-L and ER-M determinations.

The lower 10 percentile of the remaining data suggest an ER-L of about 150 ppb (Table 41). This value is supported by observations of moderate toxicity of Commencement Bay sediments to oyster larvae (mean 118.5 ppb) and the predicted LC50 in amphipod bioassays of a dilution series of Eagle Harbor sediments (150 ppb). Except for the observations of low and moderate toxicity to amphipods in Eagle Harbor sediments, effects were usually observed in association with acenaphthene concentrations of 150 ppb or greater. The data suggest an ER-M of about 650 ppb, a value supported by a Puget Sound AET for amphipod bioassays (630 ppb) and observations of highly toxic Commencement Bay sediments tested with amphipods (mean 654 ppb). The co-occurrence values from bioassays of Eagle Harbor and Commencement Bay sediments had very high standard deviations about the means, indicative of the very high variability in these data. All of the concentrations predicted by the EP method are in the high end of the range.

The degree of confidence in the ER-L and ER-M values should be considered as low. While an overall apparent effects threshold occurs at the ER-L concentration, there is relatively poor clustering of the data, the data are mostly from parts of Puget Sound, there are no single-chemical SSB data, and the concentrations derived from the EP methods are not consistent with those determined in tests of field-collected sediments.

**Table 40. Summary of sediment effects data available for acenaphthene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 630 |
| | - oyster larvae (*C. gigas*) bioassay | 500 |
| | - benthic community composition | 500 |
| | - Microtox™ bioassay | 500 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2000 |
| | - oyster larvae (*C. gigas*) bioassay | 500 |
| | - benthic community composition | 730 |
| | - Microtox™ bioassay | 500 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 63 |
| | - maximum level criterion | 630 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 9 |
| | - *R. abronius* amphipod bioassay | 56 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 7.6 ± 21.6 |
| | - moderately toxic (33.8 ± 4.7% mortality to *R. abronius* | 5.4 ± 12.1 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 9.8 ± 15.9 |
| | - significantly toxic (42.9 ≠ 19.2% mortality) to *R. abronius* | 5.9 ± 16.8 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 11.8 ± 16.8 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 48 ± 18.4 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 3.3 ± 5.9 |
| | - least toxic (23.3 ± 7.3% abnormal) to vivalve larvae | 1.8 ± 4.0 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 9.4 ± 17.9 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 3.0 ± 5.2 |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 654 ± 1049 |
| | - moderately toxic (5.2 ± 1.1 dead/20 to *R. abronius* | 127 ± 117 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 86 ± 97 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 306 ± 604 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 119 ± 105 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 57 ± 70 |

Table 40. Acenaphthene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 39557 ± 48678 |
| | - moderately toxic (3.2 ± 1.8 dead/20) to *R. abronius* | 6522 ± 8915 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 5599 ± 24392 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 150 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 3.9 ± 1.6✔ |
| | - not toxic (23.2% mortality) to *G. japonica* | 7 ± 11.8✔ |
| 58 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - significant toxicity to *A. abdita* in 10-d bioassay | 30 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 66000 |
| 6 | EPA interim freshwater sediment quality criteria based upon EP (@ 1% TOC) | 7330 |
| 25 | Sediment safe level based upon sediment/water partitioning coefficients and acute water quality criteria (@ 1% TOC) | 23000 |
| | Sediment safe level based upon sediment/water partitioning coefficients and chronic water quality criteria (@ 1% TOC) | 16500 |

| References | Background Approaches | Concentrations (ppb) |
|---|---|---|
| 43 | New England interim high contamination level for dredge material | 500 |
| 12 | USGS alert levels to flag 15 to 20% of samples analyzed | 20 |
| 20 | EPA/ACOE Puget Sound interim criteria (central basin background) | 5 |
| 23 | Rotterdam Harbor sediment quality classifications | |
| | - Class 1 (slightly contaminated) | <200 |
| | - Class 2 (moderately contaminated) | 200-2000 |
| | - Class 3 (contaminated) | 2000-10000 |
| | - Class 4 (heavily contaminated) | >10000 |


**References:**

1. Bellar *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
6. EPA, 1988
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
25. Pavlou, 1987
56. Anderson *et al.*, 1988
58. Rogerson *et al.*, 1985
80. Tetra Tech, 1985
85. CH2M Hill, 1989

* Various, please see text

**Table 41. Effects range-low and effects range-median values for acenaphthene and 15 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 119 | Commencement Bay, Washington bioassay COA |
| **150** | **ER-L** |
| 150 | Eagle Harbor, Washington bioassay COA |
| 306 | Commencement Bay, Washington bioassay COA |
| 500 | Puget Sound, Washington AET - oyster |
| 500 | Puget Sound, Washington AET - benthic |
| 500 | Puget Sound, Washington AET - Microtox™ |
| 630 | Puget Sound, Washington AET - amphipod |
| **650** | **ER-M** |
| 654 | Commencement Bay ,Washington bioassay COA |
| 730 | Puget Sound, Washington AET - benthic |
| 2000 | Puget Sound, Washington AET - amphipod |
| 7330 | EP freshwater interim criteria @ 1% TOC |
| 16500 | EP chronic marine threshold @ 1% TOC |
| 23000 | EP acute marine threshold @ 1% TOC |
| 39557 | Eagle Harbor, Washington bioassay COA |
| 66000 | EP chronic marine threshold @ 4% TOC |

### Anthracene

Data available for anthracene are from studies involving Puget Sound AET; bioassays of sediments from Commencement Bay, Eagle Harbor, San Francisco Bay, Lake Union, southern California, and Elizabeth River; national SLCs; and several EP-derived concentrations (Table 42). San Francisco Bay sediments that were moderately toxic to amphipods indicated no concordance with anthracene concentrations. Also, San Francisco Bay sediments that were significantly toxic to amphipods had anthracene concentrations similar to those that were not toxic. Commencement Bay sediments that were moderately toxic to amphipods had anthracene concentrations similar to those that were least toxic. Eagle Harbor sediments moderately toxic to amphipods indicated little concordance with anthracene concentrations. These data were not used in the determination of ER-L and ER-M values (Table B-20).

Effects were associated with mean anthracene concentrations as low as 24 ppb (Table 43) in bioassays of San Francisco Bay sediments. However, since 34 out of the 39 samples tested there were significantly toxic, this concentration may not be of much significance. The lower 10 percentile of the data indicate an ER-L of about 85 ppb, a value supported by the predicted LC50 for anthracene from bioassays of a dilution series of Eagle Harbor sediments (70 ppb) and the anthracene concentrations (mean 85.3 ppb) in San Francisco Bay sediments that were moderately toxic to bivalve larvae. The 50 percentile value in the data is equivalent to about 960 ppb and is supported by two Puget Sound AETs (both 960 ppb). With the exception of bioassay data from Eagle Harbor, there appears to be an overall threshold in the effects data at about 300 ppb. Effects are almost always observed in association with anthracene concentrations exceeding 300 ppb (Table B-20).

The degree of confidence in the ER-L and ER-M values for anthracene should be considered as relatively low and moderate, respectively. The ER-L value is not supported by clustered, consistent data from multiple approaches. The ER-M is supported by a cluster of toxicity and AET concentrations, but these data are derived from only two regions. There is some evidence of an overall apparent effects threshold for anthracene at about 300 ppb in sediments, a concentration that lies within the ER-L/ER-M range.

Table 42. Summary of sediment effects data available for anthracene.

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 1900 |
| | - oyster larvae (*C. gigas*) bioassay | 960 |
| | - benthic community composition | 1300 |
| | - Microtox™ bioassay | 960 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 13000 |
| | - oyster larvae (*C. gigas*) bioassay | 960 |
| | - benthic community composition | 4400 |
| | - Microtox™ bioassay | 960 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 130 |
| | - maximum level criterion | 1300 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 24 |
| | - *R. abronius* amphipod bioassay | 1100 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 476 ± 549 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 265 ± 228 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 227 ± 198 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 363 ± 353 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 282 ± 207 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 148 ± 148 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 7597 ± 7264 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 1177 ± 1582 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 1490 ± 5389 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 70 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 120000 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 237 ± 455 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 63 ± 72 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 110 ± 257 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 119 ± 277 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 120 ± 269 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 923 ± 558 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 85 ± 119 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 15 ± 7.5 |

Table 42. Anthracene (continued).

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 184 ± 347 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 34 ± 41 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 225 ± 131✔ |
| | - not toxic (23.2% mortality) to *G. japonica* | 36 ± 52✔ |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 264000 |
| | - LC50 (24-hr) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 147840 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 6600 |
| **National Screening Level Concentrations** | | |
| 14 | Marine sediments @ 1% TOC | 163 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 44000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 190 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 380 |

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989

* Various, please see text

**Table 43. Effects range-low and effects range-median values for anthracene and 26 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 24 | San Francisco Bay, California AET |
| 70 | Eagle Harbor, Washington bioassay COA |
| **85** | **ER-L** |
| 85 | San Francisco Bay ,California bioassay COA |
| 163 | Marine SLC @ 1% TOC |
| 184 | San Francisco Bay, California bioassay COA |
| 190 | 99 percentile EP chronic marine @ 1% TOC |

**Table 43. (continued)**

| Concentrations (ppb) | End Point |
|---|---|
| 225 | Southern California bioassay COA |
| 237 | San Francisco Bay, California bioassay COA |
| 282 | Commencement Bay, Washington bioassay COA |
| 363 | Commencement Bay, Washington bioassay COA |
| 380 | 95 percentile EP chronic marine @ 1% TOC |
| 476 | Commencement Bay, Washington bioassay COA |
| 923 | San Francisco Bay, California bioassay COA |
| 960 | Puget Sound, Washington AET - oyster |
| **960** | **ER-M** |
| 960 | Puget Sound, Washington AET - Microtox™ |
| 1100 | San Francisco Bay, California AET |
| 1300 | Puget Sound, Washington AET - benthic |
| 1900 | Puget Sound, Washington AET - amphipod |
| 4400 | Puget Sound, Washington AET - benthic |
| 6600 | Elizabeth River, Virginia bioassay COA |
| 7597 | Eagle Harbor, Washington bioassay COA |
| 13000 | Puget Sound, Washington AET - amphipod |
| 44000 | EP chronic marine @ 4% TOC |
| 120000 | Lake Union, Washington toxicity COA |
| 147840 | Elizabeth River, Virginia bioassay COA |
| 264000 | Elizabeth River, Virginia bioassay COA |

### Benzo(a)anthracene

Data available for this aromatic hydrocarbon include those from Puget Sound AET; San Francisco Bay AET and bioassay data; bioassay data from Commencement Bay, Eagle Harbor, Lake Union, Columbia River, southern California, and Elizabeth River; national SLCs; SSBs performed with *R. abronius* exposed to mixtures of hydrocarbons; and many EP-derived values (Table 44). There were small gradients in benzo(a)anthracene concentrations between San Francisco Bay sediments that were least toxic and moderately toxic to amphipods, between San Francisco Bay sediments that were not toxic and significantly toxic to amphipods, and between Commencement Bay sediments that were least toxic and moderately toxic to amphipods (Table B-21). In bioassays of lower Columbia River sediments, no toxicity to the amphipod *H. azteca* was observed in sediments that had up to 2200 ppb benzo(a)anthracene. These data were not used in the determination of ER-L and ER-M values.

Effects are suggested in association with benzo(a)anthracene concentrations as low as 60 to 80 ppb in sediments (Table 45). The lower 10 percentile value of the data is equivalent to about 230 ppb, the ER-L value. This value is supported by San Francisco Bay bioassay data (mean 232 ppb). The 50 percentile ER-M value in the data is equivalent to 1600 ppb; a concentration supported by a San Francisco Bay AET (1100 ppb), three Puget Sound AET concentrations (1300, 1600, 1600 ppb), and a threshold predicted by EP methods (1600 ppb). With the exception of Columbia River and Eagle Harbor bioassay data, effects were usually observed in association with concentrations above about 550 ppb (Table B-21). Severe acute toxicity was observed or predicted with concentrations of 10 ppm or greater (Table 45).

The degree of confidence in the ER-L value should be considered as moderate, since that value is not strongly supported by a convergence or cluster of data. However, the ER-M value is supported by data from at least two geographic areas and from the predictive EP approach, and there are few contradictory data at concentrations exceeding the ER-M. Also, the apparent effects threshold lies within the ER-L/ER-M range. Therefore, the degree of confidence in the ER-M value should be considered as moderate.

**Table 44. Summary of sediment effects data available for benzo(a)anthracene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 1600 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 4500 |
| | - Microtox™ bioassay | 1300 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 5100 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 5100 |
| | - Microtox™ bioassay | 1300 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 450 |
| | - maximum level criterion | 4500 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 60 |
| | - *R. abronius* amphipod bioassay | 1100 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 931 ± 1323 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 520 ± 523 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 476 ± 437 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 801 ± 866 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 549 ± 384 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 235 ± 247 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 11088 ± 8941 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 7370 ± 9984 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 2496 ± 4157 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 80 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 170000 |
| 52 | COLUMBIA RIVER, WASHINGTON/OREGON | |
| | - not toxic (0-13% mortality) to *H. azteca* | 2200 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 300 ± 398 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 187 ± 156 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 168 ± 324 |

**Table 44. Benzo(a)anthracene (continued).**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 236 ± 313 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 187 ± 359 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 919 ± 433 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 122 ± 126 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 56 ± 26 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 232 ± 337 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 41 ± 20 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 310 ± 180 |
| | - not toxic (23.2% mortality) to *G. japonica* | 60 ± 129 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 350000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 196000 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 8750 |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 261 |
| 14 | Marine sediments @ 1% TOC | 261 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 220000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 220000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 1600 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 21000 |
| 6 | EPA interim mean freshwater sediment quality criteria based upon EP @ 1% TOC | 13200 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute quality criteria @ 1% TOC | 55000 |
| **Spiked-Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 10000 |

**Table 44. Benzo(a)anthracene (continued)**

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
6. EPA, 1988
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
52. Johnson and Norton,, 1988
56. Anderson *et al.*, 1988
65. Plesha *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989
*-Various, please see text

**Table 45. Effects range-low and effects range-median values for benzo(a)anthracene and 30 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 60 | San Francisco Bay, California AET |
| 80 | Eagle Harbor, Washington bioassay COA |
| 122 | San Francisco Bay, California bioassay |
| **230** | **ER-L** |
| 232 | San Francisco Bay, California bioassay COA |
| 261 | Marine SLC |
| 300 | San Francisco Bay, California bioassay COA |
| 310 | Southern California bioassay COA |
| 549 | Commencement Bay,Washington bioassay COA |
| 801 | Commencement Bay, Washington bioassay COA |
| 919 | San Francisco Bay, California bioassay COA |
| 931 | Commencement Bay, Washington bioassay COA |
| 1100 | San Francisco Bay, California AET |
| 1300 | Puget Sound, Washington AET - Microtox™ |
| 1600 | Puget Sound, Washington AET - amphipod |
| **1600** | **ER-M** |
| 1600 | Puget Sound, Washington AET - oyster |
| 1600 | 99 percentile EP chronic marine @ 1% TOC |
| 4500 | Puget Sound, Washington AET - benthic |
| 5100 | Puget Sound,Washington AET - amphipod |
| 5100 | Puget Sound,Washington AET - benthic |
| 7370 | Eagle Harbor, Washington bioassay COA |
| 8750 | Elizabeth River, Virginia bioassay COA |
| 10000 | SSB with R. *abronius*: mixtures |
| 11088 | Eagle Harbor, Washington bioassay COA |
| 13200 | EP freshwater interim criteria @ 1% TOC |
| 21000 | 95 percentile EP chronic marine @ 1% TOC |
| 55000 | EP acute marine threshold @ 1% TOC |
| 170000 | Lake Union, Washington toxicity COA |
| 196000 | Elizabeth River, Virginia bioassay COA |
| 220000 | EP acute marine threshold @ 4% TOC |
| 350000 | Elizabeth River, Virginia bioassay COA |

**Benzo(a)pyrene**

Data are available for benzo(a)pyrene from Puget Sound AET, San Francisco Bay AET and bioassay data; bioassay data from Commencement Bay, Eagle Harbor, Lake Union, southern California, and Elizabeth River; national SLCs for marine sediments; concentrations predicted by EP methods; and SSBs performed with *R. abronius* exposed to a mixture of hydrocarbons (Table 46). Small gradients in benzo(a)pyrene concentrations were observed in bioassays of a dilution series of Eagle Harbor sediments, in San Francisco Bay sediments that were highly and moderately toxic to amphipods versus those that were least toxic, and in San Francisco Bay sediments that were significantly toxic versus those that were not toxic to amphipods. Those data were not used to determine the ER-L and ER-M values (Table B-22). The data from Eagle Harbor sediments that were highly toxic to amphipods also were not used, since they did not indicate concordance with benzo(a)pyrene concentrations.

Effects were observed in association with benzo(a)pyrene concentrations as low as 396 ppb (the national SLC for marine sediments) (Table 47). The lower 10 percentile value of the available data is equivalent to about 400 ppb, an ER-L value supported by marine SLCs of 396 and 397 and observations of significantly toxic San Francisco Bay sediments tested with bivalve larvae (mean of 404 ppb). With the exception of Eagle Harbor bioassay data, effects were usually observed in association with benzo(a)pyrene concentrations of roughly 700 ppb or more (Table B-22). The ER-M suggested by the data is about 2500 ppb, a value supported by a Puget Sound AET (2400 ppb) and the LC50 derived from bioassays of a dilution series of Elizabeth River sediments tested with spot (2462 ppb).

The degree of confidence in the ER-L and ER-M values should be considered as moderate. Although data are available from several areas and several approaches, and these values are supported by some convergence or clustering of the data, the clusters of concentrations cover a relatively wide range. The overall apparent effects threshold (about 700 ppb) lies within the ER-L/ER-M range. With very little conflicting evidence, it appears that effects are almost always associated with concentrations of about 700 ppb or more.

**Table 46. Summary of sediment effects data available for benzo(a)pyrene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Thresholds** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2400 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 6800 |
| | - Microtox™ bioassay | 1600 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 3000 |
| | - oyster larvae (*C. gigas*) bioassay | 1600 |
| | - benthic community composition | 3600 |
| | - Microtox™ bioassay | 1600 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 680 |
| | - maximum level criterion | 6800 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >1800 |
| | - *R. abronius* amphipod bioassay | >1300✓ |

Table 46. **Benzo(a)pyrene (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 1192 ± 1643 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 890 ± 1322 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 596 ± 593 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 1261 ± 1620 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 684 ± 464 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 329 ± 385 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 3485 ± 2475 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 5335 ± 6488 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 1959 ± 1993 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 10 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 220000 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 486 ± 484 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 432 ± 344 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 400 ± 447 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 429 ± 382 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 423 ± 465 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 1091 ± 338 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 404 ± 428 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 129 ± 61 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 465 ± 471 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 210 ± 237 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 509 ± 354 |
| | - not toxic (23.2% mortality) to *G. japonica* | 63 ± 96 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 98500 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 55160 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 2462 |
| **National Screening Level Concentrations** | | |
| 5 | marine sediments @ 1% TOC | 396 |
| 14 | marine sediments @ 1% TOC | 397 |

Table 46. Benzo(a)pyrene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 1800000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 1800000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 18000 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 45000 |
| 6 | EPA interim mean freshwater sediment quality criteria based upon EP @ 1% TOC | 10630 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria | 450000 |
| **Spiked Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 4100 ± 600 |

| Reference | Background Approach | Concentrations (ppb organic carbon) |
|---|---|---|
| 23 | Rotterdam Harbor Sediment Quality Classifications | |
| | - Class 1 (slightly contaminated) | <0.3 OC |
| | - Class 2 (moderately contaminated) | 0.3-0.6 OC |
| | - Class 3 (contaminated) | 0.6-2 OC |
| | - Class 4 (heavily contaminated) | >2 OC |


**References:**

1. Beller et al., 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
6. EPA, 1988
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
23. Jensen, 1987
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
65. Plesha *et al.*, 1988
80. Tetra Tech, 1985
85. CH2M Hill, 1989
* Various, please see text

**Table 47. Effects range-low and effects range-median values for benzo(a)pyrene and 27 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 396 | Marine SLC |
| 397 | Marine SLC |
| **400** | **ER-L** |
| 404 | San Francisco Bay, California bioassay COA |
| 465 | San Francisco Bay, California bioassay COA |
| 509 | Southern California bioassay COA |
| 684 | Commencement Bay, Washington bioassay COA |
| 890 | Commencement Bay, Washington bioassay COA |
| 1091 | San Francisco Bay, California bioassay COA |
| 1192 | Commencement Bay, Washington bioassay COA |
| 1261 | Commencement Bay,Washington bioassay COA |
| 1600 | Puget Sound, Washington AET - bivalve |
| 1600 | Puget Sound, Washington AET - Microtox™ |
| 2400 | Puget Sound, Washington AET - amphipod |
| 2462 | Elizabeth River, Virginia bioassay COA |
| **2500** | **ER-M** |
| 3000 | Puget Sound, Washington AET - amphipod |
| 3600 | Puget Sound, Washington AET - benthic |
| 4100 | SSB with *R. abronius*: mixtures |
| 5335 | Eagle Harbor, Washington bioassay COA |
| 6800 | Puget Sound, Washington AET - benthic |
| 10630 | EP interim freshwater criteria @ 1% TOC |
| 18000 | 99 percentile EP chronic marine @ 1% TOC |
| 45000 | 95 percentile EP chronic marine @ 1% TOC |
| 55160 | Elizabeth River, Virginia bioassay COA |
| 98500 | Elizabeth River, Virginia bioassay COA |
| 220000 | Lake Union, Washington bioassay COA |
| 450000 | EP acute sediment safe level |
| 1800000 | EP chronic marine @ 4% TOC |

## Benzo(e)pyrene

The data available for benzo(e)pyrene are restricted to bioassays of sediments from San Francisco Bay, southern California, and Elizabeth River (Table 48). The amount and variety of data are insufficient to warrant the determination of ER-L and ER-M values. In San Francisco Bay, observations of effects were associated with mean concentrations of benzo(e)pyrene ranging from 194 ± 228 ppb to 624 ± 234 ppb. In southern California the mean concentration associated with high toxicity was 434 ± 318, within the range observed in San Francisco Bay. Toxicity to *L. xanthurus* was recorded at higher concentrations in bioassays of Elizabeth River sediments. Additional data are needed to determine a preponderance of evidence of the benzo(e)pyrene concentrations associated with adverse biological effects.

**Table 48. Summary of sediment effects data available for benzo(e)pyrene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 92 |
| | - *R. abronius* amphipod bioassay | 690 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 366 ± 346 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 166 ± 130 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 153 ± 184 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 268 ± 276 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 157 ± 206 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 625 ± 234 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 194 ± 228 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 92 ± 44 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 250 ± 263 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 65 ± 27 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 434 ± 318 |
| | - not toxic (23.2% mortality) to *G. japonica* | 69 ± 106 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 78100 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 43736 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 1952 |

**References:**

47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
* Various, please see text.

**Biphenyl**

Data for biphenyl are available from bioassays of sediments from San Francisco Bay, southern California, Black Rock Harbor, and the Elizabeth River (Table 49). These data are insufficient to determine the ER-L and ER-M values in sediments associated with effects. Mean concentrations ranging from 6.6 ± 9.0 to 26.3 ± 9.0 ppb were associated with measures of toxicity in San Francisco Bay sediments. In southern California sediments, significant toxicity was associated with a mean concentration of 443 ppb. Elizabeth River sediments that were highly toxic to *L. xanthurus* had very high biphenyl concentrations.

**Table 49. Summary of sediment effects data available for biphenyl.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 7 |
| | - *R. abronius* amphipod bioassay | 27 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 10 ± 13 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 7 ± 9 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 6 ± 8 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 7 ± 11 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 7 ± 8 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 26 ± 9 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 6 ± 6 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 1 ± 3 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 8 ± 10 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 2 ± 4 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 443 ± 1080✓ |
| | - not toxic (23.2% mortality) to *G. japonica* | 6.2 ± 8.4✓ |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 85000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 47600 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 2125 |
| 58 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - significant toxicity to *A. abdita* in 10-d bioassay | 13.5 |

**References:**

47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
58. Rogerson *et al.*,
* Various, please see text

## Chrysene

Data for chrysene are available from studies in which Puget Sound AETs were calculated; bioassays of sediments from Commencement Bay, Eagle Harbor, Lake Union, Columbia River, San Francisco Bay, southern California, and Elizabeth River were performed; national SLCs were determined; and various EP-derived thresholds were calculated (Table 50). Small gradients in chrysene concentrations were observed in bioassays of a dilution series of Eagle Harbor sediments and in amphipod bioassays of San Francisco Bay sediments. Also, a small gradient in chrysene concentrations was observed between Commencement Bay sediments that were moderately versus least toxic to amphipods. No toxicity was observed in Columbia

River sediments that had up to 4100 ppb chrysene. These data were not used to determine ER-L and ER-M values (Table B-23).

The lower 10 percentile value of the remaining data suggest an ER-L concentration of about 400 ppb (384 rounded to 400 ppb), a value supported by a marine SLC of 384 ppb (Table 51). Some measures of effects were observed in association with chrysene concentrations as low as a mean of 368 ppb. With the exceptions of Eagle Harbor and Columbia River bioassay data, effects almost always were observed or predicted at concentrations of about 900 ppb or more. The 50 percentile value of the data suggest an ER-M of about 2800 ppb, a value supported by two Puget Sound AETs (both 2800 ppb).

The degree of confidence in the ER-L and ER-M values should be considered as moderate. Data are available from a variety of geographic areas and approaches, but are not tightly clustered around the ER-L and ER-M values. There is an overall apparent effects threshold at about 900 ppb, supported by a variety of observed and predicted concentrations associated with effects and within the ER-L/ER-M range.

**Table 50. Summary of sediment effects data available for chrysene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2800 |
| | - oyster larvae (*C. gigas*) bioassay | 2800 |
| | - benthic community composition | 6700 |
| | - Microtox™ bioassay | 1400 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 9200 |
| | - oyster larvae (*C. gigas*) bioassay | 2800 |
| | - benthic community composition | 9200 |
| | - Microtox™ bioassay | 1400 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 670 |
| | - maximum level criterion | 6700 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 1700 |
| | - *R. abronius* amphipod bioassay | 2100 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 1363 ± 1970 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 821 ± 732 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 748 ± 773 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 1218 ± 1286 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 902 ± 691 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 358 ± 365 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 10574 ± 7337 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 9203 ± 10972 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 3165 ± 4535 |

Table 50. Chrysene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 80 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 170000 |
| 52 | COLUMBIA RIVER, WASHINGTON/OREGON | |
| | not toxic (0-13% mortality) to H. azteca | 4100 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 517 ± 729 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 413 ± 385 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 378 ± 549 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 423 ± 512 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 405 ± 571 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 1679 ± 847 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 368 ± 466 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 82 ± 37 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 500 ± 671 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 198 ± 276 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 524 ± 284 |
| | - not toxic (23.2% mortality) to *G. japonica* | 127 ± 226 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 317000 |
| | - LC50 (24-hr) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 177520 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 7925✓ |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 384 |
| 14 | Marine sediments @ 1% TOC | 384 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 460000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 460000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 1200 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 4400 |

Table 50. Chrysene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria | 115000 |

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
25. Pavlou, 1987
29. Yake *et al.*, 1986
4.7 Roberts *et al.*, 1989
52. Johnson and Norton, 1988
56. Anderson *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989
* Various, please see text

**Table 51. Effects range-low and effects range-median values for chrysene and 27 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 80 | Predicted Eagle Harbor LC50--amphipod COA |
| 368 | San Francisco Bay, California bioassay COA |
| 384 | Marine SLC |
| **400** | **ER-L** |
| 500 | San Francisco Bay, California bioassay COA |
| 524 | Southern California bioassay COA |
| 902 | Commencement Bay, Washington bioassay COA |
| 1200 | 99 percentile EP chronic marine @ 1% TOC |
| 1218 | Commencement Bay, Washington bioassay COA |
| 1363 | Commencement Bay, Washington bioassay COA |
| 1400 | Puget Sound, Washington AET - Microtox™ |
| 1679 | San Francisco Bay, California bioassay COA |
| 1700 | San Francisco Bay, California bioassay COA |
| 2100 | San Francisco Bay, California bioassay COA |
| 2800 | Puget Sound, Washington AET - bivalve |
| **2800** | **ER-M** |
| 2800 | Puget Sound, Washington AET- amphipod |
| 4400 | 95 percentile EP chronic marine @ 1% TOC |
| 6700 | Puget Sound, Washington AET - benthic |
| 7925✓ | Elizabeth River, Virginia bioassay |
| 9200 | Puget Sound, Washington AET - amphipod |
| 9200 | Puget Sound, Washington AET - benthic |
| 9203 | Eagle Harbor, Washington bioassay COA |
| 10574 | Eagle Harbor, Washington bioassay COA |
| 115000 | EP acute sediment safe level |
| 170000 | Lake Union, Washington bioassay COA |
| 177520 | Elizabeth River, Virginia bioassay COA |
| 317000 | Elizabeth River, Virginia bioassay COA |
| 460000 | EP chronic marine threshold @ 4% TOC |

**Dibenz(a,h)anthracene**

Data are available for this aromatic hydrocarbon from determinations of Puget Sound and San Francisco Bay AETs, EP-derived thresholds, and evaluations of bioassay data from Commencement Bay, Eagle Harbor, and southern California (Table 52). There was either a small gradient or no concordance between dibenz(a,h)anthracene concentrations and toxicity to amphipods exposed to San Francisco Bay sediments. Commencement Bay and Eagle Harbor sediments that were highly toxic to amphipods had lower dibenz(a,h)anthracene concentrations than those respective samples that were moderately toxic. Therefore, these data were not considered in the determination of ER-L and ER-M values (Table B-24).

Effects in sediments were observed in association with mean dibenz(a,h)anthracene concentrations as low as 42 ± 46 ppb (Table 53). The lower 10 percentile of the data is equivalent to an ER-L value of about 60 ppb, a value supported by bioassay data from San Francisco Bay (mean 63 ± 80 ppb) and from southern California (mean 66 ± 46 ppb). The 50 percentile of the data suggest an ER-M of about 260 ppb, a value supported by three Puget Sound AETs (230, 230, 260 ppb), a San Francisco Bay AET (260 ppb), and Commencement Bay sediments that were highly toxic to oyster larvae (mean 263 ± 413 ppb). Except for amphipod bioassay data from Eagle Harbor and a San Francisco Bay AET for amphipod bioassays, effects were usually observed in association with concentrations of about 100 ppb or more (Table B-24). The threshold concentrations predicted by EP methods were considerably higher than those observed with measures of effects in field-collected samples.

The degree of confidence in the ER-L and ER-M values for dibenz(a,h)anthracene should be considered as moderate. A relatively small amount of data exist with which to relate chemical concentrations to measures of effects; there are no SSB data; and there was relatively poor concordance or small gradients in concentrations among samples that were toxic and those that were nontoxic. However, there was a degree of convergence among the data and there appears to be an effects threshold within the ER-L/ER-M range at about 100 ppb with few contradictory data.

**Table 52. Summary of sediment effects data available for dibenz(a,h)anthracene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 260 |
| | - oyster larvae (*C. gigas*) bioassay | 230 |
| | - benthic community composition | 1200 |
| | - Microtox™ bioassay | 230 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 540 |
| | - oyster larvae (*C. gigas*) bioassay | 230 |
| | - benthic community composition | 970 |
| | - Microtox™ bioassay | 230 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 120 |
| | - maximum level criterion | 1200 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 260 |
| | - *R. abronius* amphipod bioassay | 300 |

**Table 52. Dibenz(a,h)anthracene (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 72 ± 139 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 183 ± 344 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 73 ± 71 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 263 ± 413 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 101 ± 58 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 55 ± 41 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 399 ± 252 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 797 ± 723 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 360 ± 298 |
| | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 80 ± 88 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 44 ± 32 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 57 ± 77 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 55 ± 58 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 62 ± 80 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 217 ± 88 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 42 ± 46 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 15 ± 15 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 63 ± 80 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 21 ± 22 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 66 ± 46 |
| | - not toxic (23.2% mortality) to *G. japonica* | 24 ± 36 |
| **Equilibrium Partitioning** | | |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 12000 |
| | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 35000 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria | 240000 |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
13. Pavlou *et al.*, 1987
20. U.S. ACOE, 1988
25. Pavlou, 1987
56. Anderson *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989
* Various, please see text

**Table 53. Effects range-low and effects range-median values for dibenz(a,h)-anthracene and 18 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 42 | San Francisco Bay, California bioassay COA |
| **60** | **ER-L** |
| 63 | San Francisco Bay, California bioassay COA |
| 66 | Southern California bioassay COA |
| 101 | Commencement Bay, Washington bioassay COA |
| 183 | Commencement Bay, Washington bioassay COA |
| 217 | San Francisco Bay, California bioassay COA |
| 230 | Puget Sound, Washington AET - oyster |
| 230 | Puget Sound, Washington AET - Microtox™ |
| 260 | Puget Sound, Washington AET - amphipod |
| **260** | **ER-M** |
| 260 | San Francisco Bay, California AET |
| 263 | Commencement Bay, Washington bioassay COA |
| 540 | Puget Sound, Washington AET - amphipod |
| 797 | Eagle Harbor, Washington bioassay COA |
| 970 | Puget Sound, Washington AET - benthic |
| 1200 | Puget Sound, Washington AET - benthic |
| 12000 | 99 percentile EP chronic marine @ 1% TOC |
| 35000 | 95 percentile EP chronic marine @ 1% TOC |
| 240000 | EP acute sediment safe level |

**2,6-Dimethylnaphthalene**

Very few data are available with which to relate the concentrations of 2,6-dimethylnaphthalene to measures of effects in sediments (Table 54). The San Francisco Bay bioassay data indicated relatively high toxicity to bivalve larvae in samples with 53 ± 29 ppb 2,6-dimethylnaphthalene; whereas in southern California, sediments with similar concentrations (56 ± 10 ppb) were not toxic to amphipods. Southern California sediments that were highly toxic to amphipods had concentrations (115 ± 278 ppb) that were similar to those in sediments spiked with hydrocarbon mixtures that were toxic to amphipods (150 ± 20 ppb). There are too few data to warrant determination of ER-L and ER-M values for this chemical.

**Table 54. Summary of sediment effects data available for 2,6-dimethylnaphthalene.**

| References | Biological Approach | Concentrations (ppb) |
|---|---|---|
| Co-Occurrence Analyses | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 18 ± 28 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 10 ± 15 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 10 ± 19 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 13 ± 22 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 12 ± 20 |

**Table 54. 2,6-dimethylnaphthalene (continued)**

| References | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 53 ± 29 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 9 ± 14 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 3 ± 4 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 14 ± 22 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 5 ± 5 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 115 ± 278 |
| | - not toxic (23.2% mortality) to *G. japonica* | 56 ± 110 |
| **Spiked Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 150 ± 20 |

**References:**

56. Anderson *et al.*, 1988
65. Plesha *et al.*, 1988
* Various, please see text

**Fluoranthene**

Data are available from studies in which Puget Sound AETs were determined; toxicity thresholds were predicted using EP methods; national SLCs were calculated; SSBs were performed; and bioassays were performed with sediments from Commencement Bay, Eagle Harbor, Lake Union, Columbia River, San Francisco Bay, southern California, Palos Verdes, and Elizabeth River (Table 55). Only three of the Palos Verdes samples were analyzed for fluoranthene concentrations. There was either a small gradient or no gradient in fluoranthene concentrations between San Francisco Bay sediments that were least, moderately, and most toxic to amphipods and significantly toxic versus not toxic to amphipods. There was no gradient in fluoranthene concentrations between Commencement Bay sediments that were least and moderately toxic to amphipods. Moderately toxic Eagle Harbor sediments had a lower mean fluoranthene concentration than those that were least toxic. These data were not used to determine ER-L and ER-M values (Table B-25).

Effects in sediments were observed in association with mean fluoranthene concentrations as low as 382 ± 617 ppb (Table 56). The lower 10 percentile value in the data suggest an ER-L of about 600 ppb, a concentration supported by the predicted LC50 derived from amphipod bioassays of a dilution series of Eagle Harbor sediments (600 ppb) and a marine SLC concentration assuming 1 percent TOC content (644 ppb). The 50 percentile value in the data suggest an ER-M of about 3600 ppb. This value is supported by a chronic marine EP-derived concentration (3100 ppb), an LC50 determined in a SSB (3300 ppb), an EP-derived chronic safe level (3600 ppb), a Puget Sound AET (3700 ppb), and a San Francisco Bay AET (3900 ppb). Effects were almost always observed in association with fluoranthene concentrations of about 1000 ppb (1 ppm) or more. There were two exceptions to this apparent threshold: bioassay data from the Columbia River, in which no effects were observed in sediments with up to 2100 ppb fluoranthene; and bioassay data from Eagle Harbor, where there was no toxicity in sediments with a mean concentration of 12080 ppb (Table B-25).

The degree of confidence in these ER-L and ER-M values should be considered as relatively high. Data are available from all of the major approaches; clusters of data support the values; and the overall apparent effects threshold lies within the range of ER-L and ER-M values.

**Table 55. Summary of sediment effects data available for fluoranthene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 3900 |
| | - oyster larvae (*C. gigas*) bioassay | 2500 |
| | - benthic community composition | 6300 |
| | - Microtox™ bioassay | 1700 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 30000 |
| | - oyster larvae (*C. gigas*) bioassay | 2500 |
| | - benthic community composition | 24000 |
| | - Microtox™ bioassay | 1700 |
| 20 | PSDDA GUIDELINES (based upon Puget Sound AET) | |
| | - screening level concentration | 630 |
| | - maximum level criterion | 6300 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 2000 |
| | - *R. abronius* amphipod bioassay | >3700 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 2360 ± 3330 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 925 ± 864 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 923 ± 865 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 1655 ± 2029 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 1046 ± 655 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 489 ± 492 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 71988 ± 95713 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 8895 ± 10337 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 12080 ± 51889 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon. sediment | 600 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 570000 |
| 52 | COLUMBIA RIVER, WASHINGTON/OREGON | |
| | - not toxic (0-13% mortality) to *H. azteca* | 2100 |

Table 55. Fluoranthene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 794 ± 1210 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 509 ± 481 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 539 ± 842 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 584 ± 789 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 572 ± 880 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 2737 ± 1617 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 451 ± 562 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 136 ± 107 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 682 ± 1043 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 382 ± 617 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 382 ± 241 |
| | - not toxic (23.2% mortality) to *G. japonica* | 153 ± 307 |
| 49 | PALOS VERDES SHELF, CALIFORNIA | |
| | - significantly toxic to *R. abronius* | 193 ± 143 |
| | - not toxic to *R. abronius* | 98 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 2,370,000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | *1,327,200◊* |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 59,250 |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 432 |
| 14 | Marine sediments @ 1% TOC | 644 |
| **Equilibrium Partitioning** | | |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 36,000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 1600 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 3100 |
| 6 | EPA interim mean freshwater sediment quality criteria based upon EP @ 1% TOC | 18,800 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria | 9000 |

**Table 55. Fluoranthene (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and chronic water quality criteria | 3600 |
| **Spiked Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 15000 |
| 18 | LC50 (10-d) for *R. abronius* | 4200 |
| 19 | LC50 for *R. abronius* @ 0.2% TOC | 3300 |
| | LC50 for *R. abronius* @ 0.3% TOC | 6200 |
| | LC50 for *R. abronius* @ 0.5% TOC | 10500 |

| Reference | Background Approach | Concentrations (ppb organic carbon) |
|---|---|---|
| 23 | Rotterdam Harbor Sediment Quality Classifications | |
| | - Class 1 (slightly contaminated) | <0.4 OC |
| | - Class 2 (moderately contaminated) | 0.4-1 OC |
| | - Class 3 (contaminated) | 1-4.5 OC |
| | - Class 4 (heavily contaminated) | >4.5 OC |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
5. Neff *et al.*, 1986
6. EPA, 1988
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
18 Swartz *et al.*, 1988
19. Swartz *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz et al., 1989
23. Jensen, 1987
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
49. Swartz *et al.*, 1985
52. Johnson and Norton, 1988
56. Anderson *et al.*, 1988
65. Plesha *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989
* Various, please see text


**Table 56. Effects range-low and effects range-median values for fluoranthene and 33 concentraations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 382 | Southern California bioassay COA |
| 432 | Marine SLC |
| 451 | San Francisco Bay, California bioassay COA |
| 600 | ER-L |
| 600 | Eagle Harbor, Washington bioassay COA |
| 644 | Marine SLC |
| 682 | San Francisco Bay, California bioassay COA |

Table 56. (continued)

| Concentrations (ppb) | End Point |
|---|---|
| 1046 | Commencement Bay, Washington bioassay COA |
| 1600 | 99 percentile EP chronic marine @ 1% TOC |
| 1655 | Commencement Bay, Washington bioassay COA |
| 1700 | Puget Sound, Washington AET - Microtox™ |
| 2000 | San Francisco Bay, California AET |
| 2360 | Commencement Bay, Washington bioassay COA |
| 2500 | Puget Sound, Washington AET - oyster |
| 2737 | San Francisco Bay, California bioassay COA |
| 3100 | 95 percentile EP chronic marine @ 1% TOC |
| 3300 | SSB LC50 for *R. abronius* @ 0.2% TOC |
| **3600** | **ER-M** |
| 3600 | EP chronic sediment safe level |
| 3900 | Puget Sound, Washington AET - amphipod |
| 4200 | SSB LC50 for *R. abronius* |
| 6200 | SSB LC50 for *R. abronius* @ 0.3% TOC |
| 6300 | Puget Sound, Washington AET - benthic |
| 9000 | EP acute sediment safe level |
| 10500 | SSB LC50 for *R. abronius* @ 0.5% TOC |
| 15000 | SSB with *R. abronius*: mixtures |
| 18800 | EP interim freshwater criteria @ 1% TOC |
| 24000 | Puget Sound, Washington AET - benthic |
| 30000 | Puget Sound, Washington AET - amphipod |
| 36000 | EP acute marine threshold @ 4% TOC |
| 59250 | Elizabeth River, Virginia bioassay COA |
| 71988 | Eagle Harbor, Washington bioassay COA |
| 570000 | Lake Union, Washington bioassay COA |
| 1,327,200✓ | Elizabeth River, Virginia bioassay COA |
| 2,370,000 | Elizabeth River, Virginia bioassay COA |

**Fluorene**

Data for fluorene are available from studies in which Puget Sound AETs were calculated; national SLCs were determined; EP-derived thresholds were predicted; effects upon fish were determined in SSBs; and bioassays were performed with sediments from Commencement Bay, Eagle Harbor, Lake Union, San Francisco Bay, southern California, Elizabeth River, and Black Rock Harbor (Table 57). Data from SSBs with winter flounder (*Pseudopleuronectes americanus*) are available. The winter flounder were exposed to Venezuelan crude mixed into sediments placed in a layer in large aquaria for 4 months (Payne *et al.*, 1988). There was little or no concordance between fluorene concentrations and toxicity to amphipods in San Francisco Bay. There was a small gradient in fluorene concentrations between Commencement Bay and Eagle Harbor sediments that were least and moderately toxic to amphipods. These data were not used to determine the ER-L and ER-M values (Table B-26).

Effects determined with bivalve larvae bioassays of San Francisco Bay sediments were observed in association with very low levels of fluorene (Table 58). These data influenced the determination of the ER-L value of 35 ppb. The 50 percentile value in the data suggest an ER-M of 640 ppb, a value supported by three Puget Sound AETs (all 540 ppb), a Puget Sound AET for benthic communities (640 ppb), and high toxicity in Commencement Bay (mean 707 ppb). Except for the Eagle Harbor amphipod bioassay data, there is an overall apparent effects threshold at about 350 ppb. However, this apparent threshold is highly influenced by only Puget Sound and Commencement Bay data and not by other supporting data.

The degree of confidence in the ER-L and ER-M values for fluorene should be considered as low and moderate, respectively. Although there are data from several approaches and matching effects and chemical data from many geographic areas, the data indicate poor convergence around the ER-L value. The ER-L is supported by data only from San Francisco Bay and the ER-M is supported by data only from Puget Sound (including Commencement Bay). Some of the concentrations derived from the EP and SSB approaches suggest that the threshold for effects occurs at much higher concentrations than indicated by the ER-L and ER-M values.

**Table 57. Summary of sediment effects data available for fluorene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 540 |
| | - oyster larvae (*C. gigas*) bioassay | 540 |
| | - benthic community composition | 640 |
| | - Microtox™ bioassay | 540 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 3600 |
| | - oyster larvae (*C. gigas*) bioassay | 540 |
| | - benthic community composition | 1000 |
| | - Microtox ™ bioassay | 540 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 64 |
| | - maximum level criterion | 640 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 11 |
| | - *R. abronius* amphipod bioassay | 210 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 707 ± 1341 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 147 ± 131 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 117 ± 113 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 353 ± 746 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 143 ± 119 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 75 ± 76 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 22811 ± 65559 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 187 ± 234 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 1017 ± 4679 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 210 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 40000 |

Table 57. Fluorene (continued)

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 33 ± 77 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 30 ± 21 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 39 ± 49 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 29 ± 48 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 43 ± 51 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 162 ± 105 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 19 ± 30 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 6 ± 5 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 35 ± 64 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 16 ± 23 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 11.3 ± 8.2✔ |
| | - not toxic (23.2% mortality) to *G. japonica* | 8 ± 16✔ |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 1250000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 700000 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 31250✔ |
| 58 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - significant toxicity to *A. abdita* in 10-d bioassay | 93 |
| **National Screening Level Concentrations** | | |
| 14 | Marine sediments @ 1% TOC | 101 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold(@ 4% TOC) | 28000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 59 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 160 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria @ 1% TOC | 7000 |
| **Spiked-Sediment Bioassays** | | |
| 59 | Liver somatic condition indices elevated in winter flounder | 220550 |
| | MFO induction in winter flounder liver significantly elevated | 176510 |
| | MFO induction in winter flounder kidney significantly elevated | 285290 |

**Table 57. Fluorene (continued)**

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz et al., 1989
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
58. Rogerson *et al.*, 1985
59. Payne *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989
* Various, please see text

**Table 58. Effects range-low and effects range-median values for fluorene and 28 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 11 | San Francisco Bay, California AET |
| 19 | San Francisco Bay, California bioassay COA |
| **35** | **ER-L** |
| 35 | San Francisco Bay, California bioassay COA |
| 59 | 99 percentile EP chronic marine @ 1% TOC |
| 93 | Black Rock Harbor, Connecticut bioassay COA |
| 101 | Marine SLC |
| 143 | Commencement Bay, Washington bioassay COA |
| 160 | 95 percentile EP chronic marine @ 1% TOC |
| 162 | San Francisco Bay, California bioassay COA |
| 210 | Eagle Harbor, Washington bioassay COA |
| 353 | Commencement Bay, Washington bioassay COA |
| 540 | Puget Sound, Washington AET - amphipod |
| 540 | Puget Sound, Washington AET - oyster |
| 540 | Puget Sound, Washington AET - Microtox™ |
| **640** | **ER-M** |
| 640 | Puget Sound, Washington AET - benthic |
| 707 | Commencement Bay, Washington bioassay COA |
| 1000 | Puget Sound, Washington AET - benthic |
| 3600 | Puget Sound, Washington AET - amphipod |
| 7000 | EP acute sediment safe level |
| 22811 | Eagle Harbor, Washington bioassay COA |
| 28000 | EP chronic marine @ 4% TOC |
| 31250✓ | Elizabeth River, Virginia bioassay COA |
| 40000 | Lake Union,Washington bioassay COA |
| 176510 | SSB with flounder |
| 220550 | SSB with flounder |
| 285290 | SSB with flounder |
| 700000 | Elizabeth River, Virginia bioassay COA |
| 1250000 | Elizabeth River, Virginia bioassay COA |

### 1-methylnaphthalene

The data available for 1-methylnaphthalene are from bioassays of sediments from San Francisco Bay and southern California and amphipod bioassays of sediments spiked with mixtures of hydrocarbons. Many of the San Francisco Bay samples were not analyzed for 1-methylnaphthalene; the small amount of data available indicated poor concordance between toxicity and chemical concentrations. The mean concentration in southern California samples that were significantly toxic to amphipods was 192.8 ± 461.1 ppb versus 36.2 ± 65.6 ppb in non-toxic samples. The concentration of 1-methylnaphthalene was 500 ppb in a mixture of hydrocarbons that was toxic to amphipods. There are too little data to determine ER-L and ER-M values for this hydrocarbon.

**2-methylnaphthalene**

There are somewhat more data available for 2-methylnaphthalene (Table 59) than for 1-methylnaphthalene. They are from determinations of Puget Sound AET; bioassays of sediments from Commencement Bay, San Francisco Bay, southern California, and Elizabeth River; and amphipod bioassays of sediments spiked with hydrocarbon mixtures. There was a small gradient in 2-methylnaphthalene concentrations between San Francisco Bay samples that were least and moderately toxic to bivalve larvae. There was no concordance between toxicity to amphipods and 2-methylnaphthalene concentrations in San Francisco Bay. Commencement Bay sediments that were moderately toxic to both bivalve larvae and amphipods had 2-methylnaphthalene concentrations similar to those that were least toxic. These data were not used to determine the ER-L and ER-M values (Table B-27).

The lower 10 percentile of the data suggest an ER-L of about 65 ppb, a value supported by high toxicity in southern California sediments (mean 65 ± 154 ppb) (Table 60). The 50 percentile of the data suggest an ER-M of about 670 ppb, a value supported by four Puget Sound AETs (all 670 ppb). There appears to be an overall effects threshold at about 300 ppb, but it is supported by relatively few data and data mainly from Commencement Bay and other parts of Puget Sound (Table B-27).

The degree of confidence in the ER-L and ER-M values for 2-methylnaphthalene should be considered as low and moderate, respectively. They are supported by small clusters of data. There are no single-chemical, spiked-sediment data, no thresholds predicted by EP methods, and the matching biological and chemical data are from only a few geographic areas. However, the apparent effects threshold lies within the ER-L/ER-M range and is not contradicted by observations of no effects at greater concentrations.

**Table 59. Summary of sediment effects data available for 2-methylnaphthalene.**

| References | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 670 |
| | - oyster larvae (*C. gigas*) bioassay | 670 |
| | - benthic community composition | 670 |
| | - Microtox™ bioassay | 670 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 1900 |
| | - oyster larvae (*C. gigas*) bioassay | 670 |
| | - benthic community composition | 1400 |
| | - Microtox™ bioassay | 670 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 67 |
| | - maximum level criterion | 670 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 27 |
| | - *R. abronius* amphipod bioassay | >130 |

**Table 59. 2-methylnaphthalene (continued).**

| References | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 546 ± 490 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 213 ± 129 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 168 ± 169 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 326 ± 313 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 207 ± 169 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 165 ± 121 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 32 ± 41 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 34 ± 27 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 34 ± 33 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 31 ± 33 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 39 ± 35 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 98 ± 41 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 26 ± 23 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 20 ± 7 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 35 ± 36 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 24 ± 4 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 65 ± 154 |
| | - not toxic (23.2% mortality) to *G. japonica* | 16 ± 33 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 31800 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 17808✔ |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 795 |
| **Spiked-Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 500 |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
20. U.S. ACOE, 1988
47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
65. Plesha *et al.*, 1988
80. Tetra Tech, 1985
* Various, please see text

**Table 60. Effects range-low and effects range-median values for 2-methylnaphthalene and 15 concentrations used to determine those values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 27 | San Francisco Bay, California AET |
| **65** | **ER-L** |
| 65 | Southern California bioassay COA |
| 98 | San Francisco Bay, California bioassay COA |
| 326 | Commencement Bay, Washington bioassay COA |
| 500 | SSB with *R. abronius*: mixtures |
| 546 | Commencement Bay, Washington bioassay COA |
| 670 | Puget Sound, Washington AET - amphipod |
| 670 | Puget Sound, Washington AET - oyster |
| 670 | Puget Sound, Washington AET - benthic |
| **670** | **ER-M** |
| 670 | Puget Sound, Washington AET - Microtox™ |
| 795 | Elizabeth River, Virginia bioassay COA |
| 1400 | Puget Sound, Washington AET - benthic |
| 1900 | Puget Sound, Washington AET - amphipod |
| 17808✓ | Elizabeth River, Virginia bioassay COA |
| 31800 | Elizabeth River, Virginia bioassay COA |

**1-methylphenanthrene**

There are no data available with which to relate effects in sediments to the concentrations of this hydrocarbon in sediments.

**Naphthalene**

Puget Sound and San Francisco Bay AET concentrations, freshwater and saltwater SLCs, and three EP-derived concentrations are available for naphthalene (Table 61). Also, co-occurrence analyses were performed with bioassay data from Commencement Bay, Eagle Harbor, Puget Sound, San Francisco Bay, Lake Union, southern California, and benthic community data from the Trinity River. Concentrations predicted or projected to co-occur with toxicity in dilution series of sediments from Black Rock Harbor and Eagle Harbor are available. Data from SSBs with winter flounder and spot (*Leistomus xanthurus*) are also available. The winter flounder were exposed to Venezuelan crude mixed into sediments placed in a layer in large aquaria for 4 months (Payne *et al.*, 1988). The spot were held for 28 days in cages that were placed upon and slightly immersed in Elizabeth River sediments added to large aquaria (Roberts *et al.*, 1989).

Naphthalene represented a small proportion of the total PAH in Black Rock Harbor and Eagle Harbor sediments that were tested in dilution series. There was either no concordance or a small gradient in naphthalene concentrations among San Francisco Bay sediments tested with amphipods. Moderately toxic Eagle Harbor sediments had lower naphthalene concentrations than least toxic samples. These data were not used to determine the ER-L and ER-M values (Table B-28).

The available data (Table 62) suggest an ER-L of about 340 ppb (the lower 10 percentile of the data), a value supported by moderate toxicity in Puget Sound. There is an overall apparent threshold in the data at about 500 ppb; effects have been almost always observed above that concentration in sediments. The 50 percentile value in the data (the ER-M) is about 2100 ppb, a value supported by four Puget Sound AETs (2100 ppb) and an LC50 from a series of bioassays of Elizabeth River sediments tested with spot (2375 ppb).

There is a relatively large amount of data and they are from all the major approaches. There is a consistent cluster of data from two approaches supporting the ER-M value, but not the ER-L value. The ER-L and ER-M values were influenced mainly by San Francisco Bay and Puget Sound data, respectively. The degree of confidence in these values should be considered as moderate and high, respectively. Except for the Commencement Bay samples least toxic to amphipods and the Trinity River bioassay data, the majority of the data indicate that effects almost always occur at concentrations above about 500 ppb (0.5 ppm) napthalene. This overall apparent effects threshold is suggested by an EP-derived concentration (500 ppb) and moderately toxic Commencement Bay samples (mean 593 ± 505 ppb) and lies within the ER-L/ER-M range

**Table 61. Summary of sediment effects data available for naphthalene.**

| Reference | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2100 |
| | - oyster larvae (*C. gigas*) bioassay | 2100 |
| | - benthic community composition | 2100 |
| | - Microtox™ bioassay | 2100 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 2400 |
| | - oyster larvae (*C. gigas*) bioassay | 2100 |
| | - benthic community composition | 2700 |
| | - Microtox™ bioassay | 2100 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 210 |
| | - maximum level criterion | 2100 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >160 |
| | - *R. abronius* amphipod bioassay | >160 |
| **Co-Occurrence Analyses** | | |
| 57[1] | PUGET SOUND WASHINGTON | |
| | - highly toxic (15-minute EC50; 0.31 ± 0.13) to *P. phosphoreum* | 3934 ± 8864 |
| | - moderately toxic (15-minute EC50; 2.1 ± 0.8) to *P. phosphoreum* | 343 ± 388 |
| | - least toxic (15-minute EC50; 8.9 ± 3.3) to *P. phosphoreum* | 36 ± 50 |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 1564 ± 1735 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 594 ± 424 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 510 ± 499 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 973 ± 1041 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 593 ± 505 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 358 ± 326 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 1501 ± 2064 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 288 ± 201 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 456 ± 682 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 30 |

Table 61. Naphthalene (continued).

| Reference | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 40000 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 64 ± 46 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 48 ± 25 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 58 ± 51 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 53 ± 38 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 65 ± 54 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 127 ± 32 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 43 ± 26 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 63 ± 57 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 53 ± 40 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 89 ± 64 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 77 ± 181 |
| | - not toxic (23.2% mortality) to *G. japonica* | 8 ± 16 |
| 51 | TRINITY BAY✔, TEXAS | |
| | - low benthic species richness (28.2 ± 2.9) | 11500 ± 5600 |
| | - high benthic species richness (33.3 ± 4.0) | 5250 ± 1500 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 95000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 53200 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 2375 |
| 58 | BLACK ROCK HARBOR, CONNECTICUT | |
| | - significant toxicity to *A. abdita* in 10-d bioassay | 4.25 |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 367.0✔ |
| 14 | Marine sediments @ 1% TOC | 414 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 42000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 42000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 500 |

Table 61. Naphthalene (continued).

| Reference | Biological Approach | Concentrations (ppb) |
|---|---|---|
| **Equilibrium Partitioning** | | |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 720 |
| **Spiked-Sediment Bioassays** | | |
| 59 | Liver somatic condition indices elevated in winter flounder | 7370 |
| | MFO induction in winter flounder liver significantly elevated | 6200 |
| | MFO induction in winter flounder kidney significantly elevated | 10710 |

1 Total concentration includes sum of naphthalene, 1-methylnaphthalene, 2-methylnaphthalene, 2,6-dimethylnaphthalene, and 2,3,5-trimethylnaphthalene.

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
51. Armstrong *et al.*, 1979
56. Anderson *et al.*, 1988
57. Schiewe *et al.*, 1985
58. Rogerson *et al.*, 1985
59. Payne *et al.*, 1988
80. Tetra Tech, 1985
85. $CH^2M$ Hill, 1989

* Various, please see text

**Table 62. Effects range-low and effects range-median values for naphthalene and 28 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 77 | Southern California bioassay COA |
| 127 | San Francisco Bay, California bioassay COA |
| **340** | **ER-L** |
| 343 | Puget Sound, Washington bioassay COA |
| 367✔ | Marine SLC |
| 414 | Marine SLC |
| 500 | 99 Percentile EP chronic marine @ 1% TOC |
| 593 | Commencement Bay, Washington bioassay COA |
| 594 | Commencement Bay,Washington bioassay COA |
| 720 | 95 percentile EP chronic marine @ 1% TOC |
| 973 | Commencement Bay, Washington bioassay COA |
| 1501 | Eagle Harbor, Washington bioassay COA |
| 1564 | Commencement Bay, Washington bioassay COA COA |
| 2100 | Puget Sound, Washington AET- amphipod |
| 2100 | Puget Sound, Washington AET - oyster |
| **2100** | **ER-M** |
| 2100 | Puget Sound, Washington AET - benthic |
| 2100 | Puget Sound, Washington AET - Microtox™ |
| 2375 | Elizabeth River, Virginia bioassay COA |
| 2400 | Puget Sound, Washington AET - amphipod |
| 2700 | Puget Sound, Washington AET - benthic |

Table 62. (continued)

| Concentrations (ppb) | End Point |
|---|---|
| 3934 | Puget Sound, Washington bioassay COA |
| 6200 | SSB with flounder |
| 7370 | SSB with flounder |
| 10710 | SSB with flounder |
| 11500 | Trinity River,Texas benthos COA |
| 40000 | Lake Union, Washington bioassay COA |
| 42000 | EP acute marine threshold @ 4% TOC |
| 53200 | Elizabeth River, Virginia bioassay COA |
| 95000 | Elizabeth River, Virginia bioassay COA |

## Perylene

Data available for perylene are from studies in which bioassays of San Francisco Bay, southern California, and Elizabeth River sediments were performed (Table 63). There are too little data to warrant determination of ER-L and ER-M values, however, some of the available data suggest a degree of convergence. The San Francisco Bay AET for amphipod bioassays, San Francisco Bay sediments highly toxic to amphipods and bivalve larvae, and southern California sediments significantly toxic to amphipods had similar perylene concentrations (230, and means of 173, 212, and 175 ppb, respectively). The perylene concentrations in Elizabeth River sediments that were toxic to *L. xanthurus* were much higher (means of 1677 ppb and greater).

Table 63. Summary of sediment effects data available for perylene.

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Thresholds** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 95 |
| | - *R. abronius* amphipod bioassay | 230 |
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 173 ± 124 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 139 ± 43 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 98 ± 68 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 159 ± 92 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 85 ± 68 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 212 ± 39 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 132 ± 92 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 81 ± 78 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 146 ± 86 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 32 ± 55 |

**Table 63. Perylene (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.65% mortality) to *G. japonica* | 175 ± 120 |
| | - not toxic (23.2% mortality) to *G. japonica* | 82 ± 118 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 50700 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 28392 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 1677 |

**References:**

47. Roberts *et al.*, 1989
56. Anderson *et al.*, 1988
* Various, please see text

**Phenanthrene**

Data available for phenanthrene are from studies in which Puget Sound AETs were determined; SSBs were performed with amphipods and winter flounder; national SLCs were calculated; EP-derived thresholds were predicted; and bioassays of sediments from Commencement Bay, Eagle Harbor, Lake Union, San Francisco Bay, southern California, Columbia River, and Elizabeth River were performed (Table 64). San Francisco Bay sediments that were least, moderately, and highly toxic to amphipods had similar phenanthrene concentrations. San Francisco Bay sediments that were significantly toxic to bivalve larvae had similar concentrations of phenanthrene compared to those that were not toxic. Eagle Harbor sediments that were moderately toxic to amphipods had a lower mean phenenathrene concentration than those that were least toxic. These data were not used to determine ER-L and ER-M values (Table B-29).

The lower 10 percentile value of the data suggests an ER-L of about 225 ppb, a value supported by southern California and San Francisco Bay bioassay data (means of 222 ± 136 ppb and 224 ± 203 ppb, respectively) (Table 65). The 50 percentile of the data suggest an ER-M of about 1380 ppb, a value supported by highly toxic Commencement Bay samples (mean of 1379 ± 2546 ppb) and an EP-derived criterion of 1390 ppb. There is an overall apparent effects threshold at about 260 ppb, but there are data from Commencement Bay, Eagle Harbor, and the Columbia River that contradict that observation.

The degree of confidence in the ER-L and ER-M values for phenanthrene should be considered as moderate. There are data from all of the major approaches and there is convergence within this range, but the data from a SSB with an amphipod suggest that the effects threshold among sensitive species may occur at concentrations much greater than the ER-L/ER-M range. The AET lies within the ER-L/ER-M range, but is contradicted by observations of no effects at higher concentrations determined in three study areas.

**Table 64. Summary of sediment effects data available for phenanthrene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Thresholds** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 5400 |
| | - oyster larvae (*C. gigas*) bioassay | 1500 |
| | - benthic community composition | 3200 |
| | - Microtox™ bioassay | 1500 |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 6900 |
| | - oyster larvae (*C. gigas*) bioassay | 1500 |
| | - benthic community composition | 5400 |
| | - Microtox™ bioassay | 1500 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 320 |
| | - maximum level criterion | 3200 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 88 |
| | - *R. abronius* amphipod bioassay | 510 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 2838 ± 4603 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 597 ± 513 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 478 ± 367 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 1379 ± 2546 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 593 ± 365 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 297 ± 263 |
| 85 | EAGLE HARBOR, WASHINGTON | |
| | - highly toxic (19.1 ± 1.7 dead/20) to *R. abronius* | 33603 ± 84430 |
| | - moderately toxic (8.2 ± 1.8 dead/20) to *R. abronius* | 2142 ± 2404 |
| | - least toxic (2.6 ± 1.4 dead/20) to *R. abronius* | 2600 ± 10009 |
| 21 | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 950 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 410000 |
| 52 | COLUMBIA RIVER, WASHINGTON/OREGON | |
| | - not toxic (0-13% mortality) to *H. azteca* | 580 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 242 ± 203 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 228 ± 146 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 188 ± 197 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 220 ± 163 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 199 ± 205 |

**Table 64. Summary of sediment effects data available for phenanthrene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 475 ± 160 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 224 ± 203 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 65 ± 30 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 233 ± 208 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 159 ± 216 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 222 ± 136 |
| | - not toxic (23.2% mortality) to *G. japonica* | 119 ± 242 |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 220000 |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 2363200 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 105500 |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 259 |
| 14 | Marine sediments @ 1% TOC | 368 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 56000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 56000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 110 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 240 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria @ 1% TOC | 14000 |
| 6 | EPA interim mean freshwater sediment quality criteria @ 1% TOC | 1390 |
| | EPA interim mean marine sediment quality criteria @ 1% TOC | 1020 |
| **Spiked-Sediment Bioassays** | | |
| 65 | Significant toxicity to *R. abronius* with mixtures of aromatic and chlorinated hydrocarbons | 10000✔ |
| 59 | liver somatic condition indices elevated in winter flounder | 340 |
| | MFO induction in winter flounder liver significantly elevated | 270 |
| | MFO induction in winter flounder kidney significantly elevated | 429 |

Table 64. Phenanthrene (continued).

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Spiked-Sediment Bioassays** | | |
| 21 | LC50 (10-d) with *R. abronius* | 3680 |

**References:**

1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
6. EPA, 1988
13. Pavlou *et al.*, 1987
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
52. Johnson *et al.*, 1988
56. Anderson *et al.*, 1988
59. Payne *et al.*, 1988
65. Plesha *et al.*, 1988
85. CH²M Hill, 1989
80. Tetra Tech, 1985

* Various, please see text

**Table 65. Effects range-low and effects range-median values for phenanthrene and 34 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 88 | San Francisco Bay, California AET |
| 110 | 99 percentile EP chronic marine @ 1% TOC |
| 222 | Southern California bioassay COA |
| 224 | San Francisco Bay, California bioassay COA |
| **225** | **ER-L** |
| 240 | 95 percentile EP chronic marine @ 1% TOC |
| 259 | Marine SLC |
| 270 | SSB with flounder |
| 340 | SSB with flounder |
| 368 | Marine SLC |
| 429 | SSB with flounder |
| 475 | San Francisco Bay, California bioassay COA |
| 500 | SSB with *R. abronius*: mixtures |
| 510 | San Francisco Bay, California AET |
| 593 | Commencement Bay, Washington bioassay COA |
| 597 | Commencement Bay, Washington bioassay COA |
| 950 | Eagle Harbor, Washington bioassay COA |
| 1020 | EP interim marine criteria @ 1% TOC |
| 1379 | Commencement Bay, Washington bioassay COA |
| **1380** | **ER-M** |
| 1390 | EP interim freshwater criteria @ 1% TOC |
| 1500 | Puget Sound, Washington AET - oyster |
| 1500 | Puget Sound, Washington AET - Microtox™ |
| 2838 | Commencement Bay, Washington bioassay COA |
| 3200 | Puget Sound, Washington AET - benthic |
| 3680 | SSB with *R. abronius* LC50 |
| 5400 | Puget Sound, Washington AET- amphipod |
| 5400 | Puget Sound, Washington AET - benthic |
| 6900 | Puget Sound, Washington AET - amphipod |
| 14000 | EP acute sediment safe level |

**Table 65. (continued)**

| | |
|---|---|
| 33603 | Eagle Harbor, Washington bioassay COA |
| 56000 | EP chronic marine @ 4% TOC |
| 105500 | Elizabeth River, Virginia bioassay COA |
| 220000 | Elizabeth River, Virginia bioassay COA |
| 410000 | Lake Union, Washington bioassay COA |
| 2363200 | Elizabeth River, Virginia bioassay COA |

## Pyrene

Data available for pyrene are from studies in which Puget Sound AETs were determined; national SLCs were calculated; EP-derived thresholds were predicted; SSBs with winter flounder were conducted; and bioassays of sediments from Commencement Bay, Eagle Harbor, Lake Union, San Francisco Bay, southern California, and Elizabeth River were performed (Table 66). San Francisco Bay sediments that were significantly toxic to both amphipods and bivalve larvae had pyrene concentrations similar to the samples that were not toxic. San Francisco Bay sediments that were highly toxic to amphipods had pyrene concentrations similar to those that were least toxic. Commencement Bay sediments that were moderately toxic to amphipods had mean pyrene concentrations lower than those that were least toxic. Columbia River sediments with up to 2500 ppb pyrene were not toxic to amphipods. One each of the Puget Sound and San Francisco Bay AETs was not definitive. These data were not used to determine ER-L and ER-M values (Table B-30).

The lower 10 percentile of the data suggest an ER-L of about 350 ppb pyrene, a value supported by a predicted LC50 (350 ppb) for Eagle Harbor sediments tested with amphipods and observations of altered liver somatic condition in winter flounder exposed to petroleum (360 ppb) (Table 67). The 50 percentile value in the data suggest an ER-M of about 2200 ppb, a value supported by San Francisco Bay bioassay data (mean of 2188 ppb). Except for the Columbia River bioassay data, most of the data suggest an overall effects threshold at about 1000 ppb (1 ppm) pyrene. However, as with the other aromatic hydrocarbons, this apparent effects threshold is highly influenced by the Puget Sound AET values.

The degree of confidence in the ER-L and ER-M values should be considered as moderate. Data are available from a number of approaches and geographic areas, an apparent effects threshold lies within the ER-L/ER-M range, and there is consistency and clustering of the available data. However, there are no data from single-chemical SSBs and most of the thresholds predicted by EP methods are much higher than the concentrations within the ER-L/ER-M range.

**Table 66. Summary of sediment effects data available for pyrene.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 4300 |
| | - oyster larvae (*C. gigas*) bioassay | 3300 |
| | - benthic community composition | >7300 |
| | - Microtox™ bioassay | 2600 |

Table 66. Pyrene (continued).

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 2 | 1988 PUGET SOUND AET | |
| | - *R. abronius* amphipod bioassay | 16000 |
| | - oyster larvae (*C. gigas*) bioassay | 3300 |
| | - benthic community composition | 16000 |
| | - Microtox™ bioassay | 2600 |
| 20 | PSDDA guidelines (based upon Puget Sound AET) | |
| | - screening level concentration | 430 |
| | - maximum level criterion | 7300 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | >3400 |
| | - *R. abronius* amphipod bioassay | 2600 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 1820 ± 2252 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 865 ± 719 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 978 ± 996 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 1538 ± 1501 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 1078 ± 806 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 434 ± 442 |
| 21 | EAGLE HARBOR, WASHINGTON | |
| | - predicted LC50 for *R. abronius* in 10-d dilution series with Yaquina Bay, Oregon sediment | 350 |
| 29 | LAKE UNION, WASHINGTON | |
| | - 95% mortality to *H. azteca* | 750000 |
| 52 | COLUMBIA RIVER, WASHINGTON/OREGON | |
| | - not toxic (0-13% mortality) to *H. azteca* | 2500 |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 777 ± 908 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 1110 ± 904 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 701 ± 866 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 896 ± 870 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 743 ± 902 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 2188 ± 776 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 724 ± 939 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 216 ± 102 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 806 ± 975 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 719 ± 1123 |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 532 ± 372 |
| | - not toxic (23.2% mortality) to *G. japonica* | 184 ± 318 |

Table 66. Pyrene (continued).

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 47 | ELIZABETH RIVER, VIRGINIA | |
| | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 1350000 |
| | - LC50 (24-hr) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 756000 |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 33750 |
| **National Screening Level Concentrations** | | |
| 5 | Marine sediments @ 1% TOC | 434 |
| 14 | Marine sediments @ 1% TOC | 665 |
| **Equilibrium Partitioning** | | |
| 4 | EPA chronic marine EP threshold (@ 4% TOC) | 198000 |
| 17 | EPA acute marine EP threshold (@ 4% TOC) | 198000 |
| 13 | 99 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 850 |
| 13 | 95 percentile chronic marine permissable contaminant derived from chronic water quality criteria @ 1% TOC | 1900 |
| 6 | EPA interim mean freshwater sediment quality criteria based upon EP@ 1% TOC | 13100 |
| 25 | Sediment safe levels based upon sediment/water partitioning coefficients and acute water quality criteria | 49500 |
| **Spiked Sediment Bioassays** | | |
| 59 | Liver somatic condition indices elevated in winter flounder | 360 |
| | MFO induction in winter flounder liver significantly elevated | 300 |
| | MFO induction in winter flounder kidney significantly elevated | 182 |

**References:**


1. Beller *et al.*, 1986
2. PTI Environmental Services, 1988
4. Bolton *et al.*, 1985
5. Neff *et al.*, 1986
6. EPA, 1988
13. Pavlou *et al.*, 1983
14. Neff *et al.*, 1987
17. Lyman *et al.*, 1987
20. U.S. ACOE, 1988
21. Swartz *et al.*, 1989
25. Pavlou, 1987
29. Yake *et al.*, 1986
47. Roberts *et al.*, 1989
52. Johnson *et al.*, 1988
56. Anderson *et al.*, 1988
59. Payne *et al.*, 1988
80. Tetra Tech, 1985
* Various, please see text

**Table 67. Effects range-low and effects range-median values for pyrene and 28 concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 182 | SSB with flounder |
| 300 | SSB with flounder |
| 350 | Eagle Harbor, Washington bioassay COA |
| **350** | **ER-L** |
| 360 | SSB with flounder |
| 434 | Marine SLC |
| 532 | Southern California bioassay COA |
| 665 | Marine SLC |
| 724 | San Francisco Bay, California bioassay COA |
| 850 | 99 percentile EP chronic marine @ 1% TOC |
| 1078 | Commencement Bay,Washington bioassay COA |
| 1110 | San Francisco Bay, California bioassay COA |
| 1538 | Commencement Bay, Washington bioassay COA |
| 1820 | Commencement Bay, Washington bioassay COA |
| 1900 | 95 percentile EP chronic marine @ 1% TOC |
| 2188 | San Francisco Bay, California bioassay COA |
| **2200** | **ER-M** |
| 2600 | Puget Sound, Washington AET - Microtox™ |
| 2600 | San Francisco Bay, California AET |
| 3300 | Puget Sound, Washington AET - oyster |
| 4300 | Puget Sound, Washington AET - amphipod |
| 13100 | EP freshwater interim criteria @ 1% TOC |
| 16000 | Puget Sound, Washington AET - amphipod |
| 16000 | Puget Sound, Washington AET - benthic |
| 33750 | Elizabeth River, Virginia bioassay COA |
| 49500 | EP acute sediment safe level |
| 198000 | EP chronic marine @ 4% TOC |
| 750000 | Lake Union, Washington bioassay COA |
| 756000 | Elizabeth River, Virginia bioassay COA |
| 1350000 | Elizabeth River, Virginia bioassay COA |

**2,3,5-trimethylnaphthalene**

No data were located with which to relate 2,3,5-trimethylnaphthalene concentrations in sediments to measures of biological effects.

**Total Polynuclear Aromatic Hydrocarbons (PAH)**

The data available for total PAH include those from SSBs and co-occurrence analyses of matching bioeffects and chemical data from various investigations in the field (Table 68). The SSBs were performed with amphipods, bivalve larvae, and the fish *L. xanthurus*. The matching data are from San Francisco Bay, southern California, Eagle Harbor, Puget Sound, Commencement Bay, Mississippi Sound, Forth Estuary (Scotland), Hampton Roads, Lower Columbia River, Massachusetts Bay, and Hudson-Raritan Bay. In addition to the COA, the Mississippi Sound data from two types of bioassays (amphipod *Gammarus mucronatus* and mysid *Mysidopsis almyra*) were evaluated to determine AET concentrations.

Some of the data were not used to determine the ER-L and ER-M values (Table B-31). Some of the data from San Francisco Bay bioassays performed with amphipods, from studies of meiofauna in Forth Estuary, from bioassays of Mississippi Sound performed with mysids and with amphipods, and from moderately toxic Hampton Roads sediments tested with shrimp were not used because they either lacked a gradient in concentration or lacked concordance between the biological and the chemical data. One each of the San Francisco Bay and Mississippi Sound AETs were not definitive.

The category of total PAH is difficult to evaluate since different individual PAHs have been quantified by different investigators and reported as total PAH (Table B-31). Therefore, the data available for evaluation are not necessarily equivalent. For example, some of the data were reported as total PAH or total hydrocarbons and the identity and number of quantified hydrocarbons were not specified. Among the data sets evaluated, a minimum of 4 PAHs and a maximum of 21 PAHs were quantified. However, there is enough similarity among the data to warrant a cautious review of the concentrations associated with measures of effects in sediments. Most investigators reported the sums of 13 to 18 individual hydrocarbons. No Puget Sound AET has been reported for the category of total PAH. Also, since the Commencement Bay data were reported as sums of these two categories (low molecular weight and high molecular weight PAH), COA were performed with sums of the two mean concentrations as an approximation of total PAH. The AET concentrations determined with the Mississippi Sound data also were of questionable value. No definitive AET for the amphipod bioassay could be determined; the sample with the highest PAH concentration that was significantly toxic had 205,000 ppb PAH. Only one other sample that was significantly toxic to mysids exceeded the AET concentration of 99,400 ppb PAH in the sample.

Effects were associated with total PAH concentrations as low as 870 ppb, the AET determined for San Francisco Bay sediments tested with bivalve larvae bioassays (Table 69). The lower 10 percentile value of the data is equivalent to about 4000 ppb (3800 rounded to 4000 ppb), the ER-L concentration. This value is supported by observations in San Francisco Bay of the concentration associated with minimum measures of bioeffects (3800 ppb) and significant toxicity to bivalve larvae (mean 4022 ppb). With several exceptions, effects were usually observed in association with total PAH concentrations of about 11000 ppb or greater. There is an apparent effects threshold among the data at about 22000 ppb; effects were usually observed at higher total PAH concentrations. The 50 percentile value in the data suggests an ER-M concentration of about 35000 ppb. This concentration is supported by the observations of low Massachusetts Bay species richness (mean of 35000 ppb) and high toxicity in Hampton Roads sediments (mean of 35700 ppb).

The majority of the data are available from matching biological and chemical analyses of field-collected samples, and, therefore, are subject to the weaknesses outlined earlier in this document. The data from the few SSBs in which individual PAH were quantified indicated very high LC50s (e.g., >180,000 ppb). The individual PAH that were quantified and the number of PAH that were quantified and summed differed among investigators. There are no effects thresholds predicted by EP methods available for a category of total PAH. Small clusters of data supported the ER-L and ER-M values. The total data set had an extremely wide range in concentrations. Because of these problems, the degree of confidence in the ER-L and ER-M values for total PAH should be considered as relatively low. However, there did appear to be a relatively clear overall threshold in the data. A much more standardized method of reporting results and more data are needed to determine the total PAH concentrations associated with measures of effects in sediments.

**Table 68. Summary of sediment effects data available for total PAHs.**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET FOR LOW MOLECULAR WEIGHT PAH | |
| | - *R. abronius* amphipod bioassay | 5200 |
| | - oyster larvae (*C. gigas*) bioassay | 5200 |
| | - benthic community composition | 6100 |
| | - Microtox™ bioassay | 5200 |

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Apparent Effects Threshold** | | |
| 1 | 1986 PUGET SOUND AET FOR HIGH MOLECULAR WEIGHT PAH | |
| | - *R. abronius* amphipod bioassay | 18000 |
| | - oyster larvae (*C. gigas*) bioassay | 17000 |
| | - benthic community composition | >51000 |
| | - Microtox™ bioassay | 12000 |
| 2 | 1988 PUGET SOUND AET FOR LOW MOLECULAR WEIGHT PAH | |
| | - *R. abronius* amphipod bioassay | 24000 |
| | - oyster larvae (*C. gigas*) bioassay | 5200 |
| | - benthic community composition | 13000 |
| | - Microtox™ bioassay | 5200 |
| 2 | 1988 PUGET SOUND AET FOR HIGH MOLECULAR WEIGHT PAH | |
| | - *R. abronius* amphipod bioassay | 69000 |
| | - oyster larvae (*C. gigas*) bioassay | 17000 |
| | - benthic community composition | 69000 |
| | - Microtox™ bioassay | 12000 |
| 20 | - PSDDA screening level - low molecular weight PAH | 610 |
| | - PSDDA screening level - high molecular weight PAH | 1800 |
| | - PSDDA maximum level - low molecular weight PAH | 6100 |
| | - PSDDA maximum level - high molecular weight PAH | 51000 |
| * | SAN FRANCISCO BAY, CALIFORNIA AET | |
| | - bivalve larvae bioassay | 870 |
| | - *R. abronius* amphipod bioassay | >15000 |
| 84 | MISSISSIPPI SOUND, MISSISSIPPI AET | |
| | - AET for amphipod bioassay | >205000 |
| | - AET for mysid bioassay | 99400 |
| **Co-Occurrence Analyses** | | |
| 80 | COMMENCEMENT BAY, WASHINGTON: LOW MOLECULAR WEIGHT PAH | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 6977 ± 8437 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 2031 ± 1316 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 1602 ± 1411 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 3835 ± 4852 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 2003 ± 1405 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 1019 ± 943 |
| 80 | COMMENCEMENT BAY, WASHINGTON: HIGH MOLECULAR WEIGHT PAH | |
| | - highly toxic (15.7 ± 3.9 dead/20) to *R. abronius* | 9794 ± 12821 |
| | - moderately toxic (5.2 ± 1.1 dead/20) to *R. abronius* | 6178 ± 6438 |
| | - least toxic (2.5 ± 0.9 dead/20) to *R. abronius* | 4865 ± 4800 |
| | - highly toxic (44.5 ± 19% abnormal) to oyster larvae | 9042 ± 9573 |
| | - moderately toxic (23 ± 2.3% abnormal) to oyster larvae | 5838 ± 4042 |
| | - least toxic (15.1 ± 3.1% abnormal) to oyster larvae | 2686 ± 2631 |

**Table 68. Total PAHs (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| * | SAN FRANCISCO BAY, CALIFORNIA | |
| | - highly toxic (67 ± 11.8% mortality) to *R. abronius* | 4227 ± 5025 |
| | - moderately toxic (33.8 ± 4.7% mortality) to *R. abronius* | 3966 ± 3524 |
| | - least toxic (18 ± 6.6% mortality) to *R. abronius* | 3323 ± 4337 |
| | - significantly toxic (42.9 ± 19.2% mortality) to *R. abronius* | 3832 ± 3927 |
| | - not toxic (18.4 ± 6.8% mortality) to *R. abronius* | 3527 ± 4520 |
| | - highly toxic (92.4 ± 4.5% abnormal) to bivalve larvae | 11735 ± 5499 |
| | - moderately toxic (59.4 ± 11.3% abnormal) to bivalve larvae | 3343 ± 4039 |
| | - least toxic (23.3 ± 7.3% abnormal) to bivalve larvae | 941 ± 429 |
| | - significantly toxic (55.7 ± 22.7% abnormal) to bivalve larvae | 4022 ± 4908 |
| | - not toxic (31.9 ± 15.5% abnormal) to bivalve larvae | 2557 ± 3816 |
| 7 | - sediment quality triad significant bioeffects | ≥9500 |
| | - sediment quality triad minimum bioeffects | ≤3800 |
| | PUGET SOUND, WASHINGTON | |
| 57 | - highly toxic in Microtox™ bioassay | 55630 ± 112530 |
| | - moderately toxic in Microtox™ bioassay | 13933 ± 17427 |
| | - least toxic in Microtox™ bioassay | 763 ± 727 |
| 26 | - highly toxic (95% LPL) to *R. abronius* | 11752 ± 14548 |
| | - moderately toxic (<87.5% survival to <95% LPL) to *R. abronius* | 7627 ± 7065 |
| | - least toxic (<87.5% survival) to *R. abronius* | 4201 ± 4612 |
| 52 | COLUMBIA RIVER, WASHINGTON | |
| | - low toxicity (0-13% mortality) to *H. azteca* | 19000 |
| 84 | MISSISSIPPI SOUND, MISSISSIPPI | |
| | - highly toxic (90 ± 11.7% mortality) to mysid *M. almyra* | 11400 ± 14100 |
| | - moderately toxic ( 53.5 ± 7.4% mortality) to mysid *M. almyra* | 66100 ± 83300 |
| | - least toxic (8 ± 8.8% mortality) to mysid *M. almyra* | 8550 ± 23000 |
| | - significant mortality (71.8 ± 21.4%) to mysid *M. almyra* | 41790 ± 66160 |
| | - low mortality (8 ± 8.8%) to mysidd *M. almyra* | 8550 ± 22990 |
| | - highly toxic (76.9 ± 24.1% mortality) to amphipod *G. mucronatus* | 47760 ± 74890 |
| | - least toxic (14.4 ± 5.9% mortality) to amphipod *G. mucronatus* | 9730 ± 22390 |
| | - significantly toxic (80.7 ± 23.2% mortality) to amphipod *G. mucronatus* | 21600 ± 31000 |
| | - not toxic (16 ± 9.4% mortality) to amphipod *G. mucronatus* | 18600 ± 47000 |
| 79 | HUDSON-RARITAN ESTUARY, NEW YORK | |
| | - negative growth in nematode bioassay | 42769 ± 46084 |
| | - positive growth in nematode bioassay | 21467 ± 31160 |
| 81 | FORTH ESTUARY, SCOTLAND | |
| | - low meiofaunal density (112.4 ± 123/sample) | 83800 ± 57900 |
| | - moderate meiofaunal density (1334 ± 396/sample) | 11800 ± 9700 |
| | - high meiofaunal density (3757✓± 1804✓/sample) | 10200 ± 9950 |

**Table 68. Total PAHs (continued)**

| References | Biological Approaches | Concentrations (ppb) |
|---|---|---|
| **Co-Occurrence Analyses** | | |
| 82 | MASSACHUSETTS BAY, MASSACHUSETTS | |
| | - low macrofaunal species richness (31 ± 6.5) | 35000 ± 25400 |
| | - moderate macrofaunal species richness (58.1 ± 10.4) | 23100 ± 15400 |
| | - high macrofaunal species richness (93.6 ± 9.4) | 8700 ± 12600 |
| 31 | HAMPTON ROADS, VIRGINIA | |
| | - highly toxic (70 ± 20.3% mortality) to *P. pugio* shrimp | 35700 ± 42181 |
| | - moderately toxic (8.8 ± 1.8% mortality) to *P. pugio* shrimp | 12325 ± 10425 |
| | - least toxic (2.2 ± 1.8% mortality) to *P. pugio* shrimp | 16921 ± 20976 |
| | ELIZABETH RIVER, VIRGINIA | |
| 37 | - 56% overall mortality among spot *L. xanthurus* | 3900000 |
| | - 100% fin erosion among spot *L. xanthurus* | 3900000 |
| 47 | - 100% mortality to *L. xanthurus* exposed to 100% Elizabeth River sediment | 21200000✓ |
| | - LC50 (24-h) for *L. xanthurus* exposed to 56% Elizabeth River sediment | 11872000✓ |
| | - LC50 (28-d) for *L. xanthurus* exposed to 2.5% Elizabeth River sediment | 530000✓ |
| 56 | SOUTHERN CALIFORNIA | |
| | - significantly toxic (51.7% mortality) to *G. japonica* | 8363 |
| | - not toxic (23.2% mortality) to *G. japonica* | 2242 |
| 58 | BLACK HARBOR, CONNECTICUT | |
| | - projected concentrations significantly toxic to *A. abdita* amphipod | 11273 |
| 21 | EAGLE HARBOR, WASHINGTON | |
| | - predicted LC50 concentration toxic to *R. abronius* | 2590 |
| **Spiked-Sediment Bioassays** | | |
| 59 | - elevated liver/somatic indices in winter flounder *P. americanus* | 228722 |
| | - elevated liver MFO induction in winter flounder *P. americanus* | 183060 |
| | - elevated kidney MFO induction in winter flounder *P. americanus* | 295860 |
| 28 | - Bunker C oil LC50 for *R. abronius* | 2240000 |
| 30 | - low (7.4%) abnormality in oyster larvae (*C. gigas*) exposed to petroleum products | 10000 |

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57. Schiewe *et al.*, 1984
58. Rogerson *et al.*, 1988
59. Payne *et al.*, 1988
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80. Tetra Tech, 1985
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84. Lytle and Lytle, 1985
* various, see text

**Table 69. Effects range-low and effects range-median values for total PAHs and 34concentrations used to determine these values arranged in ascending order.**

| Concentrations (ppb) | End Point |
|---|---|
| 870 | San Francisco Bay AET--bivalve |
| 2590 | Predicted LC50 Eagle Harbor--amphipod COA |
| 3343 | San Francisco Bay moderately toxic--bivalve COA |
| 3800 | San Francisco Bay triad minimum bioeffects COA |
| **4000** | **ER-L** |
| 4022 | San Francisco Bay significantly toxic--bivalve COA |
| 7627 | Puget Sound moderately toxic--amphipod COA |
| 7841 | Commencement Bay moderately toxic--oyster COA |
| 8363 | Southern California significantly toxic--amphipod COA |
| 9500 | San Francisco Bay triad significant bioeffects COA |
| 11273 | Black Rock Harbor significantly toxic--amphipod COA |
| 11735 | San Francisco Bay highly toxic--bivalve COA |
| 11752 | Puget Sound highly toxic--amphipod COA |
| 12877 | Commencement Bay highly toxic--oyster COA |
| 13933 | Puget Sound moderately toxic--Microtox™ COA |
| 16771 | Commencement Bay highly toxic-amphipod COA |
| 23100 | Massachusetts Bay moderate species richness COA |
| 35000 | Massachusetts Bay low species richness COA |
| **35000** | **ER-M** |
| 35700 | Hampton Roads highly toxic--shrimp COA |
| 41790 | Mississippi Sound significantly toxic--mysid COA |
| 42769 | Hudson-Raritan highly toxic--nematode COA |
| 47760 | Mississippi Sound highly toxic--amphipod COA |
| 55630 | Puget Sound highly toxic--Microtox™ COA |
| 66100 | Mississippi Sound moderately toxic--mysid COA |
| 83800 | Forth Estuary low meiofauna density COA |
| 99400 | Mississippi Sound AET--mysid bioassay |
| 183060 | SSB with winter flounder liver MFO |
| 228722 | SSB with winter flounder liver condition |
| 295860 | SSB with winter flounder kidney MFO |
| 530000 | LC50 2.5% Elizabeth River--spot COA |
| 2240000 | SSB with LC50 Bunker C oil--amphipod |
| 3900000 | 56% mortality Elizabeth River--spot COA |
| 3900000 | 100% fin erosion Elizabeth River--spot COA |
| 11872000 | LC50 56% Elizabeth River--spot COA |
| 21200000 | LC100 100% Elizabeth River--spot COA |

## DISCUSSION

### Review of ER-L and ER-M values

The ER-L and ER-M concentrations for each chemical and chemical group are summarized and listed in Table 70. Also, the ratios between the respective ER-L and ER-M values for each chemical are listed as a measure of the spread or range in the chemical concentrations. This ratio was generally lowest (average of 4.2 to 1) for the trace metals (especially cadmium, chromium, arsenic, nickel, and zinc) and highest (average of 8.1 to 1) for the organic compounds (excluding total DDT, endrin, and dieldrin).

The available data for some chemicals indicate agreements among the various approaches and the various data sets that were evaluated. For example, there is a relatively large amount of data available for cadmium generated from a variety of methods. The Puget Sound AET concentrations range from 5.1 ppm to 9.6 ppm; the 10-d LC50 concentrations from many SSBs with amphipods range from 5.6 to 11.5 ppm; and significant toxicity to amphipods and reduced echinoderm abundance in Southern California sediments occurred in samples with mean cadmium concentrations of 5.3 and 6.2 ppm, respectively. Effects were not observed in sediments with cadmium concentrations of less than about 4 ppm. With some exceptions, biological effects were usually observed in association with cadmium concentrations of 5 ppm or greater. The preponderance of evidence from these data suggest that effects are likely or expected as cadmium concentrations in sediments reach about 5 ppm. Also, the effect of adding or deleting data upon the ER-L and ER-M values for cadmium would likely be relatively small.

For some other chemicals, there was less agreement among the data from various approaches and the degree of confidence in the accuracy of the resulting ER-L and ER-M values was relatively low. For example, the Puget Sound AET concentrations for chromium are 260 and 270 ppm, whereas effects were observed elsewhere in association with mean concentrations as low as 61 ppm and as high as 1646 ppm. Many of the biological measures of effects were not in concordance with chromium concentrations, suggesting that chromium had a minimal role or no role in causation. In another example, the SLCs for total PCBs range from 2.9 ppb to 42.6 ppb based upon a relatively large amount of data; whereas, the Puget Sound AET concentrations range from 130 ppb to 3100 ppb, the San Francisco Bay AET range from 54 to 260 ppb, the chronic marine threshold predicted by EP methods is 280 ppb, and the LC50 from a SSB performed with amphipods is 10800 ppb. The effect of adding or deleting data upon the ER-L or ER-M values could be significant for some of the chemicals for which there is little consistency or clustering in the data. Obviously, for many chemicals there is yet much to be learned as regards the chemical concentrations in sediments that cause biological effects.

The chemical concentrations associated with no effects often were as informative as the concentrations associated with measures of effects. Sediment bioassays performed with relatively highly contaminated sediments from San Diego Bay, New York Harbor, and Eagle Harbor indicated low toxicity; whereas, sediments from other areas or tested with other approaches with similar or lower chemical concentrations were very toxic. Assuming that these tests were conducted with proper methods, the data may suggest different degrees of availability of the sediment-sorbed chemicals. Based upon the methods described, we had no reason to eliminate these data.

Overall, the degree of confidence in the accuracy of the ER-L and ER-M values should be considered as moderate for the metals group and PCBs and low for the pesticide and PAH groups. Much more data are needed to support or refute the ER-L and ER-M values for all groups and for individual analytes within the groups.

Also included in Table 70 is a summary of the subjectively determined, overall apparent effects threshold for each chemical; the concentrations at and above which biological effects were usually or always observed. The ER-L and ER-M values were established objectively with *a priori* selection criteria, i.e., the lower 10 percentiles and 50 percentiles of the available data. They were not established following review and evaluation of the data for each chemical. However, following a review of the available data for each chemical, apparent effects thresholds were often observed and noted. These thresholds were established with a subjective approach. Therefore, they were identified and listed as evidence to support the accuracy of the ER-L/ER-M values and as hypotheses to be evaluated with additional data. They were not used to rank the NS&T Program sites. For several chemical analytes (i.e., chromium, total DDT, dieldrin), there was no apparent effects threshold. For many of the pesticides and aromatic hydrocarbons, there were insufficient data to determine a threshold, noted as not sufficient data (NSD) in Table 70. For many of the analytes, e.g., mercury, there were inconsistent data at concentrations above the apparent effects thresholds, i.e., data from some studies indicated no effects at relatively high concentrations of the analyte. The apparent effects thresholds for most of the trace metals, PCBs, DDT, and some of the aromatic hydrocarbons were very similar to the respective ER-M values or within the ER-L/ ER-M range. However, the apparent threshold was outside the ER-L/ER-M range for antimony and lead. The apparent effects threshold for antimony was 25 ppm, a concentration equivalent to the ER-M concentration. The apparent effects threshold for lead (300 ppm) on

**Table 70. Summary of ER-L, ER-M, and overall apparent effects thresholds concentrations for selected chemicals in sediment (dry weight).**

| Chemical Analyte | ER-L Concentration | ER-M Concentration | ER-L:ER-M Ratio | Overall Apparent Effects Threshold | Subjective Degree of Confidence in ER-L/ER-M Values |
|---|---|---|---|---|---|
| **Trace Elements (ppm)** | | | | | |
| Antimony | 2 | 25 | 12.5 | 25 | Moderate/moderate |
| Arsenic | 33 | 85 | 2.6 | 50 | Low/moderate |
| Cadmium | 5 | 9 | 1.8 | 5 | High/high |
| Chromium | 80 | 145 | 1.8 | No | Moderate/moderate |
| Copper | 70 | 390 | 5.6 | 300 | High/high |
| Lead | 35 | 110 | 3.1 | 300 | Moderate/high |
| Mercury | 0.15 | 1.3 | 8.7 | 1 | Moderate/high |
| Nickel | 30 | 50 | 1.7 | NSD* | Moderate/moderate |
| Silver | 1 | 2.2 | 2.2 | 1.7 | Moderate/moderate |
| Tin | NA | NA | NA | NA | NA |
| Zinc | 120 | 270 | 2.2 | 260 | High/high |
| **Polychlorinated Biphenyls (ppb)** | | | | | |
| Total PCBs | 50 | 400 | 7.6 | 370 | Moderate/moderate |
| **DDT and Metabolites (ppb)** | | | | | |
| DDT | 1 | 7 | 7 | 6 | Low/low |
| DDD | 2 | 20 | 10 | NSD | Moderate/low |
| DDE | 2 | 15 | 7.5 | NSD | Low/low |
| Total DDT | 3 | 350 | 117 | No | Moderate/moderate |
| **Other Pesticides (ppb)** | | | | | |
| Lindane | NA | NA | NA | NSD | NA** |
| Chlordane | 0.5 | 6 | 12 | 2 | Low/low |
| Heptachlor | NA | NA | NA | NSD | NA |
| Dieldrin | 0.02 | 8 | 400 | No | Low/low |
| Aldrin | NA | NA | NA | NSD | NA |
| Endrin | 0.02 | 45 | 2250 | NSD | Low/low |
| Mirex | NA | NA | NA | NSD | NA |
| **Polynuclear Aromatic Hydrocarbons (ppb)** | | | | | |
| Acenaphthene | 150 | 650 | 4.3 | 150 | Low/low |
| Anthracene | 85 | 960 | 11.3 | 300 | Low/moderate |
| Benzo(a)anthracene | 230 | 1600 | 7 | 550 | Low/moderate |
| Benzo(a)pyrene | 400 | 2500 | 6.2 | 700 | Moderate/moderate |
| Benzo(e)pyrene | NA | NA | NA | NSD | NA |
| Biphenyl | NA | NA | NA | NSD | NA |
| Chrysene | 400 | 2800 | 7 | 900 | Moderate/moderate |
| Dibenz(a,h)anthracene | 60 | 260 | 4.3 | 100 | Moderate/moderate |
| 2,6-dimethylnaphthylene | NA | NA | NA | NSD | NA |
| Fluoranthene | 600 | 3600 | 6 | 1000 | High/high |
| Fluorene | 35 | 640 | 18.3 | 350 | Low/low |
| 1-methylnaphthalene | NA | NA | NA | NSD | NA |
| 2-methylnaphthalene | 65 | 670 | 10.3 | 300 | Low/moderate |
| 1-methylphenanthrene | NA | NA | NA | NSD | NA |
| Naphthalene | 340 | 2100 | 6.2 | 500 | Moderate/high |
| Perylene | NA | NA | NA | NSD | NA |
| Phenanthrene | 225 | 1380 | 6.1 | 260 | Moderate/moderate |
| Pyrene | 350 | 2200 | 6.3 | 1000 | Moderate/moderate |
| 2,3,5-trimethylnaphthalene | NA | NA | NA | NSD | NA |
| Total PAH | 4000 | 35000 | 8.8 | 22000 | Low/low |

* NSD = not sufficient data
** NA = not available

the other hand, was considerably higher than the respective ER-M concentration (110 ppm), resulting in a somewhat lower degree of confidence in the ER-M value for lead.

**Evaluation of NS&T Program Data**

The ER-L and ER-M concentrations were compared with the ambient concentrations measured by both the Benthic Surveillance Project (3-letter site location codes) and Mussel Watch Project (4-letter site description codes) of the NS&T Program. The data from the NS&T Program were assembled from (usually) 2 successive years of measurements at numerous sites around the coastal United States. Overall average concentrations were calculated for each analyte measured in sediments from each site. Those sites in which the average analyte concentrations exceeded the respective ER-M values are listed in Table 71. Those sites in which the average analyte concentrations exceeded the respective ER-L values, but not the ER-M values, are listed in Table 72.

The ER-L and ER-M values for arsenic were not reached or exceeded at any NS&T sampling site. The average ambient concentrations of antimony, cadmium, copper, and total PAH did not exceed the respective ER-M values at any of the sites.

Among the trace metals, the ER-M value for chromium was exceeded by sediments from the most sites (25 out of about 200 sites). The average chromium concentration of 2114 ppm observed in the sediments from site SAL (located in Salem Harbor, Massachusetts) was the highest, exceeding the ER-M value by over an order of magnitude. Chromium concentrations also were very high at sites PAB (in San Pablo Bay, California) and HMB (in Humboldt Bay, California). Average lead concentrations were highest in site OEIH (in the Oakland estuary, California), exceeding the ER-M by about twofold. The ER-M of 1.3 ppm for mercury was exceeded by the average concentrations at six sites, including an average of 3.3 ppm at site HRUB (located in the Hudson/Raritan estuary, New Jersey). The average nickel concentrations at 21 sites exceeded the ER-M value for nickel. The average silver concentration of 7.2 ppm at site BOS (located in Boston Harbor, Massachusetts) exceeded the ER-M by about threefold. All but one of the sites that exceeded the silver ER-M were located in Northeast estuaries or bays.

The ER-M concentrations for many of the aromatic hydrocarbons were either not exceeded by the average ambient concentrations or exceeded at only one or two sites. Site HRUB exceeded many of the ER-M values for individual PAH and nearly exceeded the ER-M value for total PAH. Site BOS also had relatively high concentrations of some PAHs.

The average PCB concentration in site BOS was about 20 times higher than the ER-M for PCB. PCB concentrations also were high at site SAWB (located in Saint Andrew Bay in western Florida). The ER-M for total DDT was exceeded by four sites in southern California located near each other (PVRP, SPFP, SPB, SPC) and a site (CBSP) in Choctawatchee Bay, Florida. Chlordane concentrations at site CBSP and at site OEIH, located in the Oakland Inner Harbor, California, were over two-fold higher than the ER-M value.

The ER-L concentration for arsenic was not exceeded at any of the sites. The ER-L values for many of the metals, notably, chromium, copper, lead, mercury, nickel, and zinc, were exceeded by the ambient concentrations at many of the sites (Table 72). The average cadmium concentrations and acenaphthene concentrations exceeded the respective ER-L values at only two sites each. Average ambient concentrations of dieldrin, total DDT, anthracene, benzo(a)anthracene, fluoranthene, phenanthrene, and pyrene at many sites exceeded the respective ER-L values. The ER-L concentrations were sufficiently low for dieldrin and total DDT, that the average concentrations at the majority of the NS&T Program sites exceeded them. The dieldrin and total DDT data from the NS&T Program suggest that the ER-L values for these two contaminants are possibly unrealistically low, since the concentrations at such a large number of sites exceeded them.

Tables 73 and 74 summarize and rank the sites in which the average analyte concentrations exceeded the most ER-M and ER-L values, respectively. Those sites that had the greatest numbers of exceedances were those in which the potential for adverse effects were assumed to be the highest. The sediment collected at the OEIH and HRUB sites exceeded the most ER-M concentrations (Table 73). Sites HRRB and NYSH (both in the Hudson/Raritan estuary), LITN (western Long Island Sound), and BOS also exceeded many of the ER-M concentrations.

Sites BHDI (Boston Harbor), LISI, LIMR, LIHH (all Long Island Sound), and CBMP (Chesapeake Bay) exceeded the most ER-L concentrations (Table 74). As expected, the sediments from many more sites exceeded the ER-L concentrations than exceeded the ER-M values.

Overall cumulative ranks of the top 30 sites are listed in Table 75. These ranks were determined by considering exceedances of both the ER-L and ER-M concentrations. One point was assigned for each ER-L concentration exceeded by the sediments at each site. The average ratio of the ER-L values to the ER-M values in Table 70 was 4.2 for the metals and 8.1 for the organics (excluding total DDT, dieldrin, and endrin). Using these average ratios, 4.4 points were assigned for each metal ER-M that was exceeded at a site and 8.4 points for each organic ER-M that was exceeded. Then, the sum of the points for the ER-L and ER-M exceedances at each site was determined and used to formulate an overall rank of the sites.

Based upon this approach, site HRUB ranked highest in overall potential for inducing sediment-related effects (Table 75), followed by sites BOS, OEIH, and LITN. Sites LISI and LIMR sediments exceeded 20 ER-L concentrations each, but exceeded none of the ER-M concentrations. Sites PVRP, SPFP, SPB, and SPC, all located near Los Angeles, California, exceeded relatively few ER-L values, but exceeded some of the ER-M concentrations for DDT, its derivatives, and other organics. Only one site along the Gulf of Mexico coastline, site CBSP in Choctawatchee Bay, Florida, ranked among the top 30 sites. It had high concentrations of pesticides.

The sampling sites with the highest potential for adverse effects are located within the Hudson/Raritan estuary, western Long Island Sound, Boston Harbor, Chesapeake Bay, New York Bight, Oakland Inner Harbor of San Francisco Bay, St. Andrew Bay, Salem Harbor, and in parts of southern California near Los Angeles and San Pedro. Out of a total of 212 sampling sites, 172 sites exceeded at least one ER-L value. Most of the sites that did not exceed ER-L values were located along the Gulf Coast and along the outer coastal regions of the Pacific Coast. Site UISB, located in a very remote portion of Alaska and assumed to be a relatively pristine area, exceeded the ER-L values for antimony, chromium, and nickel.

## CONCLUSIONS AND RECOMMENDATIONS

Effects-based national sediment quality criteria are not currently available for all of the NS&T Program analytes. Three major approaches to the determination of effects-based sediment quality standards have been used to generate an estimate of the concentrations of selected toxicants in sediments that may be associated with or the cause of biological effects. The three approaches involve the use of equilibrium-partitioning principles, spiked-sediment bioassays, and various methods of evaluating matching biological effects and chemical data from analyses of field-collected samples. The resulting sediment quality values derived from all three approaches were used in the present document and treated as equal. A preponderance of evidence from the various approaches was used to establish informal guidelines for use in the evaluation of NOAA NS&T Program sediment chemical data. By using a preponderance of evidence, the influence of any single value in setting guidelines was minimized. These guidelines were in two forms: concentrations at the low end of the range and equivalent to the median of the range within which biological effects were observed.

ER-L values were determined as the concentrations equivalent to the lower 10 percentile of the available data in which effects were detected. These values represent an approximation of the concentrations at which adverse effects were first detected. The ER-M values were determined as the concentrations equivalent to the median (50 percentile) of the available data in which effects were detected. These values represent an estimate of the concentrations at or above which effects were often detected. Both the ER-L and ER-M values were established objectively by determining the lower 10 percentile and 50 percentile points in the data. This approach followed that of Klapow and Lewis (1979) in which marine water quality standards for California were established. In that effort, Klapow and Lewis (1979) evaluated only spiked water bioassay data, i.e., they compared apples with apples. In the present effort, data from a variety of approaches and from studies performed in areas with significantly different pollution histories were evaluated, equivalent to comparing grapes and watermelons. The necessity to compare grapes and watermelons is symptomatic of the current status of knowledge regarding the degree of sediment contamination that is associated with measures of biological effects.

ER-L and ER-M guidelines were identified for most (31) of the chemical analytes that are quantified by the NS&T Program. However, no guidelines could be established for some analytes due to a lack of sufficient data. For some analytes, there was a very low degree of confidence in the accuracy of the guidelines, due mainly to relatively poor consistency among the data from the various approaches and/or due to a lack of data from multiple complimentary approaches. For a few analytes, such as cadmium, there was good consistency among the data. Data from many approaches converged upon a relatively small range in concentrations and an overall apparent effects threshold agreed with or was within the effects range, and, therefore, there was a relatively high degree in confidence in the informal guidelines. Except for these latter few analytes, it is very obvious that more data are needed to reduce the uncertainty in the data.

**Table 71. ER-M concentrations for each NS&T Program analyte, NS&T Program sites that exceed the ER-M concentrations, geographic locations of those sites, and the average concentrations (dry weight) of the analyte at the site.**

| Site Description | Location | Concentration |
|---|---|---|
| **Antimony (≥25 ppm) *** | | |
| **Arsenic (≥85 ppm) *** | | |
| **Cadmium (≥9 ppm) *** | | |
| **Chromium (≥145 ppm)** | | **ppm** |
| BBSM | Bellingham Bay, Washington | 203.0 |
| BHDI | Boston Harbor, Massachusetts | 190.7 |
| BHDB | Boston Harbor, Massachusetts | 186.7 |
| HRLB | Hudson-Raritan Estuary, New Jersey | 147.2 |
| HRRB | Hudson-Raritan Estuary, New Jersey | 170.0 |
| LITN | Long Island Sound, New York | 161.4 |
| NYSH | New York Bight, New Jersey | 166.7 |
| PVRP | Palos Verdes, California | 156.7 |
| PVMC | Port Valdez, Alaska | 156.7 |
| SFDB | San Francisco Bay, California | 170.0 |
| SFEM | San Francisco Bay, California | 178.3 |
| SFSM | San Francisco Bay, California | 167.5 |
| SPSP | San Pablo Bay, California | 185.0 |
| TBSR | Tomales Bay, California | 218.3 |
| YHSS | Yaquina Bay, Oregon | 176.7 |
| OEIH | Oakland Estuary, California | 186.7 |
| BOD | Bodega Bay, California | 349.7 |
| BOS | Boston Harbor, Massachusetts | 263.3 |
| HMB | Humboldt Bay, California | 453.7 |
| HUN | San Francisco Bay, California | 269.7 |
| OAK | Oakland Estuary, California | 196.0 |
| PAB | San Pablo Bay, California | 521.8 |
| RAR | Raritan Bay, New Jersey | 188.9 |
| SAL | Salem Harbor, Massachusetts | 2114.7 |
| SHS | San Francisco Bay, California | 259.2 |

Table 71. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Copper (≥390 ppm) *** | | |
| **Lead (≥110 ppm)** | | **ppm** |
| BHDI | Boston Harbor, Massachusetts | 110.0 |
| BHDB | Boston Harbor, Massachusetts | 132.3 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 143.7 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 137.3 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 196.7 |
| LIHH | Long Island Sound, New York | 140.0 |
| LITN | Long Island Sound, New York | 172.2 |
| NYSH | New York Bight, New Jersey | 154.5 |
| OEIH | Oakland Estuary, California | 206.7 |
| BOS | Boston Harbor, Massachusetts | 127.0 |
| LNB | Long Beach Harbor, California | 126.3 |
| RAR | Raritan Bay, New Jersey | 182.3 |
| SAL | Salem Harbor, Massachusetts | 167.2 |
| **Mercury (≥1.3 ppm)** | | **ppm** |
| HRLB | Hudson/Raritan Estuary, New Jersey | 1.6 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 3.3 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 2.4 |
| NYSH | New York Bight, New Jersey | 1.8 |
| OEIH | Oakland Estuary, California | 2.3 |
| RAR | Raritan Bay, New Jersey | 2.3 |
| **Nickel (≥50 ppm)** | | **ppm** |
| BBSM | Bellingham Bay, Washington | 168.3 |
| BPBP | Barber's Point, Hawaii | 58.3 |
| CBHP | Chesapeake Bay, Maryland | 55.0 |
| CBMP | Chesapeake Bay, Maryland | 64.7 |
| OEIH | Oakland Estuary, California | 133.3 |
| PVMC | Port Valdez, Alaska | 65.7 |
| SFDB | San Francisco Bay, California | 90.8 |
| SFEM | San Francisco Bay, California | 110.0 |
| SFSM | San Francisco Bay, California | 112.5 |
| SPFP | San Pedro Bay, California | 55.0 |
| SPSP | San Pablo Bay, California | 121.8 |
| TBSR | Tomales Bay, California | 166.7 |
| WIPP | Whidbey Island, Washington | 56.4 |
| BOD | Bodega Bay, California | 54.8 |
| HMB | Humboldt Bay, California | 60.1 |
| HUN | San Francisco Bay, California | 100.3 |
| OAK | Oakland Estuary, California | 104.0 |
| PAB | San Pablo Bay, California | 87.8 |
| SHS | San Francisco Bay, California | 72.1 |
| UCB | Chesapeake Bay, Maryland | 62.2 |
| **Silver (≥2.2 ppm)** | | **ppm** |
| BHDI | Boston Harbor, Massachusetts | 3.1 |
| BHDB | Boston Harbor, Massachusetts | 3.1 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 2.4 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 4.6 |

Table 71. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Silver (continued)** | | **ppm** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 3.4 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 4.8 |
| LIHH | Long Island Sound, New York | 4.9 |
| LITN | Long Island Sound, New York | 5.7 |
| NBMH | Narragansett Bay, Rhode Island | 2.2 |
| NYSH | New York Bight | 4.0 |
| PVRP | Palos Verdes, California | 2.8 |
| BOS | Boston Harbor, Massachusetts | 7.2 |
| RAR | Raritan Bay, New Jersey | 4.7 |
| **Zinc (≥270 ppm)** | | **ppm** |
| CBHP | Chesapeake Bay, Maryland | 300.0 |
| CBMP | Chesapeake Bay, Maryland | 385.0 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 366.7 |
| LIHH | Long Island Sound, New York | 283.3 |
| NYSH | New York Bight, New Jersey | 281.7 |
| OEIH | Oakland Estuary, California | 330.0 |
| RAR | Raritan Bay, New Jersey | 421.5 |
| SDA | San Diego Bay, California | 324.2 |
| **PCBs (≥380 ppb)** | | **ppb** |
| BBAR | Buzzards Bay, Massachusetts | 451.2 |
| BHDB | Boston Harbor, Massachusetts | 642.2 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 393.7 |
| LITN | Long Island Sound, Connecticut | 499.2 |
| NYSH | New York Bight, New Jersey | 431.2 |
| PVRP | Palos Verdes, California | 568.6 |
| SAWB | Saint Andrew Bay, Florida | 940.8 |
| BOS | Boston Harbor, Massachusetts | 7852 |
| ELL | Elliott Bay, Washington | 415 |
| RAR | Hudson/Raritan Bay, New Jersey | 529 |
| SAL | Salem Harbor, Massachusetts | 403 |
| SDA | San Diego Harbor, California | 399 |
| **Dieldrin (≥8 ppb)** | | **ppb** |
| BHDB | Boston Harbor, Massachusetts | 12.9 |
| OEIH | Oakland Estuary, California | 12.0 |
| LITN | Long Island Sound, New York | 9.6 |
| **DDT (p,p' + o,p'-DDT) (≥7 ppb)** | | **ppb** |
| CBSP | Choctawatchee Bay, Florida | 182.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 9.1 |
| MBTP | Matagorda Bay, Texas | 9.6 |
| MBTH | Moriches Bay, New York | 14.9 |
| OSBJ | Oceanside, California | 7.6 |
| OEIH | Oakland Estuary, California | 10.1 |
| PVRP | Palos Verdes, California | 556.0 |
| SPFP | San Pedro Harbor, California | 7.1 |
| SAWB | Saint Andrew Bay, Florida | 8.3 |
| RAR | Raritan Bay, New Jersey | 8 |

Table 71. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **DDT (p,p' + o,p'-DDT) (continued)** | | ppm |
| SPB | San Pedro Bay, California | 31.7 |
| SPC | San Pedro Canyon, California | 11.3 |
| **DDD (p,p' + o,p' - DDD) (≥20 ppb)** | | **ppb** |
| BHDB | Boston Harbor, Massachusetts | 23.0 |
| CBSP | Choctawatchee Bay, Florida | 555.7 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 27.3 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 21.6 |
| LIHH | Long Island Sound, Connecticut | 24.6 |
| LITN | Long Island Sound, Connecticut | 47.8 |
| NYSH | New York Bight, New Jersey | 21.6 |
| OEIH | Oakland Estuary, California | 58.1 |
| PVRP | Palos Verdes, California | 815.2 |
| SPFP | San Pedro Harbor, California | 90.5 |
| BOS | Boston Harbor, Massachusetts | 44.2 |
| LNB | Long Beach Harbor, California | 30.7 |
| SAL | Salem Harbor, Massachusetts | 21.3 |
| SPB | San Pedro Bay, California | 45.7 |
| SPC | San Pedro Canyon, California | 54.0 |
| **DDE (p,p' + o,p' - DDE) (≥15 ppb)** | | **ppb** |
| ABWJ | Anaheim Bay, California | 20.5 |
| BHDB | Boston Harbor, Massachusetts | 19.1 |
| CBSP | Choctawatchee Bay, Florida | 80.6 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 15.7 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 15.0 |
| LITN | Long Island Sound, New York | 21.7 |
| MDSJ | Marina del Rey, California | 57.4 |
| NYSH | New York Bight, New York | 19.3 |
| NBBC | Newport Beach, California | 19.4 |
| OSBJ | Oceanside, California | 27.8 |
| PVRP | Palos Verdes, California | 2063.3 |
| SBSB | Point Santa Barbara, California | 21.3 |
| SPFP | San Pedro Harbor, California | 663.5 |
| BOS | Boston Harbor, Massachusetts | 58.2 |
| LNB | Long Beach Harbor, California | 76.6 |
| SEA | Seal Beach, California | 22.2 |
| SMB | Santa Monica Bay, California | 19.0 |
| SPB | San Pedro Bay, California | 408.3 |
| SPC | San Pedro Canyon, California | 621.3 |
| **Total DDT (≥350 ppb)** | | **ppb** |
| CBSP | Choctawatchee Bay, Florida | 818.3 |
| PVRP | Palos Verdes, California | 2936.4 |
| SPFP | San Pedro Harbor, California | 769.1 |
| SPB | San Pedro Bay, California | 485.4 |
| SPC | San Pedro Canyon, California | 578.6 |

**Table 71. (continued)**

| Site Description | Location | Concentration |
|---|---|---|
| **Chlordane (≥6 ppb)** | | **ppb** |
| CBSP | Choctawatchee Bay, Florida | 18.9 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 6.8 |
| LIHH | Long Island Sound, New York | 7.3 |
| OEIH | Oakland Estuary, California | 14.3 |
| LITN | Long Island Sound, New York | 8.5 |
| **Acenaphthene (≥650 ppb) *** | | **ppb** |
| **Anthracene (≥960 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 1983.3 |
| SAWB | Saint Andrew Bay, Florida | 1082.3 |
| SAL | Salem Harbor, Massachusetts | 1100.6 |
| **Benzo(a)anthracene (≥1600 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 3258.3 |
| **Benzo(a)pyrene (≥2500 ppb)*** | | |
| **Chrysene (≥2800 ppb) *** | | |
| **Fluoranthene (≥3600 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 4616.7 |
| **Fluorene (≥640 ppb) *** | | |
| **Naphthalene (≥2100 ppb) *** | | |
| **Phenanthrene (≥1380 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 2505.8 |
| **Pyrene (≥2200 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 6096.7 |
| **2-methylnaphthalene (≥670 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Estuary, New Jersey | 830.0 |
| BOS | Boston Harbor, Massachusetts | 3774.3 |
| **Dibenz(a,h)anthracene (≥260 ppb)** | | **ppb** |
| BOS | Boston Harbor, Massachusetts | 385.6 |
| **Total PAH (≥35000 ppb)*** | | **ppb** |

* Ambient concentrations at none of the sites exceeded or equaled the ER-M for these chemical analytes.

**Table 72. ER-L and ER-M concentrations for each NS&T Program analyte, NS&T Program sites at which the average concentrations exceeded the ER-L concentrations but not the ER-M concentrations, geographic locations of those sites, and the average concentrations (dry weight) of the analyte at the site.**

| Site Description | Location | Concentration |
|---|---|---|
| **Antimony (≥2 <10 ppm)** | | **ppm** |
| BBSM | Bellingham Bay, Washington | 3.6 |
| BHDI | Boston Harbor, Massachusetts | 6.5 |
| BHDH | Boston Harbor, Massachusetts | 7.4 |
| BHHB | Boston Harbor, Massachusetts | 3.9 |
| CBMP | Chesapeake Bay, Maryland | 3.9 |
| CBTP | Commencement Bay, Washington | 4.6 |
| EBFR | Elliott Bay, Washington | 6.4 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 3.3 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 3.6 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 5.0 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 6.0 |
| LIHH | Long Island Sound, New York | 3.2 |
| LITN | Long Island Sound, New York | 4.4 |
| NBMH | Narragansett Bay, Rhode Island | 2.4 |
| NYSH | New York Bight, New Jersey | 5.5 |
| PVMC | Port Valdez, Alaska | 2.9 |
| SSBI | South Puget Sound, Washington | 4.4 |
| SIWP | Sinclair Inlet, Washington | 9.7 |
| UISB | Unakwit Inlet, Alaska | 2.5 |
| WIPP | Whidbey Island, Washington | 3.4 |
| BOS | Boston Harbor, Massachusetts | 7.7 |
| RAR | Raritan Bay, New Jersey | 3.2 |
| SAL | Salem Harbor, Massachusetts | 3.2 |
| UCB | Upper Chesapeake Bay, Maryland | 2.1 |
| **Arsenic (≥33 <70 ppm) *** | | |
| **Cadmium (≥5 <9 ppm)** | | **ppm** |
| PVRP | Palos Verdes, California | 6.7 |
| SAL | Salem Harbor, Massachusetts | 6.2 |
| **Chromium (≥80 <145 ppm)** | | **ppm** |
| CBHP | Chesapeake Bay, Maryland | 113 |
| CBRP | Coos Bay, Oregon | 89.2 |
| DBAP | Delaware Bay, Delaware | 90.7 |
| DBBD | Delaware Bay, Delaware | 87.0 |
| EBFR | Elliott Bay, Washington | 89.7 |
| HRJB | Hudson-Raritan Estuary, New Jersey | 113.7 |
| HRUB | Hudson-Raritan Estuary, New Jersey | 90.3 |
| HMBJ | Humboldt Bay, California | 98.3 |
| LISI | Long Island Sound, Connecticut | 81.7 |
| LIHH | Long Island Sound, New York | 131.7 |
| LIHU | Long Island Sound, New York | 80.6 |
| LIMR | Long Island Sound, New York | 109.6 |
| BUZ | Buzzards Bay, Massachusetts | 85.6 |
| CHS | Charleston Harbor, South Carolina | 81.1 |
| COO | Coos Bay, Oregon | 81.0 |
| CSC | Casco Bay, Maine | 92.6 |
| ELL | Elliott Bay, Washington | 91.8 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Chromium (continued))** | | **ppm** |
| FRN | Frenchman Bay, Maine | 90.1 |
| GRB | Great Bay, New Jersey | 115.3 |
| MOB | Mobile Bay, Alabama | 91.7 |
| NAR | Narragansett Bay, Rhode Island | 101.6 |
| NIS | Puget Sound, Washington | 114.9 |
| PEN | Pensacola Bay, Florida | 102.1 |
| PNB | Penobscot Bay, Maine | 106.1 |
| NBMH | Narragansett Bay, Rhode Island | 140.0 |
| PBSI | Penobscot Bay, Maine | 93.8 |
| PRPR | Point Roberts, Washington | 89.5 |
| SPFP | San Pedro Harbor, California | 123.3 |
| SIWP | Sinclair Inlet, Washington | 135.0 |
| TBHP | Tillamook Bay, Oregon | 134.3 |
| UISB | Unakwit Inlet, Alaska | 128.3 |
| WIPP | Whidbey Island, Washington | 105.1 |
| YBOP | Yaquina Bay, Oregon | 107.3 |
| JFNB | Neah Bay, Washington | 114.7 |
| SDA | San Diego Bay, California | 129.8 |
| SEA | Seal Beach, California | 108.3 |
| SPB | San Pedro Bay, California | 93.0 |
| SPC | San Pedro Canyon, California | 106.5 |
| UCB | Upper Chesapeake Bay, Maryland | 125.2 |
| WLI | West Long Island Sound, New York | 134.2 |
| **Copper (≥70 <310 ppm)** | | **ppm** |
| BHDI | Boston Harbor, Massachusetts | 103.3 |
| BHDH | Boston Harbor, Massachusetts | 118.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 115.3 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 101.0 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 150.0 |
| LINR | Long Island Sound, Connecticut | 167.0 |
| LIHH | Long Island Sound, New York | 160.0 |
| LIHU | Long Island Sound, New York | 78.0 |
| LIMR | Long Island Sound, New York | 95.8 |
| LITN | Long Island Sound, New York | 178.8 |
| NBMH | Narragansett Bay, Rhode Island | 82.3 |
| NYSH | New York Bight, New Jersey | 126.7 |
| PVRP | Palos Verdes, California | 75.0 |
| SPFP | San Pedro Harbor, California | 181.7 |
| SIWP | Sinclair Inlet, Washington | 72.5 |
| OEIH | Oakland Estuary, California | 173.3 |
| BOS | Boston Harbor, Massachusetts | 157.1 |
| ELL | Elliott Bay, Washington | 93.0 |
| NAR | Narragansett Bay, Rhode Island | 79.2 |
| OAK | Oakland Estuary, California | 71.7 |
| RAR | Raritan Bay, New Jersey | 178.0 |
| SAL | Salem Harbor, Massachusetts | 82.3 |
| SDA | San Diego Bay, California | 207.3 |
| SPB | San Pedro Bay, California | 80.4 |
| WLI | West Long Island Sound, New York | 109.2 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Lead (≥35 <110 ppm)** | | **ppm** |
| ABWJ | Anaheim Bay, California | 36.2 |
| BHHB | Boston Harbor, Massachusetts | 35.5 |
| BBAR | Buzzards Bay, Massachusetts | 48.5 |
| CBHP | Chesapeake Bay, Maryland | 72.2 |
| CBSP | Choctawatchee Bay, Florida | 86.7 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 95.3 |
| LICR | Long Island Sound, Connecticut | 39.2 |
| LISI | Long Island Sound, Connecticut | 53.8 |
| LIHU | Long Island Sound, New York | 60.7 |
| LIMR | Long Island Sound, New York | 82.2 |
| MBTH | Moriches Bay, New York | 44.8 |
| NBMH | Narragansett Bay, Rhode Island | 91.7 |
| NBCI | Narragansett Bay, Rhode Island | 40.7 |
| PVRP | Palos Verdes, California | 49.7 |
| SAWB | Saint Andrew Bay, Florida | 40.9 |
| SFDB | San Francisco Bay, California | 38.7 |
| SFEM | San Francisco Bay, California | 35.0 |
| SFSM | San Francisco Bay, California | 35.8 |
| SPFP | San Pedro Harbor, California | 48.8 |
| SIWP | Sinclair Inlet, Washington | 61.8 |
| SSBI | South Puget Sound, Washington | 35.2 |
| TBHB | Tampa Bay, Florida | 62.8 |
| GRB | Great Bay, New Jersey | 36.6 |
| NAR | Narragansett Bay, Rhode Island | 60.0 |
| OAK | Oakland Estuary, California | 43.5 |
| PEN | Pensacola Bay, Florida | 41.7 |
| SDA | San Diego Bay, California | 86.9 |
| SPB | San Pedro Bay, California | 47.1 |
| UCB | Upper Chesapeake Bay, Maryland | 51.1 |
| WLI | West Long Island Sound, New York | 71.1 |
| **Mercury (≥0.15<1.0 ppm)** | | **ppm** |
| BBSM | Bellingham Bay, Washington | 0.23 |
| BHDI | Boston Harbor, Massachusetts | .69 |
| BHDH | Boston Harbor, Massachusetts | .83 |
| BHHB | Boston Harbor, Massachusetts | .21 |
| CBHP | Chesapeake Bay, Maryland | .21 |
| CBMP | Chesapeake Bay, Maryland | .22 |
| DBBD | Delaware Bay, Delaware | .15 |
| HHKL | Honolulu Harbor, Hawaii | .16 |
| LICR | Long Island Sound, Connecticut | .16 |
| LISI | Long Island Sound, Connecticut | .31 |
| LIHH | Long Island Sound, New York | .60 |
| LIHU | Long Island Sound, New York | .27 |
| LIMR | Long Island Sound, New York | .37 |
| MBGP | Matagorda Bay, Texas | .22 |
| MBTH | Moriches Bay, New York | .29 |
| NBDI | Narragansett Bay, Rhode Island | .15 |
| NBMH | Narragansett Bay, Rhode Island | .81 |
| NBCI | Narragansett Bay, Rhode Island | .16 |
| PVRP | Palos Verdes, California | .40 |
| PBSI | Penobscot Bay, Maine | .21 |

| Site Description | Location | Concentration |
|---|---|---|
| **Mercury (continued)** | | **ppm** |
| SAWB | Saint Andrew Bay, Florida | .32 |
| SDHI | San Diego Bay, California | .34 |
| SFDB | San Francisco Bay, California | .28 |
| SFEM | San Francisco Bay, California | .32 |
| SFSM | San Francisco Bay, California | .30 |
| SPSP | San Pablo Bay, California | .27 |
| SPFP | San Pedro Harbor, California | .46 |
| SIWP | Sinclair Inlet, Washington | .80 |
| SSBI | South Puget Sound, Washington | .21 |
| TBSR | Tomales Bay, California | .37 |
| DAN | Dana Point, California | .18 |
| ELL | Elliott Bay, Washington | .43 |
| GRB | Great Bay, New Jersey | .42 |
| HUN | San Francisco Bay, California | .18 |
| LUT | Lutak Inlet, Alaska | .24 |
| NAH | Nahku Bay, Alaska | .23 |
| NAR | Narragansett Bay, Rhode Island | .30 |
| NIS | Puget Sound, Washington | .17 |
| OAK | Oakland Estuary, California | .50 |
| OLI | Oliktok Point, Alaska | .27 |
| PAB | San Pablo Bay, California | .37 |
| **Nickel (≥30 <50 ppm)** | | **ppm** |
| BHDH | Boston Harbor, Massachusetts | 30.8 |
| CHFJ | Charleston Harbor, South Carolina | 33.0 |
| DBAP | Delaware Bay, Delaware | 30.3 |
| DBBD | Delaware Bay, Delaware | 32.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 33.5 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 35.3 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 40.3 |
| LIHH | Long Island Sound, New York | 41.2 |
| LIMR | Long Island Sound, New York | 38.7 |
| LITN | Long Island Sound, New York | 43.4 |
| PRPR | Point Roberts, Washington | 39.8 |
| SIWP | Sinclair Inlet, Washington | 47.0 |
| SSBI | South Puget Sound, Washington | 49.0 |
| TBHP | Tillamook Bay, Oregon | 42.7 |
| BOS | Boston Harbor, Massachusetts | 33.4 |
| ELL | Elliott Bay, Washington | 36.5 |
| FRN | Frenchman Bay, Maine | 31.9 |
| LNB | Long Beach, California | 41.7 |
| MOB | Mobile Bay, Alabama | 35.3 |
| NIS | Puget Sound, Washington | 33.5 |
| OLI | Oliktok Point, Alaska | 36.5 |
| PNB | Penobscot Bay, Maine | 32.6 |
| RAR | Raritan Bay, New Jersey | 39.3 |
| SPB | San Pedro Bay, California | 39.0 |
| WLI | West Long Island Sound, New York | 33.3 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Silver (≥1.0 <2.2 ppm)** | | **ppm** |
| BHHB | Boston Harbor, Massachusetts | 1.1 |
| CBSP | Choctawatchee Bay, Florida | 1.0 |
| LIMR | Long Island Sound, New York | 1.4 |
| MDSJ | Marina del Rey, California | 1.0 |
| SPFP | San Pedro Bay, California | 1.0 |
| OEIH | Oakland Estuary, California | 1.3 |
| NAR | Narragansett Bay, Rhode Island | 1.2 |
| SAL | Salem Harbor, Massachusetts | 1.8 |
| WLI | West Long Island Sound, New York | 1.6 |
| **Zinc (≥120 <260 ppm)** | | **ppm** |
| BBSM | Bellingham Bay, Washington | 128.3 |
| BHDI | Boston Harbor, Massachusetts | 145.2 |
| BHDH | Boston Harbor, Massachusetts | 182.8 |
| DBAP | Delaware Bay, Delaware | 139.0 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 143.7 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 204.7 |
| LICR | Long Island Sound, Connecticut | 127.2 |
| LISI | Long Island Sound, Connecticut | 161.5 |
| LIHU | Long Island Sound, New York | 181.3 |
| LIMR | Long Island Sound, New York | 213.3 |
| NBMH | Narragansett Bay, Rhode Island | 190.0 |
| PVRP | Palos Verdes, California | 193.3 |
| PVMC | Port Valdez, Alaska | 150.0 |
| SDHI | San Diego Bay, California | 124.3 |
| SFDB | San Francisco Bay, California | 136.7 |
| SFSM | San Francisco Bay, California | 127.5 |
| SPSP | San Pablo Bay, California | 131.7 |
| SIWP | Sinclair Inlet, Washington | 132.7 |
| SSBI | South Puget Sound, Washington | 123.3 |
| TBSR | Tomales Bay, California | 120.0 |
| ELL | Elliott Bay, Washington | 176.8 |
| GRB | Great Bay, New Jersey | 159.0 |
| HUN | San Francisco Bay, California | 127.3 |
| LNB | Long Beach, California | 195.7 |
| LUT | Lutak Inlet, Alaska | 180.8 |
| MOB | Mobile Bay, Alabama | 159.2 |
| NAH | Nahku Bay, Alaska | 191.3 |
| NAR | Narragansett Bay, Rhode Island | 143.4 |
| OAK | Oakland Estuary, California | 171.7 |
| PEN | Pensacola Bay, Florida | 138.2 |
| SAL | Salem Harbor, Massachusetts | 218.5 |
| SEA | Seal Beach, California | 125.0 |
| SPB | San Pedro Bay, California | 155.0 |
| UCB | Upper Chesapeake Bay, Maryland | 240.8 |
| WLI | West Long Island Sound, New York | 234.2 |
| **Acenaphthene (≥150 <650 ppb)** | | **ppb** |
| HRUB | Hudson/Raritan Bay, New Jersey | 368.3 |
| BOS | Boston Harbor, Massachusetts | 158.8 |

**Table 72 (continued)**

| Site Description | Location | Concentration |
|---|---|---|
| **Anthracene (≥85 <900 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 97 0 |
| BHDH | Boston Harbor, Massachusetts | 160.7 |
| CBHP | Chesapeake Bay, Maryland | 145.0 |
| CBMP | Chesapeake Bay, Maryland | 168.3 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 160.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 441.7 |
| LICR | Long Island Sound, Connecticut | 113.1 |
| LIHR | Long Island Sound, Connecticut | 140.0 |
| LISI | Long Island Sound, Connecticut | 262.0 |
| LIHH | Long Island Sound, Connecticut | 125.5 |
| LITN | Long Island Sound, Connecticut | 458.7 |
| MSBB | Mississippi Sound, Mississippi | 153.0 |
| NBMH | Narragansett Bay, Rhode Island | 85.7 |
| NYSH | New York Bight, New York | 228.3 |
| PBPI | Penobscot Bay, Maine | 93.3 |
| PBSI | Penobscot Bay, Maine | 89.7 |
| SIWP | Sinclair Inlet, Washington | 116.7 |
| OEIH | Oakland Estuary, California | 170.0 |
| BOS | Boston Harbor, Massachusetts | 804.9 |
| BUZ | Buzzards Bay, Massachusetts | 143.4 |
| CHS | Charleston Harbor, South Carolina | 135.6 |
| CSC | Casco Bay, Maine | 152.2 |
| DEL | Delaware Bay, Delaware | 110.0 |
| ELL | Elliott Bay, Washington | 156.7 |
| GRB | Great Bay, New Jersey | 120.8 |
| HUN | San Francisco Bay, California | 100.2 |
| NAR | Narragansett Bay, Rhode Island | 187.9 |
| RAR | Raritan Bay, New Jersey | 260.0 |
| SDA | San Diego Bay, California | 830.7 |
| UCB | Upper Chesapeake Bay, Maryland | 97.4 |
| WLI | West Long Island Sound, New York | 354.4 |
| **Benzo(a)anthracene (≥230 <1600 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 470.0 |
| BHDH | Boston Harbor, Massachusetts | 816.7 |
| BBAR | Buzzards Bay, Massachusetts | 397.0 |
| CBMP | Chesapeake Bay, Maryland | 308.3 |
| CBSP | Choctawatchee Bay, Florida | 398.2 |
| HRJB | Hudson/Raritan, New Jersey | 261.7 |
| HRLB | Hudson/Raritan, New Jersey | 993.3 |
| LICR | Long Island Sound, Connecticut | 462.1 |
| LIHR | Long Island Sound, Connecticut | 443.3 |
| LIMR | Long Island Sound, New York | 335.0 |
| LISI | Long Island Sound, Connecticut | 530.7 |
| LIHH | Long Island Sound, Connecticut | 370.0 |
| LITN | Long Island Sound, Connecticut | 1107.9 |
| NYSH | New York Bight, New Jersey | 468.3 |
| PBPI | Penobscot Bay, Maine | 369.7 |
| PBSI | Penobscot Bay, Maine | 238.3 |
| SAWB | Saint Andrew Bay, Florida | 962.0 |
| SFSM | San Francisco Bay, California | 280.0 |
| SIWP | Sinclair Inlet, Washington | 260.0 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Benzo(a)anthracene(continued))** | | **ppm** |
| OEIH | Oakland Estuary, California | 356.7 |
| BOS | Boston Harbor, Massachusetts | 971.7 |
| ELL | Elliott Bay, Washington | 308.3 |
| HUN | San Francisco Bay, California | 230.0 |
| RAR | Raritan Bay, New Jersey | 428.5 |
| SAL | Salem Harbor, Massachusetts | 635.7 |
| SDA | San Diego Bay, California | 361.7 |
| WLI | West Long Island Sound, New York | 246.4 |
| **Benzo(a)pyrene (≥400 <2600 ppb)** | | **ppb** |
| BBAR | Buzzards Bay Massachusetts | 434.3 |
| BHDH | Boston Harbor, Massachusetts | 838.3 |
| BHDI | Boston Harbor, Massachusetts | 433.3 |
| CBSP | Choctawatchee Bay, Florida | 620.1 |
| HHKL | Honolulu Harbor, Hawaii | 413.3 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 1005.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 2958.3 |
| LICR | Long Island Sound, Connecticut | 477.9 |
| LIHR | Long Island Sound, Connecticut | 446.7 |
| LIHH | Long Island Sound, New York | 505.0 |
| LIMR | Long Island Sound, New York | 418.8 |
| LISI | Long Island Sound, Connecticut | 551.7 |
| LITN | Long Island Sound, Connecticut | 1305.0 |
| NYSH | New York Bight, New Jersey | 513.3 |
| SAWB | Saint Andrew Bay, Florida | 848.1 |
| OEIH | Oakland Estuary, California | 763.3 |
| BOS | Boston Harbor, Massachusetts | 555.2 |
| HUN | San Francisco Bay, California | 436.7 |
| RAR | Raritan Bay, New Jersey | 514.5 |
| SAL | Salem Harbor, Massachusetts | 504.8 |
| SDA | San Diego Bay, California | 935.0 |
| WLI | West Long Island Sound, New York | 409.2 |
| **Chrysene (≥400 <2800 ppb)** | | **ppb** |
| BBAR | Buzzards Bay, Massachusetts | 422.7 |
| BHDI | Boston Harbor, Massachusetts | 545.0 |
| BHDH | Boston Harbor, Massachusetts | 960.0 |
| CBMP | Chesapeake Bay, Maryland | 483.3 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 1000.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 2653.3 |
| LICR | Long Island Sound, Connecticut | 510.0 |
| LIHR | Long Island Sound, Connecticut | 563.3 |
| LIMR | Long Island Sound, New Y ork | 490.0 |
| LISI | Long Island Sound, Connecticut | 683.8 |
| LIHH | Long Island Sound, Connecticut | 561.7 |
| LITN | Long Island Sound, Connecticut | 1244.2 |
| NYSH | Long Island Sound, Connecticut | 541.7 |
| OEIH | Oakland Estuary, California | 566.7 |
| SAWB | Saint Andrews Bay, Florida | 419.8 |
| BOS | Boston Harbor, Massachusetts | 777.1 |
| ELL | Elliott Bay, Washington | 653.3 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Chrysene (continued))** | | **ppm** |
| RAR | Raritan Bay, New Jersey | 519.8 |
| SAL | Salem Harbor, Massachusetts | 595.0 |
| SDA | San Diego Bay, California | 920.0 |
| **Fluoranthene (≥600 <3600 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 723.3 |
| BHDH | Boston Harbor, Massachusetts | 1031.7 |
| CBMP | Chesapeake Bay, Maryland | 1338.8 |
| CBSP | Choctawatchee Bay, Florida | 646.7 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 1481.7 |
| LICR | Long Island Sound, Connecticut | 778.3 |
| LIHR | Long Island Sound, Connecticut | 1216.7 |
| LISI | Long Island Sound, Connecticut | 1323.3 |
| LIHH | Long Island Sound, Connecticut | 835.0 |
| LIMR | Long Island Sound, Connecticut | 846.7 |
| LITN | Long Island Sound, Connecticut | 1576.2 |
| NYSH | New York Bight, New Jersey | 698.3 |
| PBPI | Penobscot Bay, Maine | 926.7 |
| SAWB | Saint Andrew Bay, Florida | 1503.7 |
| OEIH | Oakland Estuary, California | 826.7 |
| BOS | Boston Harbor, Massachusetts | 1401.4 |
| ELL | Elliott Bay, Washington | 618.3 |
| RAR | Raritan Bay, New Jersey | 615.7 |
| SAL | Salem Harbor, Massachusetts | 1031.9 |
| **Fluorene (≥35 <540 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 37.0 |
| BHDH | Boston Harbor, Massachusetts | 54.8 |
| CBHP | Chesapeake Bay, Maryland | 134.5 |
| CBMP | Chesapeake Bay, Maryland | 145.0 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 55.7 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 114.8 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 358.3 |
| LISI | Long Island Sound, Connecticut | 130.0 |
| LIHH | Long Island Sound, Connecticut | 66.8 |
| LITN | Long Island Sound, Connecticut | 109.9 |
| MSBB | Mississippi Sound, Mississippi | 68.8 |
| NYSH | New York Bight, New Jersey | 68.3 |
| SAWB | Saint Andrew Bay, Florida | 109.5 |
| BOS | Boston Harbor, Massachusetts | 246.0 |
| ELL | Elliott Bay, Washington | 83.8 |
| RAR | Raritan Bay, New Jersey | 49.2 |
| SDA | San Diego Bay, California | 129.0 |
| SJR | Saint Johns River, Florida | 43.2 |
| UCB | Upper Chesapeake Bay, Maryland | 87.8 |
| **Naphthalene (≥340 <2100 ppb)** | | **ppb** |
| CBMP | Chesapeake Bay, Maryland | 415.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 698.3 |
| SAWB | Saint Andrew Bay, Florida | 459.3 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Naphthalene (continued)** | | **ppb** |
| BOS | Boston Harbor, Massachusetts | 1415.7 |
| UCB | Upper Chesapeake Bay, Maryland | 403.2 |
| **Phenanthrene (≥225 <1380 ppb)** | | **ppb** |
| BBSM | Bellingham Bay, Washington | 285.0 |
| BHDI | Boston Harbor, Massachusetts | 353.3 |
| BHDH | Boston Harbor, Massachusetts | 543.3 |
| BBRH | Buzzards Bay, Massachusetts | 310.0 |
| CBHP | Chesapeake Bay, Maryland | 511.7 |
| CBMP | Chesapeake Bay, Maryland | 611.7 |
| CBSP | Choctawatchee Bay, Florida | 247.0 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 269.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 683.3 |
| LICR | Long Island Sound, Connecticut | 355.8 |
| LIHR | Long Island Sound, Connecticut | 600.0 |
| LISI | Long Island Sound, Connecticut | 872.7 |
| LIHH | Long Island Sound, Connecticut | 391.7 |
| LIMR | Long Island Sound, Connecticut | 345.0 |
| LITN | Long Island Sound, Connecticut | 753.3 |
| MSBB | Mississippi Sound, Mississippi | 295.8 |
| NBDI | Narragansett Bay, Rhode Island | 303.7 |
| NYSH | New York Bight, New Jersey | 366.7 |
| PBPI | Penobscot Bay, Maine | 398.0 |
| PBSI | Penobscot Bay, Maine | 261.7 |
| SAWB | Saint Andrew Bay, Florida | 448.8 |
| OEIH | Oakland Estuary, California | 326.7 |
| BOS | Boston Harbor, Massachusetts | 979.0 |
| ELL | Elliott Bay, Washington | 461.7 |
| HUN | San Francisco Bay, California | 321.7 |
| RAR | Raritan Bay, New Jersey | 310.4 |
| SAL | Salem Harbor, Massachusetts | 605.9 |
| SDA | San Diego Bay, California | 295.8 |
| UCB | Upper Chesapeake Bay, Maryland | 367.6 |
| **Pyrene (≥350 <2200 ppb)** | | **ppb** |
| BBMB | Barataria Bay, Louisiana | 357.2 |
| BPBP | Barbers Point, Hawaii | 417.0 |
| BIBI | Block Island, New Jersey | 356.7 |
| BHDI | Boston Harbor, Massachusetts | 670.0 |
| BHDH | Boston Harbor, Massachusetts | 962.8 |
| BBAR | Buzzards Bay, Massachusetts | 458.3 |
| BBRH | Buzzards Bay, Massachusetts | 390.0 |
| CBHP | Chesapeake Bay, Maryland | 575.0 |
| CBMP | Chesapeake Bay, Maryland | 1058.3 |
| CBSP | Choctawatchee Bay, Florida | 572.8 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 450.0 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 1726.7 |
| LICR | Long Island Sound, Connecticut | 822.9 |
| LIHR | Long Island Sound, Connecticut | 1516.7 |
| LISI | Long Island Sound, Connecticut | 1226.7 |
| LIHH | Long Island Sound, Connecticut | 841.7 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Pyrene (continued)** | | **ppb** |
| LIMR | Long Island Sound, Connecticut | 781.7 |
| LITN | Long Island Sound, Connecticut | 1927.1 |
| NBDI | Narragansett Bay, Rhode Island | 451.7 |
| NBMH | Narragansett Bay, Rhode Island | 426.7 |
| NYSH | New York Bight, New Jersey | 820.0 |
| PBPI | Penobscot Bay, Maine | 673.3 |
| PBSI | Penobscot Bay, Maine | 416.7 |
| SAWB | Saint Andrew Bay, Florida | 1659.0 |
| SFDB | San Francisco Bay, California | 543.3 |
| SFSM | San Francisco Bay, California | 617.5 |
| SPFP | San Pedro Harbor, California | 986.7 |
| SIWP | Sinclair Inlet, Washington | 590.0 |
| OEIH | Oakland Estuary, California | 1026.7 |
| BOS | Boston Harbor, Massachusetts | 1076.9 |
| ELL | Elliott Bay, Washington | 781.7 |
| HUN | San Francisco Bay, California | 773.3 |
| OAK | Oakland Estuary, California | 386.7 |
| RAR | Raritan Bay, New Jersey | 821.1 |
| SAL | Salem Harbor, Massachusetts | 1760.0 |
| SDA | San Diego Bay, California | 803.3 |
| WLI | West Long Island Sound, New York | 791.5 |
| **2-methylnaphthalene (≥65 <670 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 87.7 |
| BHDH | Boston Harbor, Massachusetts | 107.8 |
| BBAR | Buzzards Bay, Massachusetts | 79.0 |
| CBHP | Chesapeake Bay, Maryland | 253.3 |
| CBMP | Chesapeake Bay, Maryland | 256.7 |
| CBBP | Commencement Bay, Washington | 76.0 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 96.7 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 195.0 |
| LISI | Long Island Sound, Connecticut | 66.7 |
| LIHH | Long Island, Sound, Connecticut | 67.5 |
| LITN | Long Island Sound, Connecticut | 258.8 |
| NYSH | New York Bight, New Jersey | 178.3 |
| PBSI | Penobscot Bay, Maine | 142.5 |
| SAWB | Saint Andrew Bay, Florida | 203.5 |
| SPFP | San Pedro Harbor, California | 120.7 |
| COM | Commencement Bay, Washington | 80.0 |
| ELL | Elliott Bay, Washington | 79.3 |
| OLI | Oliktok Point, Alaska | 142.7 |
| RAR | Raritan Bay, New Jersey | 116.3 |
| UCB | Upper Chesapeake Bay, Maryland | 248.0 |
| **Dibenz(a,h)anthracene (≥60 <260 ppb)** | | **ppb** |
| BAR | Barataria Bay, Louisiana | 101.7 |
| ELL | Elliott Bay, Washington | 66.2 |
| PEN | Pensacola Bay, Florida | 85.8 |
| RAR | Raritan Bay, New Jersey | 111.5 |
| SAL | Salem Harbor, Massachusetts | 76.4 |

Table 72 (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Dibenz(a,h)anthracene (continued)** | | **ppb** |
| SDA | San Diego Bay, California | 162.0 |
| WLI | West Long Island Sound, New York | 71.6 |
| **Total PAH (≥4000 <35000 ppb)** | | **ppb** |
| BHDI | Boston Harbor, Massachusetts | 4054 |
| BHDH | Boston Harbor, Massachusetts | 6603 |
| CBMP | Chesapeake Bay, Maryland | 5950 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 9388 |
| HRUB | Hudson/Raritan estuary | 29324 |
| LICR | Long Island Sound, Connecticut | 4000 |
| LIHR | Long Island Sound, Connecticut | 5573 |
| LISI | Long Island Sound, Connecticut | 5660 |
| LIHH | Long Island Sound, Connecticut | 4592 |
| LITN | Long Island Sound, Connecticut | 10395 |
| NYSH | New York Bight, New Jersey | 5070 |
| OEIH | Oakland Estuary, California | 5065 |
| SAWB | Saint Andrew Bay, Florida | 9233 |
| BOS | Boston Harbor, Massachusetts | 15045 |
| ELL | Elliott Bay, Washington | 4477 |
| RAR | Raritan Bay, New Jersey | 4649 |
| SAL | Salem Harbor, Massachusetts | 7180 |
| SDA | San Diego Bay, California | 5915 |
| **Chlordane (≥0.5 <6 ppb)** | | **ppb** |
| ABWJ | Anaheim Bay, California | 0.9 |
| BHDB | Boston Harbor, Massachusetts | 2.4 |
| BHDI | Boston Harbor, Massachusetts | 3.2 |
| BHHD | Boston Harbor, Massachusetts | 0.7 |
| BBRH | Buzzards Bay, Massachusetts | 0.5 |
| CASI | Cape Ann, Massachusetts | 0.5 |
| CHFJ | Charleston Harbor, South Carolina | 0.5 |
| CBHP | Chesapeake Bay, Maryland | 1.8 |
| CBMP | Chesapeake Bay, Maryland | 1.1 |
| CBIB | Chesapeake Bay, Maryland | 0.6 |
| DBAP | Delaware Bay, Delaware | 0.6 |
| DBKI | Delaware Bay, Delaware | 0.5 |
| GBYC | Galveston Bay, Texas | 0.6 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 4.2 |
| HRLB | Hudson/Raritan estuary, New Jersey | 5.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 1.7 |
| LICR | Long Island Sound, Connecticut | 2.4 |
| LIHR | Long Island Sound, Connecticut | 2.5 |
| LISI | Long Island Sound, Connecticut | 1.0 |
| LIHU | Long Island Sound, Connecticut | 1.5 |
| LIMR | Long Island Sound, Connecticut | 3.0 |
| MDSJ | Marina del Rey, California | 1.1 |
| MSBB | Mississippi Sound, Mississippi | 1.0 |
| MSPB | Mississippi Sound, Mississippi | 0.5 |
| MBTH | Moriches Bay, New York | 0.9 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Chlordane (continued)** | | **ppb** |
| NYSH | New York Bight, New York | 3.8 |
| NBNB | Naples Bay, Florida | 1.2 |
| NBCI | Narragansett Bay, Rhode Island | 0.7 |
| NBDI | Narragansett Bay, Rhode Island | 0.9 |
| NBMH | Narragansett Bay, Rhode Island | 0.9 |
| OSBJ | Oceanside, California | 0.6 |
| PVRP | Palos Verdes, California | 1.9 |
| PBPI | Penobscot Bay, Maine | 0.8 |
| PBSI | Penobscot Bay, Maine | 0.6 |
| SBSB | Point Santa Barbara, California | 1.0 |
| RBHC | Rookery Bay, Florida | 0.6 |
| SPSM | San Pablo Bay, California | 1.0 |
| SPSP | San Pablo Bay, California | 0.6 |
| SPFP | San Pedro Harbor, California | 2.6 |
| SAWB | Saint Andrew Bay, Florida | 2.2 |
| SJCB | Saint Johns River, Florida | 0.9 |
| TBMK | Tampa Bay, Florida | 1.6 |
| TBPB | Tampa Bay, Florida | 2.5 |
| **DDT (p,p' + o,p'-DDT) (≥1 <7 ppb)** | | **ppb** |
| BHDB | Boston Harbor, Massachusetts | 2.2 |
| BHDI | Boston Harbor, Massachusetts | 4.2 |
| CBHP | Chesapeake Bay, Maryland | 1.8 |
| CBMP | Chesapeake Bay, Maryland | 1.3 |
| CBSR | Choctawatchee Bay, Florida | 6.6 |
| CRYB | Columbia River, Oregon | 1.4 |
| DBAP | Delaware Bay, Delaware | 1.2 |
| DBFE | Delaware Bay, Delaware | 5.6 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 2.6 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 5.3 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 5.8 |
| LICR | Long Island Sound, Connecticut | 5.0 |
| LIHR | Long Island Sound, Connecticut | 6.9 |
| LIHH | Long Island Sound, Connecticut | 5.5 |
| LIHU | Long Island Sound, Connecticut | 1.6 |
| LIMR | Long Island Sound, Connecticut | 2.2 |
| LITN | Long Island Sound, Connecticut | 6.1 |
| MDSJ | Marina del Rey, California | 2.0 |
| MBSC | Monterey Bay, California | 1.5 |
| NYSH | New York Bight, New York | 4.6 |
| NBMH | Narragansett Bay, Rhode Island | 1.2 |
| PBSI | Penobscot Bay, Maine | 1.2 |
| PLLH | Point Loma, California | 2.8 |
| SBSB | Point Santa Barbara, California | 1.5 |
| SFDB | San Francisco Bay, California | 3.3 |
| SFEM | San Francisco Bay, California | 4.9 |
| SPSM | San Pablo Bay, California | 4.6 |
| SPSP | San Pablo Bay, California | 2.0 |
| SIWP | Sinclair Inlet, Washington | 5.5 |
| SSBI | South Puget Sound, Washington | 3.2 |
| TBHB | Tampa Bay, Florida | 1.5 |
| TBPB | Tampa Bay, Florida | 2.0 |
| WIPP | Whidbey Island, Washington | 3.0 |

**Table 72. (continued)**

| Site Description | Location | Concentration |
|---|---|---|
| **DDT (p,p' + o,p'-DDT) (continued)** | | **ppb** |
| BOS | Boston Harbor, Massachusetts | 2.1 |
| GRB | Great Bay, New Jersey | 1.3 |
| LNB | Long Beach Harbor, California | 2.7 |
| SAL | Salem Harbor, Massachusetts | 2.6 |
| SMB | Santa Monica Bay, California | 1.0 |
| **DDD (p,p' + o,p'-DDD) (≥2 <20 ppb)** | | **ppb** |
| ABWJ | Anaheim Bay, California | 4.6 |
| BBAR | Buzzards Bay, Massachusetts | 2.1 |
| BBSM | Bellingham Bay, Washington | 2.4 |
| BHDI | Boston Harbor, Massachusetts | 12.6 |
| BHHB | Boston Harbor, Massachusetts | 3.3 |
| CBHP | Chesapeake Bay, Maryland | 8.5 |
| CBMP | Chesapeake Bay, Maryland | 8.0 |
| CBSR | Choctawatchee Bay, Florida | 2.6 |
| CRYB | Columbia River, Oregon | 2.3 |
| DBAP | Delaware Bay, Delaware | 7.5 |
| DBFE | Delaware Bay, Delaware | 6.3 |
| DBKI | Delaware Bay, Delaware | 3.9 |
| ECSP | East Cote Blanche, Louisiana | 2.0 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 19.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 13.2 |
| LIHR | Long Island Sound, Connecticut | 19.7 |
| LISI | Long Island Sound, Connecticut | 4.7 |
| LIHU | Long Island Sound, Connecticut | 7.7 |
| LIMR | Long Island Sound, Connecticut | 13.7 |
| MDSJ | Marina del Rey, California | 13.2 |
| MBLR | Matagorda Bay, Texas | 5.5 |
| MBTD | Matagorda Bay, Texas | 2.8 |
| MSBB | Mississippi Sound, Mississippi | 2.5 |
| MBCP | Mobile Bay, Alabama | 3.5 |
| BMTH | Moriches Bay, New York | 9.2 |
| NBCI | Narragansett Bay, Rhode Island | 3.5 |
| NBMH | Narragansett Bay, Rhode Island | 5.1 |
| NBBC | Narragansett Bay, Rhode Island | 3.7 |
| OSBJ | Oceanside, California | 14.8 |
| PBSI | Penobscot Bay, Maine | 2.6 |
| SBSB | Point Santa Barbara, California | 10.1 |
| SDHI | San Diego Bay, California | 4.7 |
| SFDB | San Francisco Bay, California | 8.4 |
| SFEM | San Francisco Bay, California | 18.0 |
| SFSM | San Francisco Bay,. California | 3.4 |
| SPSM | San Pablo Bay, California | 14.7 |
| SPSP | San Pablo Bay, California | 6.9 |
| SIWP | Sinclair Inlet, Washington | 2.8 |
| SSBI | South Puget Sound, Washington | 2.0 |
| SAWB | Saint Andrew Bay, Florida | 16.2 |
| SJCB | Saint Johns River, Florida | 5.8 |
| TBHB | Tampa Bay, Florida | 5.0 |
| TBPB | Tampa Bay, Florida | 3.1 |
| WIPP | Whidbey Island, Washington | 3.4 |
| COM | Commencement Bay, Washington | 2.7 |
| CSC | Casco Bay, Maine | 2.0 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **DDD (p,p' + o,p'-DDD) (continued)** | | **ppb** |
| ELL | Elliott Bay, Washington | 8.2 |
| GRB | Great Bay, New Jersey | 3.8 |
| HUN | San Francisco Bay, California | 3.0 |
| MRD | Mississippi Delta, Mississippi | 3.8 |
| NAR | Narragansett Bay, Rhode Island | 2.4 |
| OAK | Oakland Estuary, California | 3.7 |
| RAR | Raritan Bay, New Jersey | 19.3 |
| SDA | San Diego Bay, California | 5.6 |
| SEA | Seal Beach, California | 5.1 |
| SJR | Saint Johns River, Florida | 2.2 |
| SMB | Santa Monica Bay, California | 4.9 |
| UCB | Upper Chesapeake Bay, Maryland | 3.1 |
| WLI | West Long Island Sound, New York | 3.7 |
| **DDE (p,p' + o,p'-DDE) (≥2 <15 ppb)** | | **ppb** |
| APDB | Apalachicola Bay, Florida | 3.2 |
| BBAR | Buzzards Bay, Massachusetts | 6.1 |
| BBRH | Buyzzards Bay, Massachusetts | 2.8 |
| BHDI | Boston Harbor, Massachusetts | 7.3 |
| BHHB | Boston Harbor, Massachusetts | 2.1 |
| CBHP | Chesapeake Bay, Maryland | 3.7 |
| CBMP | Chesapeake Bay, Maryland | 4.2 |
| CBSR | Choctawatchee Bay, Florida | 3.3 |
| DBAP | Delaware Bay, Delaware | 6.5 |
| DBBD | Delaware Bay, Delaware | 3.1 |
| DBFE | Delaware Bay, Delaware | 4.1 |
| DBKI | Delaware Bay, Delaware | 3.8 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 14.0 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 6.5 |
| LJLJ | La Jolla, California | 6.5 |
| LICR | Long Island Sound, Connecticut | 5.2 |
| LIHR | Long Island Sound, Connecticut | 2.8 |
| LISI | Long Island Sound, Connecticut | 2.0 |
| LIHH | Ling Island Sound, Connecticut | 11.1 |
| LIHU | Long Island Sound, Connecticut | 3.9 |
| LIMR | Long Island Sound, Connecticut | 5.3 |
| MBTP | Matagordo Bay, Texas | 2.1 |
| MBVB | Mission Bay, Callifornia | 4.3 |
| MBCP | Mobile Bay, Alabama | 5.3 |
| MBTH | Moriches Bay, New York | 2.4 |
| MBSC | Monterey Bay, California | 3.8 |
| NBMH | Narragansett Bay, Rhode Island | 3.9 |
| PLLH | Point Loma, California | 12.9 |
| SFDB | San Francisco Bay, California | 4.9 |
| SFEM | San Francisco Bay, California | 5.1 |
| SFSM | San Francisco Bay, California | 3.1 |
| SPSM | San Pablo Bay, California | 6.3 |
| SPSP | San Pablo Bay, California | 3.8 |
| SAWB | Saint Andrew Bay, Florida | 14.7 |
| TBPB | Tampa Bay, Florida | 5.4 |
| WIPP | Whidbey Island, Washington | 3.3 |
| APA | Apalachicola Bay, Florida | 2.1 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **DDE (p,p' + o,p'-DDE) (continued)** | | **ppb** |
| SDHI | San Diego Bay, California | 3.7 |
| GRB | Great Bay, New Jersey | 2.3 |
| MOB | Mobile Bay, Alabama | 3.0 |
| NAR | Narragansett Bay, Rhode Island | 2.6 |
| RAR | Raritan Bay, New Jersey | 8.6 |
| SAL | Salem Harbor, Massachusetts | 7.3 |
| SDA | San Diego Bay, California | 3.5 |
| SDF | San Diego Bay, California | 13.6 |
| WLI | West Long Island Sound, New York | 2.4 |
| **Total DDT (≥3 <350 ppb)** | | **ppb** |
| ABWJ | Anaheim Bay, California | 25.8 |
| APDB | Apalachicola Bay, Florida | 5.2 |
| ABOB | Atchafalaya Bay, Louisiana | 4.1 |
| BBAR | Buzzards Bay, Massachusetts | 8.2 |
| BBSM | Bellingham Bay, Washington | 4.5 |
| BHHB | Boston Harbor, Massachusettz | 5.9 |
| BHDI | Boston Harbor, Massachusetts | 24.1 |
| BHDB | Boston Harbor, Massachusetts | 44.4 |
| CASI | Cape Ann, Massachusetts | 3.3 |
| CBMP | Chesapeake Bay, Maryland | 13.5 |
| CBHP | Chesapeake Bay, Maryland | 13.9 |
| CBSR | Choctawhatchee Bay, Florida | 12.5 |
| CRYB | Columbia River, Oregon | 4.9 |
| DBBD | Delaware Bay, Delaware | 5.9 |
| DBKI | Delaware Bay, Delaware | 7.8 |
| DBAP | Delaware Bay, Delaware | 15.2 |
| DBFE | Delaware Bay, Delaware | 17.2 |
| ECSP | East Cote Blanche, Louisiana | 3.2 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 45.6 |
| HRUB | Hudson/Raritan Estuary, New York | 25.4 |
| HRJB | Hudson/Raritan Estuary, New York | 38.3 |
| HRLB | Hudson/Raritan Estuary, New Jork | 45.6 |
| LJLJ | La Jolla, California | 8.6 |
| LISI | Long Island Sound, Connecticut | 7.0 |
| LICR | Long Island Sound, Connecticut | 120.0 |
| LIHR | Long Island Sound, Connecticut | 290.4 |
| LIHU | Long Island Sound, New York | 13.2 |
| LIMR | Long Island Sound, New York | 21.2 |
| LIHH | Long Island Sound, New York | 41.3 |
| LITN | Long Island Sound, New York | 75.6 |
| MDSJ | Marina del Rey, California | 72.6 |
| MBLR | Matagorda Bay, Texas | 7.9 |
| MSTP | Matagorda Bay, Texas | 14.5 |
| MBVB | Mission Bay, California | 5.1 |
| MBCP | Mobile Bay, Alabama | 9.4 |
| MBSC | Monterey Bay, California | 7.4 |
| MBTH | Moriches Bay, New York | 26.5 |
| NYSH | New York Bight, New Jersey | 45.5 |
| NBDI | Narragansett Bay, Rhode Island | 4.0 |
| NBCI | Narragansett Bay, Rhode Island | 5.1 |
| NBMH | Narragansett Bay, Rhode Island | 10.2 |
| NBBC | Newport Beach, California | 24.9 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Total DDT (continued)** | | **ppb** |
| OEIH | Oakland Estuary, California | 88.5 |
| OSBJ | Oceanside, California | 50.1 |
| PBPI | Penobscot Bay, Maine | 3.7 |
| PBSI | Penobscot Bay, Maine | 4.5 |
| PLLH | Point Loma, California | 17.7 |
| SBSB | Point Santa Barbara, California | 32.9 |
| SDHI | San Diego Bay, California | 9.0 |
| SFSM | San Francisco Bay, California | 6.8 |
| SFDB | San Francisco Bay, California | 16.6 |
| SFEM | San Francisco Bay, California | 38.0 |
| SPSP | San Pablo Bay, California | 12.6 |
| SPSM | San Pablo Bay, California | 25.6 |
| SIWP | Sinclair Inlet, Washington | 9.3 |
| SSBI | South Puget Sound, Washington | 6.4 |
| SAWB | Saint Andrew Bay, Florida | 41.1 |
| SJCB | Saint Johns River, Florida | 8.2 |
| TBHB | Tampa Bay, Florida | 8.4 |
| TBPB | Tampa Bay, Florida | 10.4 |
| WIPP | Whidbey Island, Washington | 9.6 |
| BOS | Boston Harbor, Massachusetts | 104.5 |
| CHS | Charleston Harbor, South Carolina | 3.5 |
| COM | Commencement Bay, Washington | 3.5 |
| ELL | Elliott Bay, Washington | 9.1 |
| GRB | Great Bay, New Jersey | 7.4 |
| HUN | San Francisco Bay, California | 3.8 |
| LNB | Long Beach Harbor, California | 110.0 |
| MOB | Mobile Bay, Alabama | 3.2 |
| MRD | Mississippi Delta, Mississippi | 4.7 |
| NAR | Narragansett Bay, Rhode Island | 5.2 |
| OAK | Oakland Estuary, California | 5.3 |
| RAR | Raritan Bay, New Jersey | 35.9 |
| SAL | Salem Harbor, Massachusetts | 31.2 |
| SAP | Sapelo Sound, Georgia | 3.2 |
| SDA | San Diego Harbor, California | 9.3 |
| SDF | San Diego Bay, California | 14.6 |
| SEA | Seal Beach, California | 27.6 |
| SMB | Santa Monica Bay, California | 24.9 |
| UCB | Upper Chesapeake Bay, Maryland | 5.8 |
| WLI | West Long Island Sound, New York | 6.6 |
| **PCBs (≥50 <380 ppb)** | | **ppb** |
| BBGH | Buzzards Bay, Massachusetts | 51.3 |
| BBRH | Buzzards Bay, Massachusetts | 231.0 |
| BHDI | Boston Harbor, Massachusetts | 231.4 |
| CBHP | Chesapeake Bay, Maryland | 111.4 |
| CBMP | Chesapeake Bay, Maryland | 90.1 |
| CBSP | Chesapeake Bay, Maryland | 109.8 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 327.7 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 370.5 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 177.7 |
| LICR | Long Island Sound, Connecticut | 137.7 |
| LIHH | Long Island Sound, Connecticut | 229.2 |
| LIHR | Long Island Sound, Connecticut | 190.5 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **PCBs (continued)** | | **ppb** |
| LIMR | Long Island Sound, Connecticut | 119.9 |
| LISI | Long Island Sound, Connecticut | 63.6 |
| MBTH | Moriches Bay, New York | 81.7 |
| OEIH | Oakland Estuary, California | 361.5 |
| SDHI | San Diego Bay, California | 99.8 |
| SFDB | San Francisco Bay, California | 71.9 |
| SFEM | San Francisco Bay, California | 74.9 |
| SFSM | San Francisco Bay, California | 70.7 |
| BUZ | Buzzards Bay, Massachusetts | 192 |
| CSC | Casco Bay, Maine | 58 |
| DEL | Delaware Bay, Delaware | 131 |
| GRB | Great Bay, New Jersey | 79 |
| LNB | Long Beach, California | 205 |
| NAR | Narragansett Bay, Rhode Island | 221 |
| OAK | Oakland Estuary, California | 61 |
| SJR | Saint Johns River, Florida | 98 |
| SPB | San Pedro Bay, California | 194 |
| SPC | San Pedro Canyon, California | 159 |
| UCB | Upper Chesapeake Bay, Maryland | 90 |
| WLI | West Long Island Sound, New York | 174 |
| **Dieldrin (≥0.02 <8 ppb)** | | **ppb** |
| ABWJ | Anaheim Bay, California | 0.3 |
| APCP | Apalachicola Bay, Florida | 0.2 |
| APDB | Apalachicola Bay, Florida | 0.3 |
| ABOB | Atchafalaya Bay, Louisiana | 0.7 |
| BBMB | Barataria Bay, Louisiana | 0.2 |
| BBSD | Barataria Bay, Louisiana | 0.3 |
| BIBI | Block Island, Rhode Island | 0.6 |
| BBBE | Bodega Bay, California | 0.05 |
| HBDI | Boston Harbor, Massachusetts | 4.0 |
| BHHB | Boston Harbor, Massachusetts | 1.2 |
| BSBG | Breton Sound, Louisiana | 0.1 |
| BSSI | Breton Sound, Louisiana | 0.1 |
| BBAR | Buzzards Bay, Massachusetts | 5.0 |
| BBGN | Buzzards Bay, Massachusetts | 0.9 |
| BBRH | Buzzards Bay, Massachusetts | 2.7 |
| CLCL | Caillou Lake, Louisiana | 0.1 |
| CLSJ | Calcasieu Lake, Louisiana | 0.4 |
| CKBP | Cedar Key, Florida | 0.1 |
| CBBI | Charlotte Harbor, Florida | 0.2 |
| CBHP | Chesapeake Bay, Maryland | 3.0 |
| CBMP | Chesapeake Bay, Maryland | 1.1 |
| CBDP | Chesapeake Bay, Maryland | 0.1 |
| CBIB | Chesapeake Bay, Maryland | 0.1 |
| CBCI | Chincoteague Bay, Virginia | 0.1 |
| CBSP | Choctawatchee Bay, Florida | 4.4 |
| CBSR | Choctawatchee Bay, Florida | 0.4 |
| CRYB | Columbia River, Oregon | 0.5 |
| CBRP | Coos Bay, Oregon | 0.1 |
| DBAP | Delaware Bay, Delaware | 1.3 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Dieldrin (continued)** | | **ppb** |
| DBBD | Delaware Bay, Delaware | 0.6 |
| DBFE | Delaware Bay, Delaware | 2.2 |
| DBKI | Delaware Bay, Delaware | 0.7 |
| ECSP | East Cote Blanche, Louisiana | 0.3 |
| ESBD | Espiritu Santo, Texas | 0.03 |
| ESSP | Espiritu Santo, Texas | 0.1 |
| GBCR | Galveston Bay, Texas | 0.2 |
| GBTD | Galveston Bay, Texas | 0.3 |
| GBYC | Galveston Bay, Texas | 0.4 |
| BHWJ | Gray's Harbor, Washington | 0.05 |
| HHKL | Honolulu Harbor, Hawaii | 0.1 |
| HRRB | Hudson/Raritan Estuary, New Jersey | 7.9 |
| HRJB | Hudson/Raritan Estuary, New Jersey | 5.6 |
| HRLB | Hudson/Raritan Estuary, New Jersey | 5.4 |
| HRUB | Hudson/Raritan Estuary, New Jersey | 3.3 |
| HMBJ | Hudson/Raritan Estuary, New Jersey | 0.3 |
| JHJH | Joseph Harbor Bayou, Louisiana | 0.3 |
| LJLJ | Point La Jolla, California | 0.2 |
| LBMP | Lake Borgne, Louisiana | 0.1 |
| LICR | Long Island Sound, Connecticut | 3.5 |
| LIHR | Long Island Sound, Connecticut | 3.0 |
| LISI | Long Island Sound, Connecticut | 1.1 |
| LIHH | Long Island Sound, Connecticut | 7.1 |
| LIHU | Long Island Sound, Connecticut | 1.5 |
| LIMR | Long Island Sound, New York | 3.0 |
| MDSJ | Marina del Rey, California | 0.5 |
| MBEM | Matagorda Bay, Texas | 0.03 |
| MBGP | Matagorda Bay, Texas | 0.1 |
| MBLR | Matagorda Bay, Texas | 0.3 |
| MBTP | Matagorda Bay, Texas | 0.03 |
| MBAR | Mesquite Bay, Texas | 0.1 |
| MBYB | Mission Bay, Texas | 0.1 |
| MSBB | Mississippi Sound, Mississippi | 0.2 |
| MSPC | Mississippi Sound, Mississippi | 0.2 |
| MBCP | Mobile Bay, Alabama | 0.4 |
| MBSC | Monterey Bay, California | 0.3 |
| MBTH | Moriches Bay, New York | 0.5 |
| NYSH | New York Bight, New Jersey | 6.8 |
| NBNB | Naples Bay, Florida | 0.6 |
| NBCI | Narragansett Bay, Rhode Island | 0.7 |
| NBDI | Narragansett Bay, Rhode Island | 0.9 |
| NBMH | Narragansett Bay, Rhode Island | 2.8 |
| NBBC | Newport Beach, California | 0.2 |
| OSBJ | Oceanside, California | 0.5 |
| PGLP | Pacific Grove, California | 0.2 |
| PVRP | Palos Verdes, California | 6.2 |
| PBPI | Penobscot Bay, Maine | 0.2 |
| PBSI | Penobscot Bay, Maine | 0.5 |
| PLLH | Point Loma, California | 0.5 |
| PRPR | Point Roberts, Washington | 0.3 |
| SBSB | Point Santa Barbara, California | 0.5 |
| QIUB | Quinby Inlet, Virginia | 0.5 |
| RBHC | Rookery Bay, Florida | 0.1 |
| SLBB | Sabine Lake, Texas | 0.03 |

Table 72. (continued)

| Site Description | Location | Concentration |
|---|---|---|
| **Dieldrin (continued)** | | **ppb** |
| SAMP | San Antonio Bay, Texas | 0.03 |
| SDHI | San Diego Bay, California | 1.9 |
| SFDB | San Francisco Bay, California | 2.8 |
| SFEM | San Francisco Bay, California | 1.5 |
| SFSM | San Francisco Bay, California | 0.4 |
| SLSL | San Luis Obispo, California | 0.1 |
| SPSP | San Pablo Bay, California | 0.8 |
| SPFP | San Pedro Harbor, California | 2.4 |
| SRTI | Savannah River, Georgia | 0.2 |
| SSBI | South Puget Sound, Washington | 0.2 |
| SAWB | Saint Andrew Bay, Florida | 0.6 |
| SJCB | Saint Johns River, Florida | 1.5 |
| TBCB | Tampa Bay, Florida | 0.1 |
| TBHB | Tampa Bay, Florida | 0.1 |
| TBMK | Tampa Bay, Florida | 0.2 |
| TBPB | Tampa Bay, Florida | 0.3 |
| TBLF | Terrebonne Bay, Louisiana | 0.1 |
| TBSR | Tomales Bay, California | 0.2 |
| VBSP | Vermillion Bay, Louisiana | 0.3 |
| BOS | Boston Harbor, Massachusetts | 3.2 |
| BUZ | Buzzards Bay, Massachusetts | 0.07 |
| COM | Commencement Bay, Washington | 0.33 |
| DEL | Delaware Bay, Delaware | 0.71 |
| HUN | San Francisco Bay, California | 0.27 |
| LCB | Lower Chesapeake Bay, Virginia | 0.12 |
| LNB | Long Beach Harbor, California | 1.30 |
| MOB | Mobile Bay, Alabama | 0.21 |
| MRD | Mississippi Delta, Mississippi | 1.16 |
| NAR | Narragansett Bay, Rhode Island | 1.68 |
| PAB | San Pablo Bay, California | 0.13 |
| RAR | Raritan Bay, New Jersey | 1.72 |
| WLI | West Long Island Sound, New York | 0.15 |

* Ambient concentrations at none of the sites exceeded or equaled the ER-L for these chemical analytes.

**Table 73. The NS&T Program sediment sampling sites in which the average chemical concentrations exceeded the respective ER-M values, ranked in descending order of the number of times exceeded.**

| Number of times exceeded | Site Codes* |
|---|---|
| 10 | OEIH |
| 9 | HRUB |
| 8 | HRRB, LITN, NYSH, BOS |
| 7 | BHDB, HRLB, PVRP, RAR |
| 5 | CBSP, LIHH, SPFP, SAL |
| 4 | SPB, SPC |
| 3 | BHDI, SAWB, LNB |
| 2 | BBSM, CBHP, CBMP, HRJB, OSBJ, PVMC, SFEM SFSM, SPSP, TBSR, BOD, HMB, HUN, OAK, PAB, SDA, SHS, UCB |
| 1 | ABWJ, BBAR, BPBP, MBTH, MBTP, MDSJ, NBBC, NBMH, SFDB, WIPP, YHSS, ELL, SEA, SMB |

* Specific locations are listed in the glossary.

**Table 74. The NS&T Program sediment sampling sites in which the average chemical concentrations exceeded the respective ER-L values, ranked in descending order of the number of times exceeded.**

| Number of times exceeded | Site Codes* |
|---|---|
| 21 | BHDI |
| 20 | LIHH, LIMR, LISI |
| 18 | CBMP |
| 17 | HRUB, LICR, HRLB, SAWB, ELL, RAR, SAL |
| 16 | HRJB, LIHR, NYSH, BOS, SAL |
| 15 | CBHP, BHDB, LITN, WLI |
| 14 | NBMH, SDA |
| 13 | SIWP |
| 12 | OEIH, PBSI, UCB |
| 11 | LIHU, SFSM |
| 10 | BBAR, SFDB, SPFP, GRB, NAR |
| 9 | CBSP, BHHB, SPSP, SSBI, HUN |
| 8 | DBAP, MBTH, PBPI, SFEM, OAK |
| 7 | HRRB, MSBB, SDHI, TBPB, WIPP |
| 6 | DBBD, MDSJ, NBCI, NBDI, PVRP, SSBI, SPB |
| 5 | ABWJ, BBSM, BBRH, CBSR, DBFE, DBKI, SBSB, SJCB, TBHB, LNB, MOB |
| 4 | CRYB, MBCP, MBTP, MBSC, OSBJ, PLLH, PRPR, SPSM, BUZ, CSC, PEN, SEA |
| 3 | APDB, ECSP, HHKL, LJLJ, MBLR, MBYB, NBBC, TBSR, CHS, COM, NAH, NIS, OLI, SJR, SMB |
| 2 | ABOB, BBGN, CASI, CBIB, CHFJ, EBFR, HMBJ, MBGP, NBNB, PVMC, RBHC, TBHP, TBMK, UISB, DEL, FRN, LUT, MRD, PNB, SAP, SDF |
| 1 | APCP, BBBE, BBSD, BIBI, BBMB, BBNR, BPBP, BSBG, BSSI, CBBI, CBBP, CBDP, CBCI, CBMP, CBRP, CBTP, CBRP, CLCL, CLSJ, CKBP, ESSP, ESBD, GBCR, GBTD, GBYC, GHWJ, MBAR, MSPC, MSPB, PGLP, QIUB, SAMP, SLBB, SLSL, SRTI, TBCB, TBLF, VBSP, YBOP, APA, BAR, COO, DBA, DAN, PAB, SPC |

* Specific locations are listed in the glossary.

The accuracy of the guidelines for metals often exceeded that for organic compounds. Many of the metals are likely more water soluble than the organics, possibly resulting in relatively higher and more consistent bioavailability, and, therefore, less variability in the data.

The ER-L and ER-M guidelines were used to evaluate and rank the relative potential for biological effects at the NS&T Program sampling sites. Those sites in which the ambient chemical concentrations exceeded the most ER-L and ER-M values were identified as having the highest potential for adverse effects. The sites with the highest potential for effects were sites HRUB, located in the Hudson-Raritan Estuary; site LITN, located in western Long Island Sound; site BOS, in Boston Harbor; and site OEIH, in the Oakland Estuary of San Francisco Bay. Sites with the highest potential for effects were generally located within the Hudson-Raritan Estuary, Long Island Sound, Boston Harbor, Chesapeake Bay, New York Bight, Salem Harbor, Saint Andrew Bay, and parts of southern California near Los Angeles and San Pedro.

The potential for contaminated sediments causing adverse biological effects should be verified by either an examination of available data or implementation of a survey at the high-potential sites. Biological effects data are available for one of the highly ranked NS&T Program sites: site OEIH in Oakland Harbor, California. Site OEIH was tested with five sediment bioassays (Long and Buchman, 1989) and the benthic community was examined at that site (unpublished data). Most of the bioassay end-points indicated relatively high toxicity in the site OEIH sediments and the benthic community had lower total abundance and crustacean abundance than at many other nearby sites in San Francisco Bay.

The data examined in the present document were the results of the use of widely varying methods. Subsequent evaluations of data such as these would be facilitated if the data were from the use of similar methods. That is, spiked-sediment bioassays should be performed with one species or, at least, with species from the same taxonomic groups (such as amphipods). Bioassays of field-collected sediments should be performed with multiple species, but at least one of the species should be used universally. The use of standardized methods is recommended.

Sediment quality values from EP, AET, and SLC methods usually are presented as absolutes, i.e., a chemical concentration not accompanied by any measure of uncertainty or variability. Values generated in spiked-sediment bioassays often are accompanied by the 95 percent confidence interval. The data reviewed in this document and with which the co-occurrence analyses were performed often indicated relatively high variability in analyses of field-collected samples (i.e., the standard deviations frequently equalled or exceeded the means). While these indications of variability may be discouraging, they do provide a suggestion as to the degree of confidence currently available for attributing biological effects to sediment-sorbed contaminants without using a preponderance of evidence from multiple approaches.

The data assembled and reported herein were evaluated by objectively determining the lower 10 percentiles and the medians in the data and by subjectively determining the overall apparent effects thresholds in the data. The same data could be evaluated using many other approaches, depending upon study objectives. For example, the screened sorted data could be used to identify the contaminant concentrations below which effects have never been observed. Also, percentiles in the data other than the lower 10 and 50 percentiles could be determined. For example, the lower 5 percentile value of the data could be examined and assumed to be analogous to a level that may protect 95 percent of the species. The ER-L, ER-M, and overall apparent effects thresholds derived from the available data could be used as hypotheses to be tested in empirical toxicity experiments. The present evaluation should be updated with additional data as they become available and should be supplemented with an evaluation of the chemical data normalized to TOC, AVS, and any other appropriate parameters in addition to dry weight.

**Table 75. Overall cumulative ranks of NS&T Program sites, based upon exceedances of ER-L and ER-M values. One point was assigned for each ER-L exceeded, 4.2 points for each metal ER-M exceeded, and 8.1 points for each organic ER-M exceeded.**

| Site | No. of ER-L values exceeded | ER-M values exceeded for metals No. x 4.2 = points | | ER-M values exceeded for organics No. x 8.1 = points | | Total points | Overall rank |
|---|---|---|---|---|---|---|---|
| HRUB | 17 | 3 | 13 | 6 | 49 | 79 | 1 |
| BOS | 16 | 3 | 13 | 5 | 41 | 70 | 2 |
| LITN | 15 | 3 | 13 | 5 | 41 | 69 | 3 |
| OEIH | 12 | 6 | 25 | 4 | 32 | 69 | 3 |
| NYSH | 16 | 5 | 21 | 3 | 24 | 61 | 5 |
| BHDB | 15 | 3 | 13 | 4 | 32 | 60 | 6 |
| HRLB | 17 | 4 | 17 | 3 | 24 | 58 | 7 |
| PVRP | 6 | 2 | 8 | 5 | 41 | 55 | 8 |
| RAR | 17 | 5 | 21 | 2 | 16 | 54 | 9 |
| HRRB | 7 | 5 | 21 | 3 | 24 | 52 | 10 |
| CBSP | 9 | 0 | 0 | 5 | 41 | 50 | 11 |
| LIHH | 20 | 3 | 13 | 2 | 16 | 49 | 12 |
| SAL | 16 | 2 | 8 | 3 | 24 | 48 | 13 |
| SPFP | 10 | 1 | 4 | 4 | 32 | 6 | 14 |
| SAWB | 17 | 0 | 0 | 3 | 24 | 41 | 15 |
| SPB | 6 | 0 | 0 | 4 | 32 | 38 | 16 |
| BHDI | 21 | 3 | 13 | 0 | 0 | 34 | 17 |
| SPC | 0 | 0 | 0 | 4 | 32 | 32 | 18 |
| HRJB | 16 | 1 | 4 | 1 | 8 | 28 | 19 |
| SDA | 14 | 1 | 4 | 1 | 8 | 26 | 20 |
| ELL | 17 | 0 | 0 | 1 | 8 | 25 | 21 |
| LNB | 5 | 1 | 4 | 2 | 16 | 25 | 21 |
| CBHP | 15 | 2 | 8 | 0 | 0 | 23 | 23 |
| LISI | 20 | 0 | 0 | 0 | 0 | 20 | 25 |
| OSBJ | 4 | 0 | 0 | 2 | 16 | 20 | 25 |
| LIMR | 20 | 0 | 0 | 0 | 0 | 20 | 25 |
| SFSM | 11 | 2 | 8 | 0 | 0 | 19 | 27 |
| SPSP | 9 | 2 | 8 | 0 | 0 | 17 | 28 |
| OAK | 8 | 2 | 8 | 0 | 0 | 16 | 29 |
| SFEM | 8 | 2 | 8 | 0 | 0 | 16 | 29 |

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# APPENDIX A

# CO-OCCURRENCE ANALYSES DATA

## Appendix A

### Description of Data Sets Used in Co-occurrence Analyses

The data sets in which biological measures of effects and concentrations of chemicals in sediments were made with the same samples are described in this appendix, along with the description of how the data were manipulated and analyzed for use in this document.

Gilbert *et al.* (1976) sampled sediments at 37 stations in Massachusetts Bay and performed chemical analyses of portions of the samples that were also examined for benthic community composition. The samples were collected with a 0.1 $m^2$ Smith-McIntyre grab sampler and sieved with 2.0 and 0.5 mm screens. Data from quantification of trace metals and selected organic groups were reported. Their data suggested the occurrence of three modes in species richness among the stations: High (mean 93.6 ± 9.4 SD, range 81-106), intermediate (mean 58.1 ± 10.4 SD, range 40-78), and low (mean 31 ± 6.5 SD, range 22-37). The means and standard deviations in chemical concentrations that co-occurred with these modes were calculated.

McGreer (1979) observed burrowing time in the bivalve *Macoma balthica* exposed to five samples (one of which was used as a control) collected in the Fraser River estuary, British Columbia. The samples were also analyzed for the concentrations of various trace metals. The 95 percent confidence limits for effective burrowing time (ET50) for Sample C were outside the 95 percent confidence limits of the ET50 for the control. The chemical data for Sample C were used in this document. McGreer (1979) also examined avoidance behavior of *M. balthica* exposed to these sediment samples. A statistically significant avoidance response was found for Sample A, therefore, the data for Sample A were used in this document.

McGreer (1982) sampled 23 sites along the Strait of Georgia, British Columbia and determined the presence and abundance of *M. balthica* and the concentrations of various trace metals. The means and standard deviations of concentrations in samples devoid of *M. balthica* and in samples with *M. balthica* present were compared.

Yake, *et al.* (1986) sampled three sites in Lake Union, Washington and tested for toxicity with the amphipod *Hyalella azteca* and determined the concentrations of many chemicals in an area known to have high PAH concentrations. Undiluted sediment from one of the sites (GWP) caused an average of 95 percent mortality; the chemical data for that site were used in this document.

Anderson *et al.* (1988) sampled 12 sites in southern California and tested for toxicity with the amphipod *Grandidierella japonica* and for the concentration of hydrocarbons and trace metals. Half of the sites was significantly toxic (mean 48.3 ± 14.6 percent survival); and half were not significantly toxic (mean 76.8 ± 11.1 percent survival) relative to controls. The chemical concentrations were compared between toxic and non-toxic samples.

Kraft and Sypniewski (1981) sampled 15 sites each in the north and south regions of the Keweenaw Waterway, Michigan and determined macroinverterbrate taxa richness and copper content in the sediments in all 30 sites. The mean copper concentrations in the northern sites (average of 8.4 taxa per site) were compared with those in the southern sites (average of 19.8 taxa per site).

The Illinois Environmental Protection Agency (1983a) sampled 21 sites in the DuPage River Basin and determined benthic taxa abundance and concentrations of hydrocarbons and trace metals. Concentrations in 18 sites with relatively high abundance (mean 15.8 ± 2.0 SD taxa per Hester-Dendy artificial sampler) were compared with those in 3 sites (mean 6.7 ± 2.5 SD taxa) with relatively low abundance.

The Illinois Environmental Protection Agency (1983b) sampled 25 sites in the Kishwaukee River and determined the number of benthic taxa and concentrations of hydrocarbons and trace metals. The chemical concentrations in 20 sites associated with relatively high numbers of taxa (mean 16.3 ± 4.6 SD per site) were compared with concentration in 5 sites with relatively low numbers of taxa (8.4 ± 0.5 per site).

Tsai *et al.* (1979) sampled nine stations in Baltimore Harbor, Maryland and determined toxicity to mummichogs (*Fundulus heteroclitus*), spot (*Leiostomus xanthurus*), and soft-shell clams (*Mya arenaria*) and the concentrations of PCBs and trace metals. Five of the stations were relatively highly toxic (mean 48-h TLm of 5.1 ± 3.5) to mummichogs and four were relatively less toxic (mean TLm of 43.2 ± 31.3). The means and standard deviations of chemical concentrations among the most and least toxic samples were compared.

VanDolah *et al.* (1984) sampled 15 stations in and near a dredged material disposal site off Georgetown, South Carolina and determined benthic community composition and concentrations of PCBs and trace metals. The maximum sediment concentrations of chemicals at sites in which no demonstrable effects upon summer benthic community species richness and total abundance was observed were used in this document.

Tatem (1986) determined bioaccumulation of PCBs and trace metals in the prawn (*Macrobrachium rosenbergii*) exposed to Sheboygan River, Wisconsin sediments. He observed that the sediments were toxic to the prawns after 22 days' exposure. The concentrations of chemicals in the toxic sediments were used in this document.

Lee and Mariani (1977) reported results of sediment toxicity tests and chemical analyses for many prospective dredge areas throughout the United States. The chemical concentrations reported associated with the observations of relatively high toxicity to the grass shrimp *Palaemonetes pugio* were used in this document.

Zagatto *et al.* (1987) reported results of toxicity tests with *D. similis* and chemical concentrations in sediments from 18 stations in Cubatao River Basin, Brazil. Minimum chemical concentrations associated with samples that were reported as significantly toxic were used in this report.

Malueg *et al.* (1984a) sampled sediments from six sites in Phillips Chain of Lakes, Wisconsin, one site in Torch Lake, Michigan, and ten sites in the Little Grizzly Creek system, California and tested for toxicity to *Daphnia magna* and *Hexagenia limbata* and the concentrations of trace metals. The chemical concentrations in the one site in Phillips Chain of Lakes that was significantly toxic were compared with those in the five other samples that were reported as not significantly toxic. The chemical concentrations in the toxic Torch Lake sample also was listed and used in this document. The chemical concentrations in the eight samples from the Little Grizzly Creek system that were reported as significantly toxic were compared with those that were not toxic and used in this document.

Malueg *et al.* (1984b) sampled five sites each in the northern and southern reaches of the Keweenaw Waterway, Michigan and determined toxicity to *D. magna* and *Hexagenia limbata* and the concentrations of trace metals. The chemical concentrations in highly toxic northern sediments were compared with those in less toxic southern sediments.

Long and Buchman (1989) sampled 15 stations in San Francisco and Tomales bays and determined toxicity to the amphipod *Rhepoxynius abronius* and mussel embryos (*Mytilus edulis*) and concentrations of trace metals and organic compounds. U.S. Navy (1987) sampled 22 stations in San Francisco Bay and performed many of the same analyses, except they used the embryos of the oyster *C. gigas*. Chapman *et al.* (1987) sampled nine stations in San Francisco Bay and performed the same analyses as Long and Buchman (1989). Word *et al.* (1988) sampled 22 stations in the Oakland Inner Harbor of San Francisco Bay and performed the same analyses as U.S. Navy (1987). The data from these four studies were combined and three types of analyses were performed. First, AET values were calculated using SedQual software developed by PTI Environmental Services (1988) and a sorting routine on Microsoft Excel spreadsheets on a Macintosh computer. Second, the mean concentrations of chemicals associated with relatively highly toxic samples (mean 67 ± 11.8 percent mortality among *R. abronius*, mean 92.4 ± 4.5 percent abnormal bivalve embryos) were compared with those that were moderately toxic (33.8 ± 4.7 percent mortality among *R. abronius*, 59.4 ± 11.3 percent abnormal bivalve embryos) and least toxic (18 ± 6.6 percent mortality among *R. abronius*, 23.3 ± 7.3 percent abnormal bivalve embryos). Third, the chemical concentrations in samples reported as significantly toxic were compared with those that were reported as not significantly toxic, however, since most of the samples were significantly different from controls, this last approach appeared to be the least satisfactory of the three.

Tetra Tech (1985) sampled 55 sites in the Commencement Bay, Washington waterways and vicinity and determined toxicity to *R. abronius* and *C. gigas* embryos and concentrations of trace metals and organic compounds. The mean concentrations in samples that were most toxic (15.7 ± 3.9 dead *R. abronius* out of 20, 44.5 ± 19 percent abnormal *C. gigas* embryos) were compared with those in samples that were moderately toxic (5.2 ± 1.1 dead *R. abronius* out of 20, 23 ± 2.3 percent abnormal *C. gigas* embryos) and least toxic (2.5 ± 0.9 dead *R. abronius* out of 20, 15.1 ± 3.1 percent abnormal *C. gigas* embryos).

Word and Mearns (1979) sampled 71 sites along a 60-m depth contour off southern California and determined benthic community composition and concentrations of trace metals and selected hydrocarbons. The chemical concentrations associated with samples that had relatively high, intermediate, and low abundances of echinoderms and arthropod were compared. The chemical concentrations associated with relatively high, intermediate, and low species richness and total abundance were also compared. They were compared, for example, between sites with high echinoderm abundance (mean 191.3 ± 70.1/0.1 square meters), intermediate abundance (56.2 ± 23.0/0.1 square meters), and lowest abundance (6.1 ± 7.2/0.1 square meters).

Schiewe *et al.* (1984) sampled 18 sites in Puget Sound, Washington. and determined toxicity to *Photobacterium phosphoreum* in a Microtox™ test of organic extracts of sediments and concentrations of petroleum hydrocarbons. Chemical concentrations in highly toxic samples (mean EC50 0.31 ± 0.13), moderately toxic samples (mean EC50 2.14 ± 0.83), and least toxic samples (mean EC50 8.9 ± 3.3) were compared for use in this document.

Swartz *et al.* (1985 and 1986) sampled seven sites in 1980 and six sites in 1983 in the Southern California Bight off Palos Verdes and determined toxicity with a *R. abronius* bioassay, macroinvertebrate community composition, and concentrations of trace metals and selected organic compounds. The data from the two surveys were combined for use in this document. The chemical concentrations in samples that were significantly toxic to *R abronius* were compared with those that were not toxic. Also, the chemical concentrations in sites reported as having "major degradation" to the macrobenthos were listed and used in the present document.

Rygg (1985) reported the relationship between sediment copper concentrations in Norwegian fjords and benthic community composition sampled at 71 stations. He reported that a 50 percent reduction in Hurlbert's diversity index was correlated with 200 ppm copper in the sediments.

Johnson and Norton (1988) sampled 12 sites in ports along the lower Columbia River, Washington and determined toxicity to the amphipod *H. azteca* and concentrations of trace metals and organic compounds. PAH concentrations differed the most among sampling sites. No significant toxicity was observed, therefore, the maximum PAH concentration in which no toxicity was observed was listed and used in this document.

Armstrong *et al.*, (1979) sampled 15 stations in Trinity Bay, Texas in a grid associated with an oilfield brine effluent and determined benthic community composition and PAH concentration. The PAH concentrations in 10 stations with relatively high species richness (mean 33.3 per station) and total abundance (mean 5178 per station) were compared with those in 7 stations with relatively low species richness (mean 28.2 per station) and abundance (mean 1285 per station).

Qasim *et al.* (1980) sampled 13 sites in the Trinity River, Texas and tested for toxicity with *D. magna* and for the concentrations of hydrocarbons and trace metals. The chemical concentrations in five sites in which significant mortality (mean 92.5 ± 11.6 percent SD) was observed were compared with those from eight sites in which lower (nonsignificant) mortality (mean 16 ± 8.9 percent SD) was observed.

Ingersoll and Nelson (in press) sampled three sites and a control in Waukegan Harbor, Illinois and vicinity and determined toxicity to *H. azteca* and concentrations of trace metals and hydrocarbons. Chemical concentrations in the least contaminated of two samples that were significantly toxic (mean 13.8 percent survival) were compared to those with higher survival (mean 88.8 percent survival).

Simmers *et al.* (1984) reported 100 percent mortality in *N. virens* exposed for 14 days to Black Rock Harbor, Connecticut dredged material. The bioassays were performed with mixtures of 25 percent dredged material and 75 percent clean material and chemical analyses were performed with the diluted material. Therefore, the reported concentrations were multiplied by a factor of four for use in this document.

Salazar and Salazar (1985) and Salazar (1980) reported results of toxicity tests and chemical analyses of various numbers of samples in San Diego Bay, California. A variety of animals were used; all indicated relatively high survival (generally, over 82 percent survival). For this document, the highest concentrations in which these high degrees of survival were observed were listed and used.

Rogerson *et al.* (1985) reported the results of toxicity tests of Black Rock Harbor, Connecticut sediments performed with the amphipod *A. abdita* and chemical data for PAH. The projected concentrations of PAH in undiluted sediments that caused significant mortality were listed and used in this document.

Tietjen and Lee (1984) sampled 17 sites in the Hudson-Raritan Bay estuary and determined toxicity in 14-d tests of growth of the nematode *Chromadorina germanica* and concentrations of hydrocarbons and trace metals. The chemical concentrations in samples that caused a negative intrinsic rate of growth were compared with those that caused a positive rate of growth.

Long (1987) determined PAH concentrations in mudflat sediments and densities of meiofaunal organisms in 10 square centimeters cores at 28 stations in the Forth estuary, Scotland. The chemical concentrations associated with high meiofaunal densities (mean 3741 ± 1773) were compared with those that had intermediate densities (mean 1335 ± 396) and lowest densities (mean 112 ± 123).

CH$^2$M-Hill (1989) sampled 86 stations in Eagle Harbor, Washington during June 1988 and determined toxicity to *R. abronius* and concentrations of PAH in bulk sediments. Chemical concentrations in 49 least toxic samples (mean of 17.4 ± 1.4 survivors out of 20) were compared with those in 7 moderately toxic samples (mean of 11.8 ± 1.8 survivors out of 20) and 12 highly toxic samples (mean of 0.9 ± 1.7 survivors out of 20).

# APPENDIX B

# SEDIMENT EFFECTS DATA

**Table B-1. Sediment effects data available for ANTIMONY arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm dw) | Biological Test | Remarks |
|---|---|---|
| 0.9 ± 1 | Commencement Bay least toxic--amphipod | No effect |
| 1 ± 1.4 | Commencement Bay least toxic--oyster | No effect |
| >1.9 | San Francisco Bay AET--bivalve | Not definitive |
| **2** | **ER-L** | **10 percentile** |
| 2 ± 5 | Commencement Bay moderately toxic--amphipod | * |
| 2 ± 5.5 | Commencement Bay moderately toxic--oyster | * |
| 2.3 ± 6.3 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 2.6 | PSDDA screening level | No effect |
| 2.7 ± 6.7 | San Francisco Bay moderately toxic--amphipod | No concordance |
| >2.9 | San Francisco Bay AET--amphipod | No concordance |
| 3.2 | 1986 Puget Sound AET--benthic | * |
| 5 ± 11.2 | San Francisco Bay least toxic--bivalve | No effect |
| 5.3 | 1986 Puget Sound AET--amphipod | * |
| 6.6 ± 1 | San Francisco Bay moderately toxic--bivalve | * |
| 6.7 ± 12.3 | San Francisco Bay not toxic--bivalve | No effect |
| 8.6 ± 11.9 | San Francisco Bay significantly toxic--bivalve | * |
| 9 ± 11.6 | San Francisco Bay least toxic--amphipod | No effect |
| 9.9 ± 11.8 | San Francisco Bay not toxic--amphipod | No effect |
| **25** | **ER-M** | **50 percentile** |
| 25 ± 0 | San Francisco Bay highly toxic--bivalve | * |
| 26 | 1986 Puget Sound AET--oyster | * |
| 26 | 1986 Puget Sound AET--Microtox™ | * |
| 27.5 ± 101.5 | Commencement Bay highly toxic--oyster | * |
| 91.5 ± 184 | Commencement Bay highly toxic--amphipod | * |
| 150 | 1988 Puget Sound AET--Microtox™ | * |
| 200 | 1988 Puget Sound AET--amphipod | * |
| ND | San Francisco Bay highly toxic--amphipod | No concordance |

* 13 concentrations used in ER-L and ER-M estimates.
ND = not detected

**Table B-2. Sediment effects data available for ARSENIC arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 1 | Stamford not toxic--shrimp | No effect |
| 1.3 | Duwamish River nontoxic--shrimp | No effect |
| 1.36 | Georgetown benthic community | No effect |
| 1.9 | Black Rock Harbor toxic--*Nereis* | Small gradient |
| 2.2 ± 1.2 | Trinity River not toxic--*Daphnia* | No effect |
| 2.7 ± 0.2 | Sheboygan River significantly toxic--prawn | Small gradient |
| 2.8 | Newport not toxic--shrimp | No effect |
| 3.4 ± 1.8 | Trinity River significant toxic--*Daphnia* | Small gradient |
| 3.4 | Norwalk not toxic--shrimp | No effect |
| 3.7 ± 1 | Kishwaukee River least taxa | No effect |
| 5 ± 1.8 | Kishwaukee River most taxa | Small gradient |
| 5.8 ± 6.4 | Southern California not toxic--amphipod | No effect |
| 5.9 ± 1.1 | DuPage River most taxa | Small gradient |
| 7.4 ± 2.2 | DuPage River least taxa | Small gradient |
| 8.32 ± 5.2 | Southern California significantly toxic--amphipod | Small gradient |
| 10.4 ± 13.4 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 12.8 | Los Angeles Harbor toxic--shrimp | Small gradient |
| 13.7 ± 14.8 | San Francisco Bay least toxic--bivalve | No effect |
| 14.6 ± 13.8 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 17.5 ± 14.1 | San Francisco Bay highly toxic--amphipod | No concordance |
| 22 ± 18.7 | San Francisco Bay not toxic--bivalve | No effect |
| 22.1 ± 19.4 | San Francisco Bay moderately toxic--bivalve | * |
| 22.6 ± 28.1 | Puget Sound non-toxic--amphipod | No effect |
| 22.8 ± 22.1 | San Francisco Bay significantly toxic--bivalve | No gradient |
| 25.1 ± 23.1 | Puget Sound moderately toxic--amphipod | Small gradient |
| 27.8 ± 30.8 | Commencement Bay least toxic--oyster | No effect |
| 28 ± 21.5 | San Francisco Bay least toxic--amphipod | No effect |
| 28.3 ± 26.6 | Commencement Bay least toxic--amphipod | No effect |
| 30.3 ± 22.4 | San Francisco Bay not toxic--amphipod | No effect |
| 32 ± 14.3 | Baltimore Harbor least toxic--fish | No effect |
| **33** | **ER-L** | **10 percentile** |
| 33 | EP chronic marine | * |
| <47.2 | Waukegan Harbor highly toxic--amphipod | Below detection |
| 50.7 ± 29.3 | San Francisco Bay highly toxic--bivalve | * |
| 54 | San Francisco Bay AET--bivalve | * |
| 57 | 1988 Puget Sound AET--benthic | * |
| 58.7 ± 148.1 | Commencement Bay moderately toxic--oyster | * |
| 63.2 ± 148 | Commencement Bay moderately toxic--amphipod | * |
| 64 | EP acute marine | * |
| 70 | PSDDA screening level | No effect |
| 70 | San Francisco Bay AET--amphipod | No concordance |
| **85** | **ER-M** | **50 percentile** |
| 85 | 1986 Puget Sound AET--benthic | * |
| 91.9 ± 78.6 | Baltimore Harbor most toxic--fish | * |
| 93 | 1986 Puget Sound AET--amphipod | * |
| 689.9 ± 2350.9 | Commencement Bay highly toxic--oyster | * |
| 700 | 1986 Puget Sound AET--oyster | * |
| 700 | 1986 Puget Sound AET--Microtox™ | * |
| 1005 ± 2777 | Puget Sound highly toxic--amphipod | * |
| 2257.1 ± 4213.7 | Commencement Bay highly toxic--amphipod | * |

* 16 concentrations used to determine ER-L and ER-M values

**Table B-3. Sediment effects data available for CADMIUM arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| <0.04 | Fraser River feral clams present | no effects |
| 0.05 ± 0 | Kishwaukee River least taxa | Below detection |
| <0.1 | Georgetown no benthic effects | No effects |
| 0.2 | Cubatao River highly toxic--*Daphnia* | Small gradient |
| 0.3 ± 0.8 | Kishwaukee River most taxa | Below detection |
| 0.4 | *Macoma* burrowing bioassay | Small gradient |
| 0.4 ± 0.1 | San Francisco Bay least toxic--bivalve | No effect |
| 0.4 ± 0.3 | Southern California high echinoderm abundance | No effect |
| 0.4 ± 0.1 | Massachusetts Bay high species richness | No effect |
| <0.5 | Duwamish River low toxicity--shrimp | No effect |
| 0.5 ± 0.3 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 0.5 ± 0.3 | Southern California moderate echinoderm abundance | No gradient |
| 0.5 ± 0.4✔ | Keweenaw Waterway least toxic--*Daphnia* | No effect |
| <0.5 | Newport not toxic--shrimp | No effect |
| 0.6 ± 0.3 | San Francisco Bay least toxic--amphipod | No effect |
| 0.6 ± 0.4 | San Francisco Bay significantly toxic--amphipod | No gradient |
| 0.6 ± 0.3 | San Francisco Bay not toxic--amphipod | No effect |
| 0.6 ± 0.4 | San Francisco Bay significantly toxic--bivalve | No gradient |
| 0.6 ± 0.3 | San Francisco Bay not toxic--bivalve | No effect |
| 0.6 ± 0.7 | Southern California moderate species richness | No concordance |
| 0.6 ± 0.3 | Keweenaw Waterway not toxic--Daphnia | No effect |
| 0.7 ± 0.3 | San Francisco Bay highly toxic--bivalve | No gradient |
| 0.7 ± 0.5 | San Francisco Bay moderately toxic--bivalve | Small gradient |
| 0.7 ± 0.7 | Southern California moderate arthropod abundance | No concordance |
| 0.7 ± 0.6 | Massachusetts Bay moderate species richness | Small gradient |
| 0.8 ± 0.5 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 0.8 ± 1.1 | Southern California moderate total abundance | No concordance |
| 0.9 ± 1 | Southern California high arthropod abundance | No effect |
| 0.9 | San Diego Bay low toxicity--various | No effect |
| 0.9 | San Diego Bay low toxicity--various | No effect |
| 0.96 | PSDDA screening level | No effect |
| 1 ± 1.1 | *R. abronius* LC50--spiked bioassay | Sand |
| 1.1 ± 2 | Southern California low total abundance | No concordance |
| 1.1 ± 1.1 | Massachusetts Bay least species richness | Small gradient |
| 1.2 ± 1 | Fraser River feral clams absent | Small gradient |
| 1.2 | San Francisco Bay AET--amphipod | No concordance |
| 1.2 ± 0.3 | Little Grizzly Creek high toxicity--*Daphnia* | Small gradient |
| 1.3 ± 0.6 | DuPage River least taxa | no concordance |
| 1.4 | *Macoma* avoidance bioassay | Small gradient |
| 1.5 ± 4 | Southern California high species richness | No effect |
| 1.5 ± 0.9 | DuPage River most taxa | No effect |
| 1.5 ± 0.2✔ | Keweenaw Waterway most toxic--*Daphnia* | Small gradient |
| 1.6 | Black Rock Harbor highly toxic--Nereis | Small gradient |
| 1.7 | San Francisco Bay AET--bivalve | Small gradient |
| 1.7 ± 0.3 | Keweenaw Waterway significantly toxic--*Daphnia* | Small gradient |
| 1.9 ± 1.1 | Commencement Bay least toxic--oyster | No effect |
| 1.98 | Lake Union toxic--amphipod | Small gradient |
| 2 | Baltimore Harbor least toxic--fish | No effect |
| 2.3 ± 1.3 | Commencement Bay least toxic--amphipod | No effect |
| 2.5 | Waukegan Harbor high toxicity--amphipod | Small gradient |
| 2.5 | Torch Lake significantly toxic--*Daphnia* | Small gradient |
| 2.7 ± 2 | Commencement Bay moderately toxic--oyster | Small gradient |

Table B-3. (continued)

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 2.8 ± 0.5 | Sheboygan River high toxicity--prawn | Small gradient |
| 2.8 | Stamford low toxicity--shrimp | No effect |
| 2.9 ± 2.3 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 3 | Los Angeles Harbor high toxicity--shrimp | Small gradient |
| 3.1 ± 0.6 | Phillips Chain low toxicity--*Daphnia* | No effect |
| 3.2 ± 6 | Southern California not toxic--amphipod | No effect |
| 4.1 | Norwalk low toxicity--shrimp | No effect |
| 4.3 ± 11.4 | Southern California low arthropod abundance | * |
| 4.7 ± 12.2 | Southern California low species richness | * |
| 4.8 ± 5.6 | Trinity River not toxic--*Daphnia* | No effect |
| 4.9 | Phillips Chain high toxicity--*Daphnia* | Small gradient |
| **5** | **ER-L** | **10 percentile** |
| 5.1 | 1988 Puget Sound AET--benthic | * |
| 5.3 ± 11.4 | Southern California significantly toxic--amphipod | * |
| 5.6 | *R. abronius*--spiked bioassay | * |
| 5.8 | 1986 Puget Sound AET--benthic | * |
| 5.8 | *R. abronius*--spiked bioassay | * |
| 6.2 ± 13.1 | Southern California low echinoderm abundance | * |
| 6.5 | *R. abronius* EC50--spiked bioassay | * |
| 6.7 | 1986 Puget Sound AET--amphipod | * |
| 6.9 | *R. abronius* LC50--spiked bioassay | * |
| 8.2 | *R. abronius* LC50--spiked bioassay | * |
| 8.4 | *E. sencillus* LC98- spiked bioassay | * |
| 8.5 | *R. abronius* LC76--spiked bioassay | * |
| 8.7 | *R. abronius* LC50--spiked bioassay | * |
| 8.8 | *R. abronius* LC50--spiked bioassay | * |
| 8.9 ± 9.2 | Palos Verdes not toxic--amphipod | No effect |
| 8.9 | *R. abronius* overall LC50--spiked bioassay | * |
| **9.0** | **ER-M** | **50 percentile** |
| 9.1 | *R. abronius* EC50--spiked bioassay | * |
| 9.4 ± 17.3 | Southern California high total abundance | No effect |
| 9.6 | 1986 Puget Sound AET--oyster | * |
| 9.6 | 1986 Puget Sound AET--Microtox™ | * |
| 9.7 | *R. abronius* EC50--spiked bioassay | * |
| 9.8 | *R. abronius* LC50--spiked bioassay | * |
| 10 | *R. abronius* LC50--spiked bioassay | * |
| 10.6 ± 8.7 | Trinity River significantly toxic--*Daphnia* | * |
| 11 | *P. affinis* lethality -spiked bioassay | * |
| 11.5 | *R. abronius* LC50--spiked bioassay | * |
| 11.8 ± 6.6 | Hudson-Raritan least toxic--nematode | No effect |
| 15.3 ± 45.1 | Commencement Bay highly toxic--oyster | * |
| 18.6 ± 8.9 | Hudson-Raritan highly toxic--nematode | * |
| 20.8 | *R. abronius* EC50--spiked bioassay | * |
| 22.7 | San Diego Bay low toxicity--polychaete | No effect |
| 22.8 ± 19.8 | Baltimore Harbor most toxic--fish | * |
| 25.9 | *R. abronius* LC50--spiked bioassay | * |
| 28 | San Diego Bay low toxicity--mysid | No effect |
| 28.7 ± 3.1 | Palos Verdes significantly toxic--amphipod | * |
| 28.7 ± 3.1 | Palos Verdes major benthic degradation | * |
| 31 | EP chronic marine | * |
| 32.5 | San Diego Bay low toxicity--clam | No effect |
| 32.5 | San Diego Bay low toxicity--various | No effect |
| 38.6 | New York Harbor low toxicity--various | No effect |
| 40 | *N. virens*--spiked bioassay | No effect |
| 41.6 ± 79.8 | Commencement Bay highly toxic--amphipod | * |
| 96 | EP acute marine | * |

* 36 concentrations used to determine ER-L and ER-M values

**Table B-4. Sediment effects data available for CHROMIUM arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 2.5 | Georgetown benthic community | No effect |
| 11.8 ± 3.7 | Commencement Bay least toxic--oyster | No effect |
| 15.3 | Duwamish River low toxicity | No effect |
| 16.2 ± 8.1 | Commencement Bay least toxic--amphipod | No effect |
| 17.7 ± 7.3 | Commencement Bay moderately toxic--amphipod | No gradient |
| 17.7 ± 7.3 | Commencement Bay moderately toxic--oyster | Small gradient |
| 18.1 ± 16.8 | Trinity River not toxic--*Daphnia* | No effect |
| 19.7 ± 11.3 | Commencement Bay highly toxic--amphipod | Small gradient |
| 19.9 | Newport low toxicity--shrimp | No effect |
| 20 | Lake Union highly toxic--amphipod | Small gradient |
| 22.2 ± 9 | Commencement Bay highly toxic--oyster | Small gradient |
| 26 | San Diego Bay low toxicity--various | No effect |
| 26 | San Diego Bay low toxicity--various | No effect |
| 27 ± 11.1 | Massachusetts Bay high species richness | No effect |
| 29 ± 14✓ | Keweenaw Waterway least toxic--*Daphnia* | No effect |
| 29.2 ± 9.1 | Kishwaukee River most taxa | No effect |
| 29.6 ± 15.6 | Southern California high echinoderm abundance | No effect |
| 32.3 ± 17.5 | Southern California moderate echinoderm abundance | No gradient |
| 34 ± 5.9 | DuPage River most taxa | No effect |
| 36.3 ± 21.9 | Keweenaw Waterway not toxic--*Daphnia* | No effect |
| 38.1 ± 36.3 | Southern California moderate species richness | No concordance |
| 38.5 | Waukegan Harbor highly toxic--amphipod | Small gradient |
| 40.7 ± 30.9 | Southern California high arthropod abundance | No effect |
| 42 ± 11 | Fraser River *Macoma* present | No effect |
| 42 ± 39.8 | Southern California moderate total abundance | No concordance |
| 43.4 ± 22.5 | Kishwaukee River least taxa | Small gradient |
| 46.3 ± 43.3 | Southern California moderate arthropod abundance | Small gradient |
| 47.6 | Los Angeles Harbor high toxicity | Small gradient |
| 54 ± 83.5 | Southern California low total abundance | No concordance |
| 59.7 ± 28.7 | DuPage River least taxa | Weak concordance |
| 60 | *Macoma* burrowing bioassay | Small gradient |
| 60.9 ± 27.5 | Massachusetts Bay moderate species richness | * |
| 62.3 ± 139.2 | Southern California high species richness | No effect |
| 67.5 | Norwalk low toxicity--shrimp | No effect |
| 72.6 ± 60.6 | Trinity River significantly toxic--Daphnia | * |
| 73 ± 124.4 | Southern California not toxic--amphipod | No effect |
| **80** | **ER-L** | **10 percentile** |
| 81 ± 29.3 | Massachusetts Bay low species richness | * |
| 81.4 ± 88.5 | Southern California significantly toxic--amphipod | * |
| 86 | Stamford low toxicity--shrimp | No effect |
| 87 ± 47 | Little Grizzly Creek high toxicity--*Daphnia* | * |
| 87.3 ± 22.1 | Fraser River Macoma absent | * |
| 88.2 ± 82.7 | San Francisco Bay least toxic--bivalve | No effect |
| 90 | *Macoma* avoidance bioassay | * |
| 97.5 ± 66.7 | San Francisco Bay highly toxic--bivalve | No concordance |
| 101.6 ± 23✓ | Keweenaw Waterway highly toxic--*Daphnia* | * |
| 108.7 ± 19.6 | Keweenaw Waterway significantly toxic--*Daphnia* | * |
| 128 ± 4 | Sheboygan River significant toxicity--prawn | * |
| 133.7 ± 94.2 | San Francisco Bay significantly toxic--bivalve | No effect |
| 141.8 ± 86.5 | San Francisco Bay highly toxic--amphipod | No concordance |
| 144.6 ± 88.6 | Hudson-Raritan least toxic--nematode | No effect |
| **145** | **ER-M** | **50 percentile** |
| 145.8 ± 307.9 | Southern California low arthropod abundance | * |
| 150.2 ± 85.9 | San Francisco Bay not toxic--bivalve | No effect |
| 154.9 ± 102.1 | San Francisco Bay significantly toxic --amphipod | No concordance |
| 156.6 ± 320.9 | Southern California low species richness | * |
| 160.3 ± 85.4 | Hudson-Raritan most toxic--nematode | * |

**Table B-4. (continued)**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 163.3 ± 116.7 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 164 ± 91.4 | San Francisco Bay moderately toxic--bivalve | No concordance |
| 180 | Torch Lake significantly toxic--*Daphnia* | * |
| 195 ± 93.9 | San Francisco Bay least toxic--amphipod | No effect |
| 201.3 ± 349 | Southern California low echinoderm abundance | * |
| 202.6 ± 97.3 | San Francisco Bay not toxic--amphipod | No effect |
| 254.8 | San Diego Bay low toxicity--shrimp | No effect |
| 260 | 1988 Puget Sound AET--benthic | * |
| 270 | 1988 Puget Sound AET--amphipod | * |
| 280 | San Francisco Bay AET--bivalve | No concordance |
| 292.6 ± 459.3 | Southern California high total abundance | No effect |
| 299.5 | San Diego Bay low toxicity--clam | No effect |
| 299.5 | San Diego Bay low toxicity--polychaete | No effect |
| 299.5 | San Diego Bay low toxicity--fish | No effect |
| 315.4 ± 236 | Phillips Chain least toxic--*Daphnia* | No effect |
| 335 ± 179.7 | Baltimore Harbor least toxic--fish | No effect |
| 369.2 | Black Rock Harbor high toxicity | * |
| 370 | San Francisco Bay AET--amphipod | No concordance |
| 669.3 | Palos Verdes major benthic degradation | * |
| 980 | Phillips Chain significantly toxic--*Daphnia* | * |
| 1646 ± 1628 | Baltimore Harbor most toxic--fish | * |

* 21 concentrations used to determine ER-L and ER-M values

**Table B-5. Sediment effects data available for COPPER arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 1.02 | Georgetown benthic community | No effect |
| 4 ± 3 | Mississippi River high toxicity--midge | No concordance |
| 5 ± 2 | Massachusetts Bay high species richness | No effect |
| 7.9 ± 5 | Mississippi River low toxicity | No effect |
| 8.9 ± 4 | Mississippi River low toxicity | No effect |
| 12 ± 6 | Southern California high echinoderm abundance | No effect |
| 12.2 | Newport low toxicity--shrimp | No effect |
| 13.4 ± 14 | Southern California moderate echinoderm abundance | No gradient |
| 15 ± 7 | Massachusetts Bay moderate species richness | * |
| 16 ± 7 | Massachusetts Bay low species richness | No gradient |
| 17.8 | Mississippi River low toxicity | No effect |
| 17.8 | ET50 burrowing time bioassay--clam | * |
| 18 ± 15 | Trinity River nontoxic--*Daphnia* | No effect |
| 19.5 | Waukegan Harbor highly toxic--amphipod | * |
| 19.5 ± 6 | Kishwaukee River high number of taxa | Small gradient |
| 23.6 ± 11✓ | Keweenaw Waterway least toxicity | No effect |
| 27.5 ± 16 | Feral Fraser River *Macoma* present | No effect |
| 33 | Keweenaw Waterway high number of taxa | No effect |
| 34.5 ± 17 | San Francisco Bay least toxic--bivalve | No effect |
| 42.8 | Duwamish River nontoxic--shrimp | No effect |
| 43 ± 49 | Keweenaw Waterway nontoxic--*Daphnia* | No effect |
| 45.4 ± 53 | Kishwaukee River low number of taxa | * |
| 46.9 ± 26 | San Francisco Bay not toxic--bivalve | No effect |
| 62.1 ± 25 | DuPage River high number of taxa | No effect |
| 62.3 ± 78 | Southern California nontoxic--amphipod | No effect |
| 64 ± 40 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 67 | *Macoma* burrowing bioassay | * |
| 68.2 ± 48 | San Francisco Bay significantly toxic--bivalve | * |
| 68.4 ± 62 | Trinity River significant toxicity--*Daphnia* | * |
| **70** | **ER-L** | **10 percentile** |
| 70 ± 47 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 72.1 ± 41 | San Francisco Bay least toxic--amphipod | No effect |
| 72.6 ± 75 | Commencement Bay least toxic--oyster | No effect |
| 74.6 ± 43 | San Francisco Bay not toxic--amphipod | No effect |
| 76 ± 51 | San Francisco Bay moderately toxic--bivalve | * |
| 77.3 ± 39 | DuPage River low number of taxa | Small gradient |
| 81 | PSDDA screening level | No effect |
| 84.6 ± 63 | San Francisco Bay highly toxic--amphipod | * |
| 85.1 ± 69 | Commencement Bay least toxic--amphipod | No effect |
| 87.7 ± 33 | San Francisco Bay highly toxic--bivalve | * |
| 96.7 ± 177 | Southern California low echinoderm abundance | * |
| 98 ± 90 | Puget Sound nontoxic--amphipod | No effect |
| 106.3 ± 93 | Commencement Bay moderately toxic--oyster | * |
| 110 | San Francisco Bay AET--bivalve | * |
| 117.8 ± 98 | Commencement Bay moderately toxic--amphipod | * |
| 134.6 ± 57 | Feral Fraser River *Macoma* absent | * |
| 135.2 ± 118 | Phillips Chain nontoxic--*Daphnia* | No effect |
| 136 | EP chronic marine @4% TOC | * |
| 138 ± 124 | Puget Sound moderately toxic--amphipod | * |
| 145 ± 2 | Sheboygan River toxic--prawn | * |
| 147 | Los Angeles Harbor toxic--shrimp | * |

Table B-5. (continued)

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 150 | *Macoma* avoidance bioassay | * |
| 156 | Lake Union high toxicity--amphipod | * |
| 157.5 ± 29 | Baltimore Harbor least toxic--fish | No effect |
| 180 | San Francisco Bay AET--amphipod | * |
| 181.3 ± 173 | Southern California significant toxicity--amphipod | * |
| 200 | Norwegian benthos species diversity | * |
| 210 | San Diego Bay nontoxic--various | No effect |
| 216 | EP acute marine @4% TOC | * |
| 217.8 | Stamford nontoxic--shrimp | No effect |
| 223.7 | Norwalk nontoxic--shrimp | No effect |
| 250.5 ± 232 | Hudson-Raritan nontoxic--nematode | No effect |
| 251 ± 227 | Palos Verdes nontoxic--amphipod | No effect |
| 310 | 1986 Puget Sound AET--benthic | * |
| 312.3 | San Diego Bay nontoxic--mysid | No effect |
| **390** | **ER-M** | **50 percentile** |
| 390 | 1986 Puget Sound AET--oyster | * |
| 390 | 1986 Puget Sound AET- Microtox™ | * |
| 453 ± 311 | Hudson-Raritan highly toxic--nematode | * |
| 530 | 1988 Puget Sound AET--benthic | * |
| 540 | Phillips Chain significant toxicity--*Daphnia* | * |
| 589 | Keweenaw Waterway least number of taxa | * |
| 591.7 ± 126 | Palos Verdes major benthic degradation | * |
| 591.7 ± 126 | Palos Verdes significant toxicity--amphipod | * |
| 612 | Black Rock Harbor highly toxic | * |
| 612 ± 318✓ | Keweenaw Waterway highly toxic--*Daphnia* | * |
| 681 | LC50 *Daphnia* spiked bioassay--Soap Creek | * |
| 730 | Keweenaw Waterway significant toxicity--*Daphnia* | * |
| 810 | 1986 Puget Sound AET--amphipod | * |
| 857 | LC50 midge spiked bioassay--Soap Creek | * |
| 917.8 ± 2750 | Commencement Bay highly toxic--oyster | * |
| 937 | LC50 *Daphnia* spiked bioassay--Tualatin River | * |
| 964 | LC50 amphipod spiked bioassay- Soap Creek | * |
| 995 | San Diego Bay nontoxic--clam | No effect |
| 995 | San Diego Bay nontoxic--polychaete | No effect |
| 1071 ± 948 | Baltimore Harbor most toxic-fish | * |
| 1078 | LC50 amphipod spiked bioassay--Soap Creek | * |
| 1260 ± 3251 | Puget Sound highly toxic--amphipod | * |
| 1300 | 1988 Puget Sound AET--amphipod | * |
| 1374 ± 809 | Little Grizzly Creek toxic--*Daphnia* | * |
| 1800 | Torch Lake highly toxic--*Daphnia* | * |
| 2296 | LC50 midge spiked bioassay--Tualatin River | * |
| 2820 ± 4881 | Commencement Bay highly toxic--amphipod | * |

* 51 concentrations used to determine ER-L and ER-M values

**Table B-6. Sediment effects data available for LEAD arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| <0.5 | Georgetown disposal site benthos | No effect |
| 9.5 ± 9 | Southern California moderate echinoderm abundance | No concordance |
| 9.5 ± 10.3✓ | Keweenaw least toxic--*Daphnia* | No effect |
| 10.7 ± 10 | Keweenaw nontoxic--*Daphnia* | No effect |
| 11.3 ± 8 | Southern California moderate species richness | No concordance |
| 11.7 ± 13 | Southern California high echinoderm abundance | No effect |
| 12.4 ± 9 | Southern California high arthropod abundance | No effect |
| 12.5 ± 4 | Massachusetts Bay high benthhic species richness | No effect |
| 12.5 ± 10 | Southern California moderate arthropod abundance | No gradient |
| 12.6 ± 10 | Southern California moderate total abundance | No concordance |
| 14 ± 9 | Feral Fraser River *Macoma* present | No effect |
| 16.6 ± 24 | Southern California low total abundance | No concordance |
| 18 | Cubatao River Brazil high toxicity--*Daphnia* | Small gradient |
| 19.8 ± 34 | Southern California high species richness | No effect |
| 21.2 ± 11 | Kishwaukee River high number of taxa | No effect |
| 25.2 ± 17 | San Francisco Bay least toxic--bivalve | No effect |
| 27 ± 9✓ | Keweenaw Waterway highly toxic--*Daphnia* | * |
| 27.1 | Duwamish River nontoxic--shrimp | No effect |
| 29 ± 8 | Keweenaw significantly toxic--*Daphnia* | * |
| 30.6 ± 26 | Kishwaukee River least number of taxa | * |
| 32 ± 18 | Little Grizzly Creek significant toxicity | No concordance |
| 32 | *Macoma* burrowing bioassay | * |
| <32.4 | Waukegan Harbor highly toxic--amphipod | Detection limits |
| 35 | Norway benthos diversity | * |
| **35** | **ER-L** | **10 percentile** |
| 35.1 ± 22 | Trinity River least toxicity--*Daphnia* | No effect |
| 41.3 | Los Angeles Harbor >50% mortality--shrimp | * |
| 42.1 ± 27 | San Francisco Bay moderately toxic--amphipod | * |
| 42.4 ± 26 | Massachusetts Bay moderate species richness | * |
| 43.1 ± 33 | San Francisco Bay nontoxic--bivalve | No effect |
| 45.6 ± 59 | Southern California nontoxic--amphipod | No effect |
| 46.7 ± 17 | Massachusetts Bay low benthic species richness | * |
| 46.9 ± 31 | Puget Sound nontoxic--amphipod | No effect |
| 47.8 ± 103 | Southern California low arthropod abundance | * |
| ≤50 | San Francisco Bay triad minimum bioeffects | * |
| 51 ± 34 | San Francisco Bay least toxic--amphipod | No effect |
| 51 ± 111 | Southern California low species richness | * |
| 53.7 ± 27 | Trinity River significantly toxic--*Daphnia* | * |
| 54.4 ± 36 | San Francisco Bay nontoxic--amphipod | No effect |
| 57.1 ± 20 | DuPage River high number of taxa | No effect |
| 58.3 ± 61 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 58.9 ± 63 | San Francisco Bay significantly toxic--bivalve | * |
| >60 | FWPCA heavy: benthos absent | * |
| 63.4 ± 63 | San Francisco Bay moderately toxic--bivalve | * |
| 64.4 ± 118 | Southern California low echinoderm abundance | * |
| 66 | PSDDA screening level | No effect |
| 73.1 ± 42 | Southern California significantly toxic--amphipod | * |
| 74 | *Macoma* avoidance bioassay | * |
| 77.6 ± 75 | Commencement Bay least toxic--amphipod | No effect |
| 78.6 ± 34 | Phillips Chain low toxicity--*Daphnia* | No effect |
| 81.7 ± 49 | Feral Fraser River *Macoma* absent | * |

**Table B-6. (continued)**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 89.6 | Black Rock Harbor 100% mortality--*Nereis* | * |
| 94.9 ± 154 | Southern California high total abundance | No effect |
| 95.7 ± 93 | San Francisco Bay highly toxic--amphipod | * |
| 104.5 ± 87 | San Francisco Bay highly toxic--bivalve | * |
| 104.7 ± 173 | Commencement Bay least toxic--oyster | No effect |
| **110** | **ER-M** | **50 percentile** |
| 110 | Torch Lake significantly toxic | * |
| 113.1 ± 123 | Commencement Bay moderately toxic--oyster | * |
| 120 | San Francisco Bay AET amphipod | * |
| 122.9 | Stamford nontoxic--shrimp | No effect |
| ≥130 | San Francisco Bay triad significant bioeffects | * |
| 132 | EP chronic marine @4% TOC | * |
| 136.6 ± 140 | Puget Sound moderately toxic--amphipod | * |
| 140 | San Francisco Bay AET--bivalve | * |
| 143.7 ± 110 | DuPage River low number of taxa | * |
| 145.2 ± 132 | Hudson-Raritan not toxic--nematode | No effect |
| 160 | Phillips Chain significantly toxic | * |
| 170.8 ± 192 | Commencement Bay moderately toxic--amphipod | * |
| 213 ± 131 | Baltimore Harbor least toxic--fish | No effect |
| 253 ± 47 | Sheboygan River significantly toxic | * |
| 276.9 | Norwalk nontoxic--shrimp | No effect |
| 300 | 1986 Puget Sound AET--benthic | * |
| 300 | Lake Union 95% mortality--amphipod | * |
| 312.3 ± 23 | Palos Verdes major benthic degradation | * |
| 320.9 ± 195 | Hudson-Raritan highly toxic--nematode | * |
| 450 | 1988 Puget Sound AET--benthic | * |
| 512 ± 231✔ | Baltimore Harbor most toxic--fish | * |
| 530 | 1986 Puget Sound AET--Microtox™ | * |
| 570.1 ± 1489 | Commencement Bay highly toxic--oyster | * |
| 660 | 1986 Puget Sound AET--amphipod | * |
| 660 | 1986 Puget Sound AET-oyster | * |
| 750.2 ± 1763 | Puget Sound highly toxic--amphipod | * |
| 1613.2 ± 2628 | Commencement Bay highly toxic--amphipod | * |
| 3360 | EP acute marine @ 4% TOC | * |

* 47 concentrations used to determine ER-L and ER-M values

**Table B-7. Sediment effects data available for MERCURY arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| <0.1 ± 0✓ | Mississippi River low toxicity--insects✓ | No effect✓ |
| 0.026 | Newport not toxic--shrimp | No effect |
| 0.032 | EP chronic marine @4% TOC | * |
| 0.035 | Mississippi River low toxicity | No effect |
| 0.05 | Duwamish River not toxic--shrimp | No effect |
| 0.06 | Massachusetts Bay high benthos species richness | No effect |
| 0.08 | Waukegan Harbor highly toxic--*Hyalella* | * |
| 0.08 ± 0.1 | Kishwaukee River high number of taxa | No effect |
| 0.09 ± 0.1 | Kishwaukee River low number of taxa | No gradient |
| <0.1 | Sheboygan River significant toxicity--prawn | Below detection |
| 0.1 ± 0.1 | Feral Fraser River *Macoma* present | No effect |
| 0.1 ± 0.1✓ | Keweenaw Waterway least toxic--*Daphnia* | No effect |
| 0.11 ± 0.02 | Massachusetts Bay low benthos species richness | No gradient |
| 0.13 ± 0.1 | Keweenaw Waterway not toxic--*Daphnia* | No effect |
| 0.147 | Los Angeles toxic (>50% mortality)--shrimp | * |
| **0.15** | **ER-L** | **10 percentile** |
| 0.162 | Stamford not toxic--shrimp | No effect |
| 0.173 | Lake Union 95% mortality--amphipod | * |
| 0.18 ± 0.1 | Massachusetts. Bay moderate benthos species richness | No gradient |
| 0.18 | *Macoma* burrowing time bioassay | * |
| 0.2 ± 0.8✓ | Keweenaw Waterway most toxic--*Daphnia* | No gradient |
| 0.2 ± 0.1 | Commencement Bay least toxic--amphipod | No effect |
| 0.2 ± 0.1 | Commencement Bay moderately toxic--oyster | No gradient |
| 0.2 ± 0.1 | Commencement Bay least toxic--oyster | No effect |
| 0.2 ± 0.1 | Keweenaw Waterway significantly toxic--*Daphnia* | No gradient |
| 0.21 | PSDDA screening level | No effect |
| 0.28 ± 0.2 | DuPage River high number of taxa | No effect |
| 0.29 | Torch Lake significant mortality--*Daphnia* | * |
| 0.3 ± 0.2 | Commencement Bay moderately toxic--amphipod | No gradient |
| 0.3 ± 0.2 | San Francisco Bay least toxic--bivalve | No effect |
| 0.3 ± 0.1 | Trinity River significantly toxic--*Daphnia* | No concordance |
| 0.3 | Norwalk not toxic--shrimp | No effect |
| 0.33 ± 0.1 | Southern California significantly toxic--amphipod | No gradient |
| 0.34 ± 0.02 | Southern California not toxic--amphipod | No effect |
| 0.38 ± 0.1 | Baltimore Harbor least toxic--fish | No effect |
| 0.41 | 1986 Puget Sound AET--Microtox™ | * |
| 0.42 ± 0.2 | Feral Fraser River *Macoma* absent | * |
| 0.47 ± 0.5 | Puget Sound nontoxic--amphipod | No effect |
| 0.48 | *Macoma* avoidance bioassay | * |
| 0.5 ± 0.4 | San Francisco Bay least toxic--amphipod | No effect |
| 0.5 ± 0.3 | San Francisco Bay not toxic--bivalve | No effect |
| 0.59 | 1986 Puget Sound AET--oyster | * |
| 0.6 ± 0.4 | San Francisco Bay not toxic--amphipod | No effect |
| 0.6 ± 0.4 | San Francisco Bay highly toxic--bivalve | No concordance |
| 0.6 ± 0.7 | Trinity River low toxicity--*Daphnia* | No effect |
| 0.6 | EP acute marine @4% TOC | * |
| 0.61 | Georgetown benthic community | No effect |
| 0.65-1.15 | *Pontoporeia* activity not significantly decreased | No effect |
| 0.7 ± 0.8 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 0.7 ± 0.8 | San Francisco Bay significantly toxic--amphipod | No gradient) |
| 0.7 ± 0.9 | San Francisco Bay significantly toxic--bivalve | No gradient |
| 0.88 | 1986 Puget Sound AET--benthic | * |

**Table B-7. (continued)**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 0.9 ± 1 | San Francisco Bay moderately toxic--bivalve | * |
| 0.9 | Cubatao River EC50 toxicity--*Daphnia* | * |
| 0.96 ± 1 | San Francisco Bay highly toxic--amphipod | * |
| 1.02 ± 1.3 | Phillips Chain not toxic--*Daphnia* | No effect |
| **1.3** | **ER-M** | **50 percentile** |
| 1.3 | San Francisco Bay AET-amphipod | * |
| 1.38 ± 4.6 | Puget Sound intermediate toxicity--amphipod | * |
| 1.5 | San Francisco Bay AET--bivalve | * |
| 1.5 ± 0.9 | L. Grizzly Creek significantly toxic--*Daphnia* | * |
| 1.6 ± 1.1 | Baltimore Harbor most toxic--fish | * |
| 1.6 ± 2 | DuPage River low number of taxa | * |
| 2.1 | 1986 Puget Sound AET--amphipod | * |
| 2.1 | 1988 Puget Sound AET--benthic | * |
| 2.15-3.35 | *Pontoporeia* activity sign decreased | * |
| 2.7 | San Diego Bay not toxic--various | No effect |
| 3.5 ± 12.5 | Commencement Bay highly toxic--oyster | * |
| 5 ± 6.7 | Hudson-Raritan not toxic--nematode | No effect |
| 5.04 ± 14.8 | Puget Sound highly toxic | * |
| 8.9 ± 7.5 | Hudson-Raritan highly toxic--nematode | * |
| 9.4 | Phillips Chain significantly toxic | * |
| 11.2 ± 22.8 | Commencement Bay highly toxic--amphipod | * |
| 13.1 | LC50 amphipod bioassay | * |
| 34.9 | New York nontoxic, 100-d, various species | No effect |
| 58.2 | San Diego Bay not toxic--mysid | No effect |
| 66.5 | San Diego Bay not toxic--clam | No effect |
| 254.4 | San Diego Bay not toxic--fish | No effect |

* 30 concentrations used to determine ER-L and ER-M values

**Table B-8. Sediment effects data available for NICKEL arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 3 | Cubatao River toxicity--*Daphnia* | No concordance |
| 6 | Georgetown benthic community | No effect |
| 10±3 | Massachusetts Bay high species richness | No effect |
| 10 | Newport not toxic--shrimp | No effect |
| 12±3 | Commencement Bay least toxic--oyster | No effect |
| 16±7 | Commencement Bay least toxic--amphipod | No effect |
| 17±8 | Commencement Bay moderately toxic--oyster | Small gradient |
| 17.5 | Duwamish River nontoxic--shrimp | No effect |
| 20±13 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 20±15 | Southern California not toxic--amphipod | No effect |
| 21±11 | Massachusetts Bay moderate species richness | * |
| 24±22 | Southern California significantly toxic--amphipod | Small gradient |
| 28 | 1986 Puget Sound AET--Microtox™ | * |
| 28 | PSDDA screening level | No effect |
| 29 ± 3.6✓ | Keweenaw least toxic--*Daphnia* | No effect |
| 29±26 | Trinity River significantly toxic--*Daphnia* | No concordance |
| **30** | **ER-L** | **10 percentile** |
| 30±22 | Commencement Bay highly toxic--oyster | * |
| 31 | Los Angeles Harbor (>50% mortality)--shrimp | * |
| <31.8 | Waukegan Harbor significantly toxic--amphipod | below detection |
| 33±12 | Massachusetts Bay low species richness | * |
| 34±14 | Feral Fraser River *Macoma* present | No effect |
| 35±14 | Keweenaw Waterway not toxic--*Daphnia* | No effect |
| 36±29 | Trinity River not toxic--*Daphnia* | No effect |
| 38 | Stamford not toxic | No effect |
| 39 | 1986 Puget Sound AET--oyster | * |
| 40±16 | Little Grizzly Creek significantly toxic--*Daphnia* | * |
| 41±32 | Commencement Bay highly toxic--amphipod | * |
| 43 | Norwalk not toxic--shrimp | No effect |
| 44±3 | Feral Fraser River *Macoma* absent | Small gradient |
| 49 | 1986 Puget Sound AET--benthic | * |
| **50** | **ER-M** | **50 percentile** |
| 52 | Black Rock Harbor 100% mortality--*Nereis* | * |
| 70±14 | Baltimore Harbor least toxic--fish | No effect |
| 78±42 | San Francisco Bay least toxic--bivalve | No effect |
| 88 | Lake Union highly toxic--amphipod | * |
| 93±3 | San Francisco Bay highly toxic--bivalve | Small gradient |
| 94±5 | Palos Verdes major benthic degradation | * |
| 97±53 | Baltimore Harbor most toxic--fish | * |
| 99±35 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 100±35 | San Francisco Bay significantly toxic--bivalve | No gradient |
| 100 ± 26✓ | Keweenaw Waterway highly toxic --*Daphnia* | * |
| 102±44 | San Francisco Bay not toxic--bivalve | No effect |
| 105±36 | San Francisco Bay significantly toxic--amphipod | No gradient |
| 106±74 | Phillips Chain least toxic --*Daphnia* | No effect |
| 108±25 | San Francisco Bay least toxic--amphipod | No effect |
| 108±27 | San Francisco Bay not toxic--amphipod | No effect |
| 109±19 | Keweenaw Waterway significantly toxic--*Daphnia* | * |
| 110±0 | Sheboygan River significant mortality--prawn | * |
| 112±31 | San Francisco Bay moderately toxic--bivalve | Poor concordance |
| 113±43 | San Francisco Bay highly toxic--amphipod | Small gradient |
| >120 | 1986 Puget Sound AET--amphipod | No definitive value |
| >140 | 1988 Puget Sound AET--amphipod | No definitive value |
| >140 | 1988 Puget Sound AET--benthic | No definitive value |
| 150 | Torch Lake significant toxicity--*Daphnia* | * |
| >170 | San Francisco Bay AET--bivalve | Not definitive |
| >170 | San Francisco Bay AET--amphipod | Not definitive |
| 350 | Phillips Chain significant toxicity--*Daphnia* | * |

* 18 concentrations used to determine ER-L and ER-M values

**Table B-9. Sediment effects data available for SILVER arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 0.2 ± 0.1 | Commencement Bay highly toxic--amphipod | No gradient |
| 0.3 ± 0.1 | Commencement Bay moderately toxic--amphipod | No gradient |
| 0.3 ± 0.1 | Commencement Bay least toxic--amphipod | No gradient |
| 0.3 ± 0.1 | Commencement Bay highly toxic--oyster | No gradient |
| 0.3 ± 0.1 | Commencement Bay moderately toxic--oyster | No gradient |
| 0.3 ± 0.1 | Commencement Bay least toxic--oyster | No gradient |
| 0.3 ± 0.1 | Puget Sound least toxic--amphipod | No effect |
| 0.5 ± 0.4 | San Francisco Bay least toxic--bivalve | No effect |
| >0.6 | 1986 Puget Sound AET--oyster | No definitive value |
| >0.6 | 1986 Puget Sound AET--Microtox™ | No definitive value |
| 0.6 ± 1 | Puget Sound highly toxic--amphipod | * |
| 0.6 ± 0.5 | San Francisco Bay not toxic--bivalve | No effect |
| 0.6 ± 0.8 | Southern California high echinoderm abundance | No effect |
| 0.6 ± 0.7 | Southern California moderate echinoderm abundance | No gradient |
| 0.7 ± 1 | Southern California moderate arthropod abundance | No concordance |
| 0.7 ± 0.8 | Southern California moderate species richness | No concordance |
| 0.8 ± 0.6 | Feral Fraser River *Macoma* present | No effect |
| 0.8 | San Diego Bay high survival--various | No effect |
| 0.8 | San Diego Bay high survival--various | No effect |
| 0.9 ± 0.9 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 0.9 ± 1.6 | Southern California high arthropod abundance | No effect |
| 0.9 ± 2.1 | Southern California high species richness | No effect |
| 1 | *Macoma* avoidance bioassay | * |
| **1** | **ER-L** | **10 percentile** |
| 1 ± 0.6 | San Francisco Bay moderately toxic--bivalve | * |
| 1 ± 2 | Southern California moderate abundance | No concordance |
| 1.1 | San Francisco Bay AET--bivalve | * |
| 1.1 ± 1.9 | Southern California not toxic--amphipod | No effect |
| 1.2 | PSDDA screening level | No effect |
| 1.2 ± 1.7 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 1.3 ± 1.8 | San Francisco Bay least toxic--amphipod | No effect |
| 1.3 ± 1.4 | Southern California significantly toxic--amphipod | No gradient |
| 1.3 ± 1.8 | Southern California low abundance | No concordance |
| 1.4 ± 1.9 | San Francisco Bay not toxic--amphipod | No effect |
| 1.7 ± 2.6 | San Francisco Bay highly toxic--amphipod | No concordance |
| 1.7 ± 2.2 | San Francisco Bay significantly toxic-- bivalve | * |
| 2.1 ± 1.3 | Feral Fraser River *Macoma* absent | * |
| 2.2 ± 3.9 | Southern California low arthropod abundance | * |
| **2.2** | **ER-M** | **50 percentile** |
| 2.5 ± 4.1 | Southern California low species richness | * |
| 2.6 | *Macoma* burrowing bioassay | * |
| 3.1 ± 4.5 | Southern California low echinoderm abundance | * |
| 3.2 ± 5.6 | Southern California high abundance | No effect |
| >3.7 | 1986 Puget Sound AET--amphipod | No definitive value |
| 5.2 | 1986 Puget Sound AET--benthic | * |
| >6.1 | 1988 Puget Sound AET--benthic | No definitive value |
| 6 | 1988 Puget Sound AET--amphipod | * |
| 6.9 ± 2.5 | San Francisco Bay highly toxic--bivalve | * |
| >8.6 | San Francisco Bay AET--amphipod | Not definitive |

* 13 concentrations used to determine ER-L and ER-M values

**Table B-10. Sediment effects data available for ZINC arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppm) | Biological Test | Remarks |
|---|---|---|
| 11 | Georgetown benthic community | No effect |
| 20 | Cubatao River highly toxic--*Daphnia* | No concordance |
| 32 ± 7 | Massachusetts Bay high species richness | No effect |
| 50 ± 13 | Southern California high echinoderm abundance | No effect |
| 50 ± 22 | Southern California moderate species richness | No concordance |
| 51 ± 24 | Southern California high arthropod abundance | No effect |
| 51 | Amphipod avoidance bioassay | * |
| 52 ± 28 | Southern California moderate arthropod abundance | No gradient |
| 53 ± 28 | Southern California moderate abundance | No concordance |
| 55 ± 34 | Southern California moderate echinoderm abundance | No gradient |
| 55 | Newport low toxicity--shrimp | No effect |
| 58 ± 41 | Trinity River low mortality--*Daphnia* | No effect |
| 59 to 124 | *Pontoporeia* bioassay | * |
| 62 ± 20✓ | Keweenaw Waterway low toxicity--*Daphnia* | No effect |
| 65 ± 19 | Feral Fraser River *Macoma* present | No effect |
| 69 ± 24 | Keweenaw Waterway not toxic--*Daphnia* | No effect |
| 71 ± 106 | Southern California high species richness | No effect |
| 73 ± 81 | Southern California low abundance | No concordance |
| 72 | Duwamish River low toxicity--shrimp | No effect |
| 76 | LC08 amphipod bioassay | No effect |
| 79 | LC05 amphipod bioassay | No effect |
| 80 | Norwegian benthic species diversity | Poor concordance |
| 89 ± 41 | San Francisco least toxic--bivalve | No effect |
| 96 ± 52 | Kishwaukee River highest benthic species richness | No effect |
| 98 ± 64 | Massachusetts Bay moderate species richness | * |
| 107 ± 122 | Commencement Bay least toxic--oyster | No effect |
| 107 ± 31 | Kishwaukee River least benthic species richness | No gradient |
| 108 ± 79 | Commencement Bay least toxic--amphipod | No effect |
| 109 | *Macoma* burrowing time bioassay | No concordance |
| 114 ± 52 | Puget Sound nontoxic--amphipod | No effect |
| 117 ± 42 | Massachusetts Bay lowest species richness | * |
| **120** | **ER-L** | **10 percentile** |
| 121 ± 100 | Trinity River significant mortality--*Daphnia* | * |
| 127 | Waukegan Harbor high toxic--amphipod | * |
| 130 | San Francisco Bay AET--bivalve | * |
| 136 ± 78 | San Francisco Bay not toxic--bivalve | No effect |
| 146 ± 73 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 154 ± 91 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 154 ± 54✓ | Keweenaw highly toxic--*Daphnia* | * |
| 158 ± 87 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 160 | PSDDA screening level | No effect |
| 168 ± 52 | Keweenaw Waterway significantly toxic--*Daphnia* | * |
| 169 ± 53 | Feral Fraser River *Macoma* absent | * |
| 171 ± 91 | San Francisco Bay least toxic--amphipod | No effect |
| 172 | *Macoma* avoidance bioassay | * |
| 172 ± 92 | San Francisco Bay moderately toxic--bivalve | * |
| 177 ± 96 | San Francisco Bay not toxic--amphipod | No effect |
| 182 ± 384 | Southern California low arthropod abundance | * |
| 182 ± 56 | DuPage River highest benthic species richness | No effect |
| 185 ± 335 | Commencement Bay moderately toxic--oyster | * |
| 187 ± 115 | San Francisco Bay highly toxic--amphipod | No gradient |

**Table B-10. (continued)**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 188 | Amphipod avoidance bioassay | * |
| 195 ± 166 | Puget Sound moderately toxic--amphipod | * |
| 197 ± 415 | Southern California low species richness | * |
| 205 ± 90 | San Francisco Bay highly toxic--bivalve | * |
| 211 ± 342 | Commencement Bay moderately toxic--amphipod | * |
| 212 ± 243 | Southern California not toxic--amphipod | No effect |
| 216 ± 213 | Phillips Chain low mortality--*Daphnia* | No effect |
| 223 | Los Angeles Harbor >50% mortality--shrimp | * |
| 230 | San Francisco Bay AET--amphipod | * |
| 230 ± 444 | Southern California low echinoderm abundance | * |
| 245 ± 201 | Hudson-Raritan positive growth--nematode | No effect |
| 260 | 1986 Puget Sound AET--benthic | * |
| 267 ± 298 | Little Grizzly Creek significant mortality--*Daphnia* | * |
| **270** | **ER-M** | **50 percentile** |
| 276 | LC50 for amphipod bioassay | * |
| 290 ± 10 | Sheboygan River significant mortality--prawn | * |
| 310 | Torch Lake significant mortality--*Daphnia* | * |
| 320 | Lake Union high mortality--amphipod | * |
| 327 ± 162 | DuPage River least benthic species richness | * |
| 334 | Black Rock Harbor 100% mortality--*Nereis* | * |
| 340 | Stamford low mortality--shrimp | No effect |
| 347 ± 592 | Southern California high abundance | No concordance |
| 348 ± 234 | Southern California significantly toxic--amphipod | * |
| 387 ± 783 | Commencement Bay highly toxic--oyster | * |
| 410 | 1988 Puget Sound AET--benthic | * |
| 449 ± 252 | Hudson-Raritan negative growth--nematode | * |
| 570 | Phillips Chain significant mortality | * |
| 613 | 54.7% mortality--*Rhepoxynius* bioassay | * |
| 636 | Norwalk 0% mortality--shrimp | No effect |
| 707 ± 955 | Puget Sound highly toxic--amphipod | * |
| 738 ± 394 | Baltimore Harbor least toxic--fish | No effect |
| 739 ± 139 | Palos Verdes major benthic degradation | * |
| 760 | EP marine chronic @4% TOC | * |
| 870 | 1986 Puget Sound AET--amphipod | * |
| 941 ± 1373 | Commencement Bay highly toxic--amphipod | * |
| 960 | 1988 Puget Sound AET--amphipod | * |
| 1600 | 1986 Puget Sound AET--oyster | * |
| 1600 | 1986 Puget Sound AET--Microtox™ | * |
| 1804 ± 2098 | Baltimore Harbor most toxic--fish | * |
| 2240 | EP marine acute @4% TOC | * |

* 46 concentrations used to determine ER-L and ER-M values

**Table B-11. Sediment effects data available for PCBs arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 0.005 ± 0 | Trinity River significant mortality--*Daphnia* | No gradient |
| 0.005 ± 0 | Trinity River low mortality--*Daphnia* | No effect |
| 0.7 ± 0.3 | Mississippi River 55% survival--midges | No concordance |
| <1.13 | MIssissippi River 25% survival--mayfly | No concordance |
| 2 ± 1 | Massachusetts Bay high species richness | No effect |
| 2.9 | SLC freshwater | * |
| 5 ± 5 | Massachusetts Bay moderate species richness | No gradient |
| 5 ± 5 | Massachusetts Bay low species richness | No gradient |
| 7 ± 6 | Kishwaukee River highest species richness | No effect |
| 12 ± 20 | Mississippi River high survival--mayfly | No effect |
| 15 ± 22 | Mississippi River 90% survival--midges | No effect |
| 20 ± 20 | Southern California high echinoderm abundance | No effect |
| 25 | San Diego Bay high survival--various | No effect |
| 25 | San Diego Bay high survival--various | No effect |
| 26 ± 16 | San Francisco least toxic--bivalve | No effect |
| 28 ± 27 | Commencement Bay least toxic--oyster | No effect |
| 30 ± 50 | Southern California moderate echinoderm abundance | Small gradient |
| 31 ± 19 | DuPage River highest species richness | No effect |
| 36.6 | SLC marine | * |
| 38 ± 32 | Commencement Bay highly toxic--amphipod | No concordance |
| 42.6 | SLC marine | * |
| 50 | Georgetown benthic community | No effect |
| **50** | **ER-L** | **10 percentile** |
| 54 | San Francisco Bay AET--bivalve | * |
| 60 ± 70 | Southern California moderate arthropod abundance | No concordance |
| 60 | Mississippi River high survival | No effect |
| 61 ± 88 | Commencement Bay least toxic--amphipod | No effect |
| 80 ± 100 | Southern California high arthropod abundance | No effect |
| 80 ± 140 | Southern California moderate abundance | No concordance |
| 94 ± 147 | San Francisco Bay least toxic--amphipod | No effect |
| 99 ± 120 | Puget Sound nontoxic--amphipod | No effect |
| ≤100 | San Francisco Bay triad minimum bioeffects | * |
| 101 ± 153 | San Francisco Bay not toxic--amphipod | No effect |
| 127 ± 171 | San Francisco Bay significantly toxic--bivalve | No concordance |
| 128 ± 264 | Kishwaukee River least species richness | * |
| 130 | 1986 Puget Sound AET--Microtox™ | * |
| 130 | PSDDA screening level | No effect |
| 140 ± 262 | Commencement Bay moderately toxic--oyster | * |
| 146 ± 218 | San Francisco Bay significantly toxic--amphipod | * |
| 151 ± 260 | San Francisco Bay moderately toxic--amphipod | * |
| ≥160 | San Francisco Bay triad significant bioeffects. | * |
| 160 ± 430 | Southern California low abundance | No concordance |
| 164 ± 100 | San Francisco Bay highly toxic--bivalve | No gradient |
| 165 ± 232 | San Francisco Bay moderately toxic--bivalve | * |
| 169 ± 171 | San Francisco Bay highly toxic--amphipod | No gradient |
| 180 ± 160 | Baltimore Harbor least toxic--fish | No effect |
| 190 ± 214 | DuPage River least species richness | * |
| 216 ± 376 | San Francisco not toxic--bivalve | No effect |
| 220 ± 540 | Southern California high species richness | No effect |

Table B-11. (continued)

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 251 ± 556 | Commencement Bay moderately toxic--amphipod | No concordance |
| 259 ± 407 | Puget Sound moderately toxic--amphipod | * |
| 260 | San Francisco Bay AET--amphipod | * |
| 272 ± 217 | Southern California significantly toxic--amphipod | No concordance |
| 276 ± 365 | Puget Sound highly toxic--amphipod | Small gradient |
| 280 | EP chronic marine (hexa-PCB) | * |
| 290 ± 502 | Hudson-Raritan positive growth--nematode | No effect |
| 368 ± 695 | Commencement Bay highly toxic--oyster | * |
| **400** | **ER-M** | **50 percentile** |
| 400 ± 600 | Southern California moderate species richness | * |
| 480 ± 724 | Southern California not toxic--amphipod | No effect |
| 638 ± 512 | Hudson-Raritan negative growth--nematode | * |
| 1000 | 1988 Puget Sound AET--benthic | * |
| 1000 ± 2400 | Southern California low arthropod abundance | * |
| 1000 ± 300 | Significant toxicity--*Rhepoxynius* in mixtures | * |
| 1100 | 1986 Puget Sound AET--oyster | * |
| 1100 | 1986 Puget Sound AET--benthic | * |
| 1100 ± 800 | Baltimore Harbor most toxic--fish | * |
| 1110 ± 2600 | Southern California low species richness | * |
| 1300 ± 2610 | Southern California low echinoderm abundance | * |
| 1700 | Black Rock Harbor significantly toxic--amphipod | * |
| 2260 ± 3530 | Southern California high abundance | No effect |
| 2500 | 1986 Puget Sound AET--amphipod | * |
| 3100 | 1988 Puget Sound AET--amphipod | * |
| 4300 | Lake Union significantly toxic--amphipod | * |
| 7280 | New York Harbor low mortality--various | No effect |
| 10800 | LC50 *Rhepoxynius* 10-d bioassay | * |
| ND-174,000✔ | Waukegan Harbor least toxic--Microtox™ | No effect |
| 1141300 ± 2229700 | Waukegan Harbor moderately toxic--Microtox™ | * |
| 3550050 ± 6598300✔ | Waukegan Harbor highly toxic--Microtox™ | * |

* 34 concentrations used to determine ER-L and ER-M values

**Table B-12. Sediment effects data available for p,p'-DDT arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 0.4 | EP 99 percentile chronic marine | * |
| 0.6 | San Francisco Bay highly toxic--bivalve | No concordance |
| 0.7 | EP 95 percentile chronic marine | * |
| **1** | **ER-L** | **10 percentile** |
| 1.22 | San Francisco Bay not toxic--amphipod | No effect |
| 1.3 | San Francisco Bay least toxic--amphipod | No effect |
| 1.6 | EP chronic safe level @1% TOC | * |
| 2.1 | San Francisco Bay least toxic--bivalve | No effect |
| 2.4 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 3.2 | San Francisco Bay not toxic-bivalve | No effect |
| 3.9 | 1986 Puget Sound AET--amphipod | * |
| 5.1 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| >6 | 1986 Puget Sound AET--oyster | No definitive value |
| 6 | EP chronic marine @4% TOC | * |
| 6.4 | EP chronic marine @4% TOC | * |
| 6.6 | San Francisco Bay moderately toxic--bivalve | * |
| **7** | **ER-M** | **50 percentile** |
| 7.5 | San Francisco Bay significantly toxic--amphipod | * |
| 9.6 | San Francisco Bay AET--bivalve | Poor concordance |
| 9.6 | San Francisco Bay AET--amphipod | * |
| 11 | 1986 Puget Sound AET--benthic | * |
| 12.2 | San Francisco Bay highly toxic--amphipod | * |
| 34 | 1988 Puget Sound AET--benthic | * |
| 49.5 | Overall LC50 *R. abronius* spiked bioassay @ 1% TOC | * |
| <50 | Georgetown benthic communities | No effect |
| 74 | Palos Verdes not toxic--amphipod (n=1) | No effect |
| 83 | Palos Verdes significantly toxic--amphipod (n=2) | Small sample size |
| 210 | EP acute safe level @1% TOC | * |
| >270 | 1988 Puget Sound AET--amphipod | No definitive value |
| 840 | EP acute marine @4% TOC | * |

* 15 concentrations used to determine ER-L and ER-M values

**Table B-13. Sediment effects data available for p,p'-DDE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 0.1±0 | Mississippi River 55% survival--midge | No gradient |
| <0.2✔ | Mississippi River 80 to100% survival--midge | No effect |
| <0.2✔ | Mississipi River 90% survival--midge | No effect |
| <0.2 | Mississippi River 25% survival--mayfly (n=1) | Small sample size |
| 0.28 | Mississippi River 80 to100% survival--scud | No effect |
| 0.6±0.7 | San Francisco Bay least toxic--amphipod | No effect |
| 0.7±0.7 | San Francisco Bay not toxic--amphipod | No effect |
| 0.7±1 | San Francisco Bay least toxic--bivalve | No effect |
| 1±0.5 | San Francisco Bay highly toxic--bivalve | No gradient |
| 1.2±1 | San Francisco Bay not toxic--bivalve | No effect |
| 1.2±1 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 1.7±3.4 | San Francisco Bay significantly toxic--bivalve | No gradient |
| **2** | **ER-L** | **10 percentile** |
| 2.1±4 | San Francisco Bay moderately toxic--bivalve | * |
| 2.2 | San Francisco Bay AET--bivalve | * |
| 2.2±4 | San Francisco Bay significantly toxic--amphipod | * |
| 2.2 | San Francisco Bay AET--amphipod | * |
| 3.4±5.2 | San Francisco Bay highly toxic--amphipod | * |
| 9 | 1986 Puget Sound AET--benthic | * |
| **15** | **ER-M** | **50 percentile** |
| 15 | 1986 Puget Sound AET--amphipod | * |
| 27 | EP 99 percentile chronic marine @1% TOC | * |
| <50 | Georgetown benthic communities | No effect |
| 60 | EP 95 percentile chronic marine @1% TOC | * |
| 3374±3153 | Palos Verdes not toxic--amphipod | No effect |
| 5157±1065 | Palos Verdes significantly toxic--amphipod | * |
| 5157±1065 | Palos Verdes major benthic degradation | * |
| 7000 | EP safe acute @1% TOC | * |
| 28000 | EP acute marine @4% TOC | * |

* 13 concentrations used to determine ER-L and ER-M values.

**Table B-14. Sediment effects data available for p,p'-DDD arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 0.6 ± 0.7 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 0.9 ± 1.6 | San Francisco Bay significantly toxic--amphipod | No gradient |
| **2** | **ER-L** | **10 percentile** |
| 1.3 ± 0.3 | San Francisco Bay highly toxic--bivalve | No concordance |
| 1.3 ± 1.2 | San Francisco Bay least toxic--amphipod | No effect |
| 1.3 ± 2.1 | San Francisco Bay highly toxic--amphipod | No gradient |
| 2 | 1986 Puget Sound AET--benthic | * |
| 2.3 ± 0.1 | San Francisco Bay not toxic--amphipod | No effect |
| 6 | EP 99 percentile chronic marine | * |
| 10 ± 7.4 | San Francisco Bay least toxic--bivalve | No effect |
| 12.5 ± 8.5 | San Francisco Bay not toxic--bivalve | No effect |
| 13.3 ± 21 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 16 | San Francisco Bay AET--bivalve | No gradient |
| 16 | San Francisco Bay AET--amphipod | No gradient |
| 16 | 1988 Puget Sound AET--benthic | * |
| 16.1 ± 23.2 | San Francisco Bay moderately toxic--bivalve | Small gradient |
| **20** | **ER-M** | **50 percentile** |
| 22 | EP 95 percentile chronic marine | * |
| 43 | 1986 Puget Sound AET--amphipod | * |
| <50 | Georgetown benthic communities | No effect |
| 324 ± 387 | Palos Verdes not significantly toxic--amphipod | No effect |
| 1090.7 ± 573 | Palos Verdes signficantly toxic--amphipod | Small sample size |
| 3250 | EP acute safe level @1% TOC | * |
| 13000 | EP acute marine @4% TOC | * |

* 7 concentrations used to determine ER-L and ER-M values

**Table B-15. Sediment effects data available for total DDT arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentration (ppb) | Biological Test | Remarks |
|---|---|---|
| 1.58 | EP saltwater chronic, assuming 1% TOC | * |
| 1.9 | Freshwater SLC, assuming 1% TOC | * |
| **3** | **ER-L** | **10 percentile** |
| 3.29 | EP saltwater chronic, assuming 1% TOC | * |
| 6.9 | PSDDA screening level | No effect |
| 6.9 ± 9.8 | Trinity River low mortality--*Daphnia* | No effect |
| 8.28 | Interim EP saltwater criteria, assuming 1% TOC | * |
| 19.6 ± 18.4 | DuPage River highest taxa richness | No effect |
| 20 | Lethal threshold-*Crangon* bioassay | * |
| 28.6 ± 36.1 | Southern California not toxic--amphipod (excludes Palos Verdes sample) | No effect |
| 31 | 97-h LC50 *Crangon* spiked bioassay | * |
| 31.4 ± 20.4 | Trinity River significant mortality--*Daphnia* | * |
| 45.9 | Calculated EP threshold for freshwater | * |
| 50 ± 60 | Southern California high echinoderm abundance | No effect |
| 68 ± 71.7 | Southern California significantly toxic--amphipod | No concordance |
| 79 ± 126✔ | Southern California moderate echinoderm abundance | * |
| 100 ± 150 | Southern California high arthropod abundance | No effect |
| 210 ± 490 | Southern California moderate total abundance | No concordance |
| 221.7 ± 281.6 | DuPage River least taxa richness | * |
| 250 ± 620 | Southern California moderate species richness | No concordance |
| **350** | **ER-M** | **50 percentile** |
| 350 ± 710 | Southern California moderate arthropod abundance | * |
| 428 | Saltwater SLC, assuming 1% TOC | * |
| 505 | Saltwater SLC, assuming 1% TOC | * |
| 1018.2 ± 2424 | Southern California not toxic-amphipod (includes Palos Verdes sample) | No effect |
| 1874 ± 6660✔ | Southern California high species richness | No effect |
| 1410 ± 5440 | Southern California low total abundance | No concordance |
| 4950 | Overall LC50 for *Rhepoxynius* bioassay | * |
| 11000 | LC50 *H. azteca* bioassay @ 3% TOC | * |
| 13420 ± 37670 | Southern California low arthropod abundance | * |
| 14190 ± 40200 | Southern California low species richness | * |
| 16500 | No deaths *N. virens* spiked bioassay | No effect |
| 18260 ± 43080 | Southern California low echinoderm abundance | * |
| 19600 | LC50 *H. azteca* bioassay @ 7.2% TOC | * |
| 35300 ± 59540 | Southern California high total abundance | No effect |
| 49700 | LC50 *H. azteca* bioassay @ 10.5% TOC | * |
| 67232 | LD50 cricket nymph bioassay | * |

* 21 concentrations used to determine ER-L and ER-M values

**Table B-16. Sediment effects data available for CHLORDANE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| ND | San Francisco Bay moderately toxic--amphipod | No concordance |
| ND | San Francisco Bay least toxic--amphipod | No effect |
| ND | San Francisco Bay highly toxic--bivalve | No concordance |
| 0.3 | EP 99 percentile chronic marine | * |
| 0.5 ± 1 | San Francisco Bay least toxic--bivalve | No effect |
| **0.5** | **ER-L** | **10 percentile** |
| 0.6 | EP 95 percentile chronic marine | * |
| 1 ± 1.4 | San Francisco Bay not toxic--amphipod | No effect |
| 1 ± 1.4 | San Francisco Bay not toxic--bivalve | No effect |
| 1.7 ± 2.3 | Trinity River not toxic--*Daphnia* | No effect |
| 2 | San Francisco Bay AET--bivalve | Poor concordance |
| 2 | San Francisco Bay AET--amphipod | * |
| 3.5 ± 6.3 | San Francisco Bay significantly toxic--amphipod | * |
| 3.5 ± 6.3 | San Francisco Bay significantly toxic--bivalve | * |
| 4.1 ± 6.6 | San Francisco Bay moderately toxic--bivalve | * |
| **6** | **ER-M** | **50 percentile** |
| 6.4 ± 7.5 | San Francisco Bay highly toxic--amphipod | * |
| 8.3 ± 4.3 | DuPage River most benthic taxa | No effect |
| 17.4 | EP lethal threshold freshwater | * |
| 25 ± 22.3 | DuPage River least benthic taxa | * |
| 31.3 ± 29.4 | Trinity River significantly toxic--*Daphnia* | * |
| <50 | Georgetown benthic communities | No effect |
| 120 | LC50 *Crangon* bioassay | * |
| ≤5800 | LC50 *N. virens* bioassay | * |

* 12 concentrations used to determine ER-L and ER-M values

**Table B-17. Sediment effects data available for DIELDRIN arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| ND | San Francisco Bay highly toxic–bivalve | No gradient |
| 0.01 | EP 99 percentile chronic marine | * |
| **0.02** | **ER-L** | **10 percenitle** |
| 0.02 | EP 95 percentile chronic marine | * |
| 0.21 | Freshwater SLC @1% TOC | * |
| 4.1 | LC50 Crangon spiked bioassay | * |
| 4.3 ± 2.1 | Kishwaukee River most benthic taxa | No effect |
| 4.4 ± 2.3 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 5.2 ± 1.2 | San Francisco Bay least toxic--amphipod | No effect |
| 5.2 ± 1.2 | San Francisco Bay least toxic–bivalve | No effect |
| 5.6 ± 2.2 | DuPage River most benthic taxa | No effect |
| 6.2 ± 0.6 | San Francisco Bay not toxic--amphipod | No effect |
| 6.2 ± 0.6 | San Francisco Bay not toxic--bivalve | No effect |
| 6.6 | San Francisco Bay AET--bivalve | * |
| 6.6 | San Francisco Bay AET--amphipod | * |
| 7.4 ± 4.8 | Kishwaukee River least benthic taxa | * |
| 7.6 ± 7.5 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 7.6 ± 7.5 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| **8** | **ER-M** | **50 percentile** |
| 8.2 ± 8.1 | San Francisco Bay moderately toxic--bivalve | * |
| 10.3 ± 9.6 | San Francisco Bay highly toxic--amphipod | * |
| 11.9 | EP lethal freshwater threshold | * |
| 16 ± 12.1 | DuPage River least benthic taxa | * |
| 25.5 ± 33.2 | Trinity River significantly toxic--*Daphnia* | No gradient |
| 25.5 ± 61.1 | Trinity River not toxic--*Daphnia* | No effect |
| <50 | Georgetown disposal site benthic communities | No effect |
| 57.7 | EP interim marine criteria | * |
| 199 | EP interim freshwater criteria | * |
| 13000 | LC50 *Nereis* spiked bioassay | * |

* 14 concentrations used to determine ER-L and ER-M values

**Table B-18. Sediment effects data available for ENDRIN arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 0.01 | EP 99 percentile chronic marine | * |
| **0.02** | **ER-L** | **10 percentile** |
| 0.02 | EP 95 percentile chronic marine | * |
| 2.15 | EP interim marine criteria @1% TOC | * |
| 3.8 ± 3.1 | Trinity River low mortality-*Daphnia* | No effect |
| 10.4 | EP interim freshwater criteria @1% TOC | * |
| 15.4 | EP freshwater lethal threshold | * |
| 18.3 ± 2 | Trinity River significant mortality--*Daphnia* | * |
| **45** | **ER-M** | **50 percentile** |
| 47 | LC50 *Crangon* spiked bioassay | * |
| <50 | Georgetown benthic communities | No effect |
| 174 | EP chronic sediment/water marine @1% TOC | * |
| 321 | EP chronic sediment/biota marine @1% TOC | * |
| 4400 | LC50 *H. azteca* @3% TOC | * |
| 4800 | LC50 *H. azteca* @6.1% TOC | * |
| 6000 | LC50 *H. azteca* @11.2 % TOC | * |
| 28000 | LC50 *N. virens* spiked bioassay | * |

* 13 concentrations used to determine ER-L and ER-M values

**Table B-19. Sediment effects data available for ACENAPHTHENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 1.8 ± 4 | San Francisco Bay least toxic--bivalve | No effect |
| 3 ± 5.2 | San Francisco Bay not toxic--bivalve | No effect |
| 3.3 ± 5.9 | San Francisco Bay moderately toxic--bivalve | Small gradient |
| 3.9 ± 1.6✔ | Southern California highly toxic--amphipod | No concordance |
| 5.4 ± 12.1 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 5.9 ± 16.8 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 7 ± 11.8✔ | Southern California not toxic--amphipod | No effect |
| 7.6 ± 21.6 | San Francisco Bay highly toxic--amphipod | No concordance |
| 9 | San Francisco Bay AET--bivalve | Small gradient |
| 9.4 ± 17.9 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 9.8 ± 15.9 | San Francisco Bay least toxic--amphipod | No effect |
| 11.8 ± 16.8 | San Francisco Bay not toxic--amphipod | No effect |
| 30 | Black Rock Harbor highly toxic--amphipod | Small gradient |
| 48 ± 18.4 | San Francisco Bay highly toxic--bivalve | Small gradient |
| 56 | San Francisco Bay AET--amphipod | No concordance |
| 56.7 ± 70 | Commencement Bay least toxic--oyster | No effect |
| 86 ± 97 | Commencement Bay least toxic--amphipod | No effect |
| 118.5 ± 105 | Commencement Bay moderately toxic--oyster | * |
| 127 ± 117 | Commencement Bay moderately toxic--amphipod | Small gradient |
| **150** | **ER-L** | **10 percentile** |
| 150 | Predicted LC50 amphipod bioassay-Eagle Harbor | * |
| 306 ± 604 | Commencement Bay highly toxic--oyster | * |
| 500 | 1986 Puget Sound AET--oyster | * |
| 500 | 1986 Puget Sound AET--benthic | * |
| 500 | 1986 Puget Sound AET--Microtox™ | * |
| 630 | 1986 Puget Sound AET--amphipod | * |
| **650** | **ER-M** | **50 percentile** |
| 654 ± 1049 | Commencement Bay highly toxic--amphipod | * |
| 730 | 1988 Puget Sound AET--benthic | * |
| 2000 | 1988 Puget Sound AET--amphipod | * |
| 5599 ± 24392 | Eagle Harbor least toxic--amphipod | No effect |
| 6522 ± 8915 | Eagle Harbor moderately toxic--amphipod | Small gradient |
| 7330 | EP freshwater interim criteria @1% TOC | * |
| 16500 | EP chronic marine level @1% TOC | * |
| 23000 | EP acute marine level @1% TOC | * |
| 39557 ± 48678 | Eagle Harbor highly toxic--amphipod | * |
| 66000 | EP chronic marine @4% TOC | * |

*15 concentrations used to determine ER-L and ER-M values.

**Table B-20 Sediment effects data available for ANTHRACENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 15.4 ± 7.5 | San Francisco Bay least toxic--bivalve | No effect |
| 24 | San Francisco Bay AET--bivalve | * |
| 34.3 ± 41.2 | San Francisco Bay not toxic--bivalve | No effect |
| 36 ± 52✔ | Southern California not toxic--amphipod | No effect |
| 63 ± 72 | San Francisco Bay moderately toxic-amphipod | No concordance |
| 70 | Predicted LC50 Eagle Harbor-amphipod | * |
| **85** | **ER-L** | **10 percentile** |
| 85.3 ± 119.3 | San Francisco Bay moderately toxic--bivalve | * |
| 110 ± 257 | San Francisco Bay least toxic--amphipod | No effect |
| 119.8 ± 276.7 | San Francisco Bay significantly toxic--amphipod | No gradient |
| 120.2 ± 269.2 | San Francisco Bay not toxic--amphipod | No effect |
| 130 | PSDDA screening level | No effect |
| 147.8 ± 148 | Commencement Bay least toxic--oyster | No effect |
| 163 | Saltwater SLC @1% TOC | * |
| 183.9 ± 347.2 | San Francisco Bay significantly toxic--bivalve | * |
| 190 | 99 percentile chronic marine @1% TOC | * |
| 225 ± 131✔ | Southern California significantly toxic--amphipod | * |
| 227.3 ± 197.6 | Commencement Bay least toxic--amphipod | No effect |
| 237 ± 455 | San Francisco Bay highly toxic--amphipod | * |
| 264.6 ± 227.8 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 282.3 ± 206.9 | Commencement Bay moderately toxic--oyster | * |
| 363 ± 353.4 | Commencement Bay highly toxic--oyster | * |
| 380 | 95 percentile chronic marine @1% TOC | * |
| 476.2 ± 549.2 | Commencement Bay highly toxic--amphipod | * |
| 922.7 ± 558.1 | San Francisco Bay highly toxic--bivalve | * |
| 960 | 1986 Puget Sound AET--oyster | * |
| **960** | **ER-M** | **50 percentile** |
| 960 | 1986 Puget Sound AET--Microtox™ | * |
| 1100 | San Francisco Bay AET--amphipod | * |
| 1177 ± 1582 | Eagle Harbor moderately toxic--amphipod | No concordance |
| 1300 | 1986 Puget Sound AET--benthic | * |
| 1490 ± 5389 | Eagle Harbor least toxic--amphipod | No effect |
| 1900 | 1986 Puget Sound AET--amphipod | * |
| 4400 | 1988 Puget Sound AET--benthic | * |
| 6600 | 28-d LC50 2.5% Elizabeth River--spot | * |
| 7597 ± 7264 | Eagle Harbor highly toxic--amphipod | * |
| 13000 | 1988 Puget Sound AET--amphipod | * |
| 44000 | EP chronic marine @4% TOC | * |
| 120000 | Lake Union highly toxic--amphipod | * |
| 147840 | 24-h LC50 58% Elizabeth River--spot | * |
| 264000 | LC100 100% Elizabeth River--spot | * |

*26 concentrations used to determine ER-L and ER-M values.

**Table B-21 Sediment effects data available for BENZO(A)ANTHRACENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 40.7 ± 20 | San Francisco Bay not toxic--bivalve | No effect |
| 56.4 ± 25.7 | San Francisco Bay least toxic--bivalve | No effect |
| 59.6 ± 129 | Southern California not toxic--amphipod | No effect |
| 60 | San Francisco Bay AET--bivalve | * |
| 80 | Predicted LC50 Eagle Harbor--amphipod | * |
| 122.1 ± 125.9 | San Francisco Bay moderately toxic--bivalve | * |
| 167.7 ± 324.2 | San Francisco Bay least toxic--amphipod | No effect |
| 187 ± 156.2 | San Francisco Bay moderately toxic--amphipod | Small gradient |
| 187.2 ± 359.2 | San Francisco Bay not toxic--amphipod | No effect |
| **230** | **ER-L** | **10 percentile** |
| 232 ± 336.8 | San Francisco Bay significantly toxic--bivalve | * |
| 234.7 ± 246.8 | Commencement Bay least toxic--oyster | No effect |
| 236.3 ± 313.2 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 261 | Saltwater SLC @1 % TOC | * |
| 300 ± 398.3 | San Francisco Bay highly toxic--amphipod | * |
| 310 ± 179.8 | Southern California significantly toxic--amphipod | * |
| 450 | PSDDA screening level | No effect |
| 475.6 ± 437.1 | Commencement Bay least toxic--amphipod | No effect |
| 520 ± 523.1 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 548.5 ± 384 | Commencement Bay moderately toxic--oyster | * |
| 801 ± 866.2 | Commencement Bay highly toxic--oyster | * |
| 919.3 ± 432.7 | San Francisco Bay highly toxic--bivalve | * |
| 931 ± 1322.8 | Commencement Bay highly toxic--amphipod | * |
| 1100 | San Francisco Bay AET--amphipod | * |
| 1300 | 1986 Puget Sound AET--Microtox™ | * |
| 1600 | 1986 Puget Sound AET--amphipod | * |
| **1600** | **ER-M** | **50 percentile** |
| 1600 | 1986 Puget Sound AET--oyster | * |
| 1600 | EP 99 percentile chronic marine @ 1% TOC | * |
| 2200 | Columbia River maximum--amphipod | No effect |
| 2496 ± 4157 | Eagle Harbor least toxic--amphipod | No effect |
| 4500 | 1986 Puget Sound AET--benthic | * |
| 5100 | 1988 Puget Sound AET--amphipod | * |
| 5100 | 1988 Puget Sound AET--benthic | * |
| 7370 ± 9984 | Eagle Harbor moderately toxic--amphipod | * |
| 8750 | 28-d LC50 2.5% Elizabeth River--spot | * |
| 10000 | Spiked bioassay with mixture--amphipod | * |
| 11088 ± 8941 | Eagle Harbor highly toxic--amphipod | * |
| 13200 | EP freshwater interim criteria @ 1% TOC | * |
| 21000 | EP 95 percentile chronic marine @ 1% TOC | * |
| 55000 | EP acute safe level @ 1% TOC | * |
| 170000 | Lake Union highly toxic--amphipod | * |
| 196000 | 24-h LC50 56% Elizabeth River--spot | * |
| 220000 | EP acute marine @ 4% TOC | * |
| 350000 | LC100 100% Elizabeth River--spot | * |

* 30 concentrations used to determine ER-L and ER-M values.

**Table B-22 Sediment effects data available for BENZO(A)PYRENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 10 | Eagle Harbor predicted LC50--amphipod | Small gradient |
| 63 ± 96 | Southern California not toxic--amphipod | No effect |
| 129 ± 61 | San Francisco Bay least toxic--bivalve | No Effect |
| 210 ± 237 | San Francisco Bay not toxic--bivalve | No effect |
| 329 ± 385 | Commencement Bay least toxic--oyster | No effect |
| 396 | Marine SLC @1% TOC | * |
| 397 | Marine SLC @1% TOC | * |
| 400 ± 447 | San Francisco Bay least toxic--amphipod | No effect |
| **400** | **ER-L** | **10 percentile** |
| 404 ± 428 | San Francisco Bay moderately toxic--bivalve | * |
| 423 ± 465 | San Francisco Bay not toxic--amphipod | No effect |
| 429 ± 382 | San Francisco Bay significantly toxic--amphipod | No gradient |
| 432 ± 344 | San Francisco Bay moderately toxic--amphipod | Small gradient |
| 465 ± 471 | San Francisco Bay significantly toxic--bivalve | * |
| 486 ± 484 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 509 ± 354 | Southern California significantly toxic--amphipod | * |
| 596 ± 593 | Commencement Bay least toxic--amphipod | No effect |
| 680 | PSDDA screening level | No effect |
| 684 ± 464 | Commencement Bay moderately toxic--oyster | * |
| 890 ± 1322 | Commencement Bay moderately toxic--amphipod | * |
| 1091 ± 338 | San Francisco Bay highly toxic--bivalve | * |
| 1192 ± 1643 | Commencement Bay highly toxic--amphipod | * |
| 1261 ± 1620 | Commencement Bay highly toxic--oyster | * |
| >1300✔ | San Francisco Bay AET--amphipod | Not definitive✔ |
| 1600 | 1986 Puget Sound AET--oyster | * |
| 1600 | 1986 Puget Sound AET--Microtox™ | * |
| >1800✔ | San Francisco Bay AET--bivalve | Not definitive |
| 1959 ± 1993 | Eagle Harbor least toxic-amphipod | No effect |
| 2400 | 1986 Puget Sound AET--amphipod | * |
| 2462 | LC50 2.5% Elizabeth River--spot | * |
| **2500** | **ER-M** | **50 percentile** |
| 3000 | 1988 Puget Sound AET--amphipod | * |
| 3485 ± 2475 | Eagle Harbor highly toxic--amphipod | No concordance |
| 3600 | 1988 Puget Sound AET--benthic | * |
| 4100 ± 600 | Significantly toxic mixtures--amphipod | * |
| 5335 ± 6488 | Eagle Harbor moderately toxic--amphipod | * |
| 6800 | 1986 Puget Sound AET--benthic | * |
| 10630 | EP interim freshwater criteria @ 1% TOC | * |
| 18000 | 99 percentile chronic marine @1% TOC | * |
| 45000 | 95 percentile chronic marine @1% TOC | * |
| 55160 | LC50 56% Elizabeth River--spot | * |
| 98500 | LC100 100% Elizabeth River--spot | * |
| 220000 | Lake Union highly toxic-amphipod | * |
| 450000 | EP acute safe level | * |
| 1800000 | EP chronic marine @ 4% TOC | * |

*27✔ concentrations used to determine ER-L and ER-M values.

**Table B-23. Sediment effects data available for CHRYSENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 80 | Eagle Harbor predicted LC50--amphipod | * |
| 82 ± 37 | San Francisco Bay least toxic--bivalve | No effect |
| 127 ± 226 | Southern California not toxic--amphipod | No effect |
| 198 ± 276 | San Francisco Bay not toxic--bivalve | No effect |
| 358 ± 365 | Commencement Bay least toxic--oyster | No effect |
| 368 ± 466 | San Francisco Bay moderately toxic--bivalve | * |
| 378 ± 549 | San Francisco Bay least toxic--amphipod | No effect |
| 384 | Marine SLC @1% TOC | * |
| **400** | **ER-L** | **10 percentile** |
| 405 ± 571 | San Francisco Bay not toxic--amphipod | No effect |
| 413 ± 385 | San Francisco Bay moderately toxic--amphipod | Small gradient |
| 423 ± 512 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 500 ± 671 | San Francisco Bay significantly toxic--bivalve | * |
| 517 ± 729 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 524 ± 284 | Southern California significantly toxic--amphipod | * |
| 670 | PSDDA screening level | No effect |
| 748 ± 773 | Commencement Bay least toxic--amphipod | No effect |
| 821 ± 732 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 902 ± 691 | Commencement Bay moderately toxic--oyster | * |
| 1200 | 99 percentile chronic marine @1% TOC | * |
| 1218 ± 1286 | Commencement Bay highly toxic--oyster | * |
| 1363 ± 1970 | Commencement Bay highly toxic--amphipod | * |
| 1400 | 1986 Puget Sound AET--Microtox™ | * |
| 1679 ± 847 | San Francisco Bay highly toxic--bivalve | * |
| 1700 | San Francisco Bay AET--bivalve | * |
| 2100 | San Francisco Bay AET--amphipod | * |
| 2800 | 1986 Puget Sound AET--amphipod | * |
| 2800 | 1986 Puget Sound AET--oyster | * |
| **2800** | **ER-M** | **50 percentile** |
| 3165 ± 4535 | Eagle Harbor least toxic--amphipod | No effect |
| 4100 | Columbia River bioassay--amphipod | No effect |
| 4400 | 95 percentile chronic marine @1% TOC | * |
| 6700 | 1986 Puget Sound AET--benthic | * |
| 7925✔ | LC50 2.5% Elizabeth River--spot | * |
| 9200 | 1988 Puget Sound AET--amphipod | * |
| 9200 | 1988 Puget Sound AET--benthic | * |
| 9203 ± 10972 | Eagle Harbor moderately toxic--amphipod | * |
| 10574 ± 7337 | Eagle Harbor highly toxic--amphipod | * |
| 115000 | EP acute safe level | * |
| 170000 | Lake Union significantly toxic--amphipod | * |
| 177520 | LC50 56% Elizabeth River--spot | * |
| 317000 | LC100 100% Elizabeth River--spot | * |
| 460000 | EP chronic marine @4% TOC | * |

* 27 concentrations used to determine ER-L and ER-M values.

**Table B-24. Sediment effects data available for DIBENZ(A,H)ANTHRACENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 15 ± 15 | San Francisco Bay least toxic--bivalve | No effect |
| 21 ± 22 | San Francisco Bay not toxic--bivalve | No effect |
| 24 ± 36 | Southern California not toxic--amphipod | No effect |
| 42 ± 46 | San Francisco Bay moderately toxic--bivalve | * |
| 44 ± 32 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 55 ± 41 | Commencement Bay least toxic--bivalve | No effect |
| 55 ± 58 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 57 ± 77 | San Francisco Bay least toxic--amphipod | No effect |
| **60** | **ER-L** | **10 percentile** |
| 26 ± 80 | San Francisco Bay not toxic--amphipod | No effect |
| 63 ± 80 | San Francisco Bay significantly toxic--bivalve | * |
| 66 ± 46 | Southern California significantly toxic--amphipod | * |
| 72 ± 139 | Commencement Bay highly toxic--amphipod | No gradient |
| 73 ± 71 | Commencement Bay least toxic--amphipod | No effect |
| 80 ± 88 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 101 ± 58 | Commencement Bay moderately toxic--oyster | * |
| 120 | PSDDA screening level | No effect |
| 183 ± 344 | Commencement Bay moderately toxic--amphipod | * |
| 217 ± 88 | San Francisco Bay highly toxic--bivalve | * |
| 230 | 1986 Puget Sound AET--oyster | * |
| 230 | 1986 Puget Sount AET---Microtox™ | * |
| 260 | 1986 Puget Sound AET--amphipod | * |
| **260** | **ER-M** | **50 percentile** |
| 260 | San Francisco Bay AET--bivalve | * |
| 263 ± 413 | Commencement Bay highly toxic--bivalve | * |
| 300 | San Francisco Bay AET--amphipod | Poor concordance |
| 360 ± 298 | Eagle Harbor least toxic--amphipod | No effect |
| 399 ± 252 | Eagle Harbor highly toxic--amphipod | Small gradient |
| 540 | 1988 Puget Sound AET--amphipod | * |
| 797 ± 723 | Eagle Harbor moderately toxic--amphipod | * |
| 970 | 1988 Puget Sound AET--benthic | * |
| 1200 | 1986 Puget Sound AET--benthic | * |
| 12000 | 99 percentile EP chronic marine @ 1% TOC | * |
| 35000 | 95 percentile EP chronic marine @ 1% TOC | * |
| 240000 | EP acute safe level | |

* 18 concentrations used to determine ER-L and ER-M values.

**Table B-25. Sediment effects data available for FLUORANTHENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 98 | Palos Verdes not toxic--amphipod | No effect |
| 136 ± 107 | San Francisco Bay least toxic--bivalve | No effect |
| 153 ± 307 | Southern California not toxic--amphipod | No effect |
| 193 | Palos Verdes significantly toxic--amphipod | Small sample size |
| 382 ± 617 | San Francisco Bay not toxic--bivalve | No effect |
| 382 ± 241 | Southern California significantly toxic--amphipod | * |
| 432 | Marine SLC @ 1% TOC | * |
| 451 ± 562 | San Francisco Bay moderately toxic--bivalve | * |
| 489 ± 492 | Commencement Bay least toxic--oyster | No effect |
| 509 ± 481 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 539 ± 842 | San Francisco Bay least toxic--amphipod | No effect |
| 572 ± 880 | San Francisco Bay not toxic--amphipod | No effect |
| 584 ± 789 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| **600** | **ER-L** | **10 percentile** |
| 600 | Predicted LC50 Eagle Harbor--amphipod | * |
| 630 | PSDDA screening level | No effect |
| 644 | Marine SLC @ 1% TOC | * |
| 682 ± 1043 | San Francisco Bay significantly toxic--bivalve | * |
| 794 ± 1210 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 923 ± 865 | Commencement Bay least toxic--amphipod | No effect |
| 925 ± 864 | Commencement Bay moderately toxic--amphipod | No gradient |
| 1046 ± 655 | Commencement Bay moderately toxic--oyster | * |
| 1600 | 99 percentile EP chronic marine @ 1% TOC | * |
| 1655 ± 2029 | Commencement Bay highly toxic--oyster | * |
| 1700 | 1986 Puget Sound AET--Microtox™ | * |
| 2000 | San Francisco Bay AET--bivalve | * |
| 2100 | Columbia River bioassay--amphipod | No effect |
| 2360 ± 3330 | Commencement Bay highly toxic--amphipod | * |
| 2500 | 1986 Puget Sound AET--oyster | * |
| 2737 ± 1617 | San Francisco Bay highly toxic--bivalve | * |
| 3100 | 95 percentile EP chronic marine @ 1% TOC | * |
| 3300 | LC50 spiked bioassays @ 0.2% TOC--amphipod | * |
| **3600** | **ER-M** | **50 percentile** |
| 3600 | EP chronic safe level | * |
| >3700 | San Francisco Bay AET--amphipod | Not definitive |
| 3900 | 1986 Puget Sound AET--amphipod | * |
| 4200 | LC50 spiked bioassays--amphipod | * |
| 6200 | LC50 spiked bioassays @ 0.3% TOC--amphipod | * |
| 6300 | 1986 Puget Sound AET--benthic | * |
| 8895 ± 10337 | Eagle Harbor moderately toxic--amphipod | No concordance |
| 9000 | EP acute safe level | * |
| 10500 | LC50 spiked bioassays @ 0.5% TOC--amphipod | * |
| 12080 ± 51889 | Eagle Harbor least toxic--amphipod | No effect |
| 15000 | Mixtures spiked bioassays--amphipod | * |
| 18800 | EP interim freshwater criteria @ 1% TOC | * |
| 24000 | 1988 Puget Sound AET--benthic | * |
| 30000 | 1988 Puget Sound AET--amphipod | * |
| 36000 | EP acute marine @ 4% TOC | * |
| 59250 | LC50 2.5% Elizabeth River--spot | * |
| 71988 ± 95713 | Eagle Harbor highly toxic--amphipod | * |
| 570000 | Lake Union significantly toxic--amphipod | * |
| 1327200✔ | LC50 56% Elizabeth River--spot | * |
| 2370000 | LC500 100% Elizabeth River--spot | * |

* 33 concentrations used to determine ER-L and ER-M values.

**Table B-26. Sediment effects data available for FLUORENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 6 ± 5 | San Francisco Bay least toxic--bivalve | No effect |
| 8 ± 16✔ | Southern California✔ not toxic--amphipod | No effect |
| 11 | San Francisco Bay AET--bivalve | * |
| 11.3 ± 8.2✔ | Southern California significantly toxic--amphipod✔ | Small gradient✔ |
| 16 ± 23 | San Francisco Bay not toxic--bivalve | No effect |
| 19 ± 30 | San Francisco Bay moderately toxic--bivalve | * |
| 29 ± 48 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 30 ± 21 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 33 ± 77 | San Francisco Bay highly toxic--amphipod | No gradient |
| **35** | **ER-L** | **10 percentile** |
| 35 ± 64 | San Francisco Bay significantly toxic--bivalve | * |
| 39 ± 49 | San Francisco Bay least toxic--amphipod | No effect |
| 43± 51✔ | San Francisco Bay not toxic--amphipod | No effect |
| 59 | 99 percentile EP chronic marine @ 1% TOC | * |
| 64 | PSDDA screening level | No effect |
| 75 ± 76 | Commencement Bay least toxic--oyster | No effect |
| 93 | Black Rock Harbor significant toxic--amphipod | * |
| 101 | Marine SLC @1% TOC | * |
| 117 ± 113 | Commencement Bay least toxic--amphipod | No effect |
| 143 ± 119 | Commencement Bay moderately toxic--oyster | * |
| 147 ± 131 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 160 | 95 percentile EP chronic marine @ 1% TOC | * |
| 162 ± 105 | San Francisco Bay highly toxic--bivalve | * |
| 187 ± 234 | Eagle Harbor moderatley toxic--amphipod | No concordance |
| 210 | Eagle Harbor predicted LC50--amphipod | * |
| 210 | San Francisco Bay AET--amphipod | No concordance |
| 353 ± 746 | Commencement Bay highly toxic--oyster | * |
| 540 | 1986 Puget Sound AET--amphipod | * |
| 540 | 1986 Puget Sound AET--oyster | * |
| 540 | 1986 Puget Sound AET--Microtox™ | * |
| **640** | **ER-M** | **50 percentile** |
| 640 | 1986 Puget Sound AET--benthic | * |
| 707 ± 1341 | Commencement Bay highly toxic--amphipod | * |
| 1000 | 1988 Puget Sound AET--benthic | * |
| 1017 ± 4679 | Eagle Harbor least toxic--amphipod | No effect |
| 3600 | 1988 Puget Sound AET--amphipod | * |
| 7000 | EP acute safe level | * |
| 22811 ± 65559 | Eagle Harbor highly toxic--amphipod | * |
| 28000 | EP chronic marine @ 4% TOC | * |
| 31250✔ | LC50 2.5% Elizabeth River--spot | * |
| 40000 | Lake Union significantly toxic--amphipod | * |
| 176510 | Winter flounder liver--MFO | * |
| 220550 | Winter flounder liver--somatic condition | * |
| 285290 | Winter flounder kidney--MFO | * |
| 700000 | LC50 56% Elizabeth River--spot | * |
| 1250000 | LC100 100% Elizabeth River--spot | * |

* 28 concentrations used to determine ER-L and ER-M values.

**Table B-27. Sediment effects data available for 2-METHYLNAPHTHALENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 16 ± 33 | Southern California not toxic--amphipod | No effect |
| 20 ± 7 | San Francisco Bay least toxic--bivalve | No effect |
| 24 ± 4 | San Francisco Bay not toxic--bivalve | No effect |
| 26 ± 23 | San Francisco Bay moderately toxic--bivalve | Small gradient |
| 27 | San Francisco Bay AET--bivalve | * |
| 31 ± 33 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 32 ± 41 | San Francisco Bay highly toxic--amphipod | No gradient |
| 34 ± 27 | San Francisco Bay moderately toxic--amphipod | No gradient |
| 34 ± 33 | San Francisco Bay least toxic--amphipod | No effect |
| 35 ± 36 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 39 ± 35 | San Francisco Bay not toxic--amphipod | No effect |
| **65** | **ER-L** | **10 percentile** |
| 65 ± 154 | Southern California significantly toxic--amphipod | * |
| 67 | PSDDA screening level | No effect |
| 98 ± 41 | San Francisco Bay highly toxic--bivalve | * |
| >130 | San Francisco Bay AET--amphipod | Not definitive |
| 165 ± 121 | Commencement Bay least toxic--oyster | No effect |
| 168 ± 169 | Commencement Bay least toxic--amphipod | No effect |
| 207 ± 169 | Commencement Bay moderately toxic--oyster | Small gradient |
| 213 ± 129 | Commencement Bay moderately toxic--amphipod | Small gradient |
| 326 ± 313 | Commencement Bay highly toxic--oyster | * |
| 500 | Mixtures spiked bioassay--amphipod | * |
| 546 ± 490 | Commencement Bay highly toxic--amphipod | * |
| 670 | 1986 Puget Sound AET--amphipod | * |
| 670 | 1986 Puget Sound AET--oyster | * |
| **670** | **ER-M** | **50 percentile** |
| 670 | 1986 Puget Sound AET--benthic | * |
| 670 | 1986 Puget Sound AET--Microtox™ | * |
| 795 | LC50 2.5% Elizabeth River--spot | * |
| 1400 | 1988 Puget Sound AET--benthic | * |
| 1900 | 1988 Puget Sound AET--amphipod | * |
| 17808✓ | LC50 56% Elizabeth River--spot | * |
| 31800 | LC100 100% Elizabeth River--spot | * |

*15 concentrations used to determine ER-L and ER-M values.

**Table B-29. Sediment effects data available for PHENANTHRENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 65±30 | San Francisco Bay least toxic--bivalve | No effect |
| 88 | San Francisco Bay AET--bivalve | * |
| 110 | 99 percentile chronic marine @1% TOC | * |
| 119±242 | Southern California not toxic--amphipod | No effect |
| 159±216 | San Francisco Bay not toxic--bivalve | No effect |
| 188±197 | San Francisco Bay least toxic--amphipod | No effect |
| 199±205 | San Francisco Bay not toxic--amphipod | No effect |
| 220±163 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 222±136 | Southern California significantly toxic--amphipod | * |
| 224±203 | San Francisco Bay moderately toxic--bivalve | * |
| **225** | **ER-L** | **10 percentile** |
| 228±146 | San Francisco Bay moderately toxic--amphipod | Small gradient |
| 233±208 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 240 | 95 percentile chronic marine @ 1% TOC | * |
| 242±203 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 259 | Marine SLC @1% TOC | * |
| 270 | Winter flounder liver--MFO induction | * |
| 297±263 | Commencement Bay least toxic--oyster | No effect |
| 320 | PSDDA screening level | No effect |
| 340 | Winter flounder liver--somatic condition | * |
| 368 | Marine SLC @1% TOC | * |
| 429 | Winter flounder kidney--MFO induction | * |
| 475±160 | San Francisco Bay highly toxic--bivalve | * |
| 478±367 | Commencement Bay least toxic--amphipod | No effect |
| 500 | Mixtures bioassays--amphipod | * |
| 510 | San Francisco Bay AET--amphipod | * |
| 580 | Columbia River bioassays--amphipod | No effect |
| 593±365 | Commencement Bay moderately toxic--oyster | * |
| 597±513 | Commencement Bay moderately toxic--amphipod | * |
| 950 | Eagle Harbor predicted LC50--amphipod | * |
| 1020 | EP marine interim criteria @1% TOC | * |
| 1379±2546 | Commencement Bay highly toxic--oyster | * |
| **1380** | **ER-M** | **50 percentile** |
| 1390 | EP freshwater interim criteria @1% TOC | * |
| 1500 | 1986 Puget Sound AET--oyster | * |
| 1500 | 1986 Puget Sound AET--Microtox™ | * |
| 2142±2404 | Eagle Harbor moderately toxic--amphipod | No concordance |
| 2600±10009 | Eagle Harbor least toxic--amphipod | No effect |
| 2838±4603 | Commencement Bay highly toxic--amphipod | * |
| 3200 | 1986 Puget Sound AET--benthic | * |
| 3680 | LC50 spiked bioassay--amphipod | * |
| 5400 | 1986 Puget Sound AET--amphipod | * |
| 5400 | 1988 Puget Sound AET--oyster | * |
| 6900 | 1988 Puget Sound AET--amphipod | * |
| 14000 | EP acute safe level @1% TOC | * |
| 33603±84430 | Eagle Harbor highly toxic--amphipod | * |
| 56000 | EP chronic marine @4% TOC | * |
| 105500 | LC50 2.5% Elizabeth River--spot | * |
| 220000 | LC100 100% Elizabeth River--spot | * |
| 410000 | Lake Union significantly toxic--amphipod | * |
| 2363200 | LC50 56% Elizabeth River--spot | * |

*34 concentrations used to determine ER-L and ER-M values.

**Table B-28. Sediment effects data available for NAPHTHALENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 4.2 | Black Rock Harbor projected highly toxic--amphipod | Small gradient |
| 8.2 ± 16.1 | Southern California not toxic--amphipod | No effect |
| 30 | Predicted Eagle Harbor--amphipod bioassay LC50 | Small gradient |
| 36 ± 50 | Puget Sound least toxic--Microtox™ EC50 | No effect |
| 43.1 ± 26.2 | San Francisco Bay moderately toxic--bivalve | No concordance |
| 48 ± 24.7 | San Francisco Bay moderately toxic--amphipod | No concordance |
| 53.4 ± 40 | San Francisco Bay significantly toxic--amphipod | No concordance |
| 53.4 ± 37.6 | San Francisco Bay significantly toxic--bivalve | No concordance |
| 58 ± 50.6 | San Francisco Bay least toxic--amphipod | No effect |
| 63.2 ± 57.2 | San Francisco Bay least toxic--bivalve | No effect |
| 64 ± 45.8 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 65.2 ± 53.5 | San Francisco Bay not toxic--amphipod | No effect |
| 77.3 ± 180.6 | Southern California significantly toxic--amphipod | * |
| 88.7 | San Francisco Bay not toxic--bivalve | No effect |
| 127.3 ± 32.4 | San Francisco Bay highly toxic--bivalve | * |
| >160 | San Francisco Bay AET--bivalve | Not definitive |
| >160 | San Francisco Bay AET--amphipod | Not definitive |
| 210 | PSDDA screening level | No effect |
| 288 ± 201 | Eagle Harbor moderately toxic--amphipod | No concordance |
| **340** | **ER-L** | **10 percentile** |
| 343 ± 388 | Puget Sound moderately toxic--Microtox™EC50 | * |
| 358 ± 326 | Commencement Bay least toxic--oyster | No effect |
| 367✔ | Saltwater SLC | * |
| 414 | Saltwater SLC | * |
| 456 ± 682 | Eagle Harbor least toxic--amphipod | No effect |
| 500 | 99 percentile EP chronic marine @1% TOC | * |
| 510 ± 499 | Commencement Bay least toxic--amphipod | No effect |
| 593 ± 505 | Commencement Bay moderately toxic--oyster | * |
| 594 ± 424 | Commencement Bay moderately toxic--amphipod | * |
| 720 | 95 percentile EP chronic marine @1% TOC | * |
| 973 ± 1041 | Commencement Bay highly toxic--oyster | * |
| 1501 ± 2064 | Eagle Harbor highly toxic--amphipod | * |
| 1564 ± 1735 | Commencement Bay highly toxic--amphipod | * |
| 2100 | 1986 Puget Sound AET--amphipod | * |
| 2100 | 1986 Puget Sound AET--oyster | * |
| 2100 | 1986 Puget Sound AET--benthic | * |
| 2100 | 1986 Puget Sound AET--Microtox™ | * |
| **2100** | **ER-M** | **50 percentile** |
| 2375 | 28-d LC50 for spot-2.5% Elizabeth River sediments | * |
| 2400 | 1988 Puget Sound AET--amphipod | * |
| 2700 | 1988 Puget Sound AET--benthic | * |
| 3934 ± 8864 | Puget Sound highly toxic--Microtox™ EC50 | * |
| 5250 ± 1500 | Trinity River high species richness | No effect |
| 6200 | Winter flounder spiked bioassays--hepatic MFO | * |
| 7370 | Winter flounder spiked bioassays--HSI | * |
| 10710 | Winter flounder spiked bioassays--kidney MFO | * |
| 11500 ± 5600 | Trinity River low species richness | * |
| 40000 | Lake Union highly toxic--*Hyallella* | * |
| 42000 | EP acute marine threshold @4% TOC | * |
| 53200 | 24-h LC50 for spot-56% Elizabeth River | * |
| 95000 | LC100 for spot-100% Elizabeth River | * |

*28 concentrations used to determine ER-L and ER-M values.

**Table B-31. Sediment effects data available for total PAH arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values and the number of the PAHs that were quantified to determine the totals.**

| Concentrations (ppb) | Biological Test | Remarks | PAH Reported |
|---|---|---|---|
| 763 ±727 | Puget Sound least toxic–Microtox™ | No effect | unspecified |
| 870 | San Francisco Bay AET–bivalve | * | ** |
| 941 ± 429 | San Francisco Bay least toxic–bivalve | No effect | ** |
| 2242 | Southern California not toxic–amphipod | No effect | 18 |
| 2557 ± 3816 | San Francisco Bay not toxic–bivalve | No effect | ** |
| 2590 | Predicted LC50 Eagle Harbor–amphipod | * | 13 |
| 3322 ± 4337 | San Francisco Bay least toxic–amphipod | No effect | ** |
| 3343 ± 4039 | San Francisco Bay moderately toxic–bivalve | * | ** |
| 3527 ± 4520 | San Francisco Bay not toxic–amphipod | No effect | ** |
| 3705 | Commencement Bay least toxic–oyster | No effect | 16 |
| 3800 | San Francisco Bay triad minimum bioeffects | * | 9 |
| 3832 ± 3927 | San Francisco Bay significantly toxic–amphipod | Small gradient | ** |
| 3966 ± 3524 | San Francisco Bay moderately toxic–amphipod | Small gradient | ** |
| **4000** | **ER-L** | **10 percentile** | |
| 4022 ± 4908 | San Francisco Bay significantly toxic–bivalve | * | ** |
| 4201 ± 4612 | Puget Sound nontoxic–amphipod | No effect | unspecified |
| 4227 ± 5025 | San Francisco Bay highly toxic–amphipod | Small gradient | 16 |
| 6467 | Commencement Bay least toxic–amphipod | No effect | 16 |
| 7627 ± 7065 | Puget Sound moderately toxic–amphipod | * | unspecified |
| 7841 | Commencement Bay moderately toxic–oyster | * | 16 |
| 8209 | Commencement Bay moderately toxic–amphipod | Small gradient | 16 |
| 8363 | Southern California significantly toxic–amphipod | * | 18 |
| 8550 ± 22990 | Mississippi Sound not toxic–mysid | No effect | unspecified |
| 8550 ± 23000 | Mississippi Sount least toxic–mysid | No effect | unspecified |
| 8700 ± 12600 | Massachusetts Bay high species richness | No effect | unspecified |
| 9500 | San Francisco Bay triad significant bioeffects | * | 18 |
| 9730 ± 22390 | Mississippi Sound least toxic–amphipod | No effect | unspecified |
| 10000 | Petroleum product spiked bioassay–oyster larvae | No effect | unspecified |
| 10200 ± 9950 | Forth Estuary high meiofauna density | No effect | unspecified |
| 11273 | Black Rock Harbor significantly toxic–amphipod | * | 20 |
| 11400 ± 14100 | Mississippi Sound highly toxic–mysid | No concordance | unspecified |
| 11735 ± 5499 | San Francisco Bay highly toxic–bivalve | * | ** |
| 11752 ± 14548 | Puget Sound highly toxic–amphipod | * | unspecified |
| 11800 ± 9700 | Forth Estuary moderate meiofauna density | Small gradient | unspecified |
| 12325 ± 10425 | Hampton Roads moderately toxic–shrimp | No concordance | 16 |
| 12877 | Commencement Bay highly toxic–oyster | * | 16 |
| 13933 ± 17427 | Puget Sound moderately toxic–Microtox™ | * | unspecified |
| >15000 | San Francisco Bay AET–amphipod | Not definitive | 18 ** |
| 16771 | Commencement Bay highly toxic–amphipod | * | 16 |
| 16921 ± 20976 | Hampton Roads least toxic–shrimp | No effect | 16 |
| 18600 ± 47000 | Mississippi Sound not toxic–amphipod | No effect | unspecified |
| 19000 | Lower Columbia River bioassays–amphipod | No effect | 17 |
| 21467 ± 31160 | Hudson-Raritan least toxic–nematode | No effect | unspecified |
| 21600 ± 31000 | Mississippi Sound significantly toxic–amphipod | No gradient | unspecified |
| 23100 ± 15400 | Massachusetts Bay moderate species richness | * | unspecified |
| 35000± 2540 | Massachusetts Bay low species richness | * | unspecified |
| **35000** | **ER-M** | **50 percentile** | |
| 357000 ± 42181 | Hampton Roads highly toxic–shrimp | * | 16 |
| 41790 ± 66160 | Mississippi Sound significantly toxic–mysid | * | unspecified |
| 42769 ± 46084 | Hudson-Raritan highly toxic–nematode | * | unspecified |
| 47760 ± 74890 | Mississippi Sound highly toxic–amphipod | * | unspecified |
| 55630 ± 112530 | Puget Sound highly toxic–Microtox™ | * | unspecified |
| 66100 ± 83300 | Mississippi Sound moderately toxic–mysid | * | unspecified |
| 83800 ± 57900 | Forth Estuary low meiofauna density | * | unspecified |

**Table B-30. Sediment effects data available for PYRENE arranged in ascending order with remarks regarding use of the concentrations to determine ER-L and ER-M values.**

| Concentrations (ppb) | Biological Test | Remarks |
|---|---|---|
| 182 | Kidney MFO induction--winter flounder | * |
| 184 ± 318 | Southern California not toxic--amphipod | No effect |
| 216 ± 102 | San Francisco Bay least toxic--bivalve | No effect |
| 300 | Liver MFO induction--winter flounder | * |
| 350 | Eagle Harbor predicted LC50--amphipod | * |
| **350** | **ER-L** | **10 percentile** |
| 360 | Liver somatic condition--winter flounder | * |
| 430 | PSDDA screening level | No effect |
| 434 ± 442 | Commencement Bay least toxic--oyster | No effect |
| 434 | Marine SLC @1% TOC | * |
| 532 ± 372 | Southern California significantly toxic--amphipod | * |
| 665 | Marine SLC @1% TOC | * |
| 701 ± 866 | San Francisco Bay least toxic--amphipod | No effect |
| 719 ± 1123 | San Francisco Bay not toxic--bivalve | No effect |
| 724 ± 939 | San Francisco Bay moderately toxic--bivalve | * |
| 743 ± 902 | San Francisco Bay not toxic--amphipod | No effect |
| 777 ± 908 | San Francisco Bay highly toxic--amphipod | Small gradient |
| 806 ± 975 | San Francisco Bay significantly toxic--bivalve | Small gradient |
| 850 | EP 99 percentile chronic marine @ 1% TOC | * |
| 865 ± 719 | Commencement Bay moderately toxic--amphipod | No concordance |
| 896 ± 870 | San Francisco Bay significantly toxic--amphipod | Small gradient |
| 978 ± 996 | Commencement Bay least toxic--amphipod | No effect |
| 1078 ± 806 | Commencement Bay moderately toxic--oyster | * |
| 1110 ± 904 | San Francisco Bay moderately toxic--amphipod | * |
| 1538 ± 1501 | Commencement Bay highly toxic--oyster | * |
| 1820 ± 2252 | Commencement Bay highly toxic--amphipod | * |
| 1900 | EP 95 percentile chronic marine @ 1% TOC | * |
| 2188 ± 776 | San Francisco Bay highly toxic--bivalve | * |
| **2200** | **ER-M** | **50 percentile** |
| 2500 | Columbia River bioassays--amphipod | No effect |
| 2600 | 1986 Puget Sound AET--Microtox™ | * |
| 2600 | San Francisco Bay AET--amphipod | * |
| 3300 | 1986 Puget Sound AET--oyster | * |
| >3400 | San Francisco Bay AET--bivalve | Not definitive |
| 4300 | 1986 Puget Sound AET--amphipod | * |
| >7300 | 1986 Puget Sound AET--benthic | No definitive value |
| 13100 | EP interim freshwater criteria @ 1% TOC | * |
| 16000 | 1988 Puget Sound AET--amphipod | * |
| 16000 | 1988 Puget Sound AET--benthic | * |
| 33750 | LC50 2.5% Elizabeth River--spot | * |
| 49500 | EP acute safe level | * |
| 198000 | EP chronic marine @ 4% TOC | * |
| 750000 | Lake Union significantly toxic--amphipod | * |
| 756000 | LC50 56% Elizabeth River--spot | * |
| 1350000 | LC100 100% Elizabeth River--spot | * |

*28 concentrations used to determine ER-L and ER-M values.

Table B-31 (Continued)

| Concentrations (ppb) | Biological Test | Remarks | PAH Reported |
|---|---|---|---|
| 99400 | Mississippi Sound AET--mysid bioassay | * | unspecified |
| 183060 | Spiked bioassays--winter flounder liver MFO | * | 4 |
| >205000 | Mississippi Sound AET--amphipod bioassay | Not definitive | unspecified |
| 228722 | Spiked bioassays--winter flounder liver condition | * | 4 |
| 295860 | Spiked bioassays--winter flounder kidney MFO | * | 4 |
| 530000 | LC50 2.5% Elizabeth River--spot | * | 21 |
| 2240000 | LC50 Bunker C oil spiked bioassay--amphipod | * | gravimetric |
| 3900000 | 56% mortality Elizabeth River--spot | * | 20 |
| 3900000 | 100% fin erosion Elizabeth River--spot | * | 20 |
| 11872000 | LC50 56% Elizabeth River--spot | * | 21 |
| 21200000 | LC100 100% Elizabeth River--spot | * | 21 |

* 34 concentrations used to determine ER-L and ER-M values.

** Long and Buchman, 1989, 18 PAH ; Chapman *et al.*, 1986, 18 PAH; Word *et al*, 1988, 16 PAH; U. S. Navy, 1987, 6 or 7 PAH

# GLOSSARY

# NATIONAL STATUS AND TRENDS PROGRAM SITES

## NS&T Program Mussel Watch Sites

| Code | General Location | Specific Location | State |
|---|---|---|---|
| AIAC | Absecon Inlet | Atlantic City | New Jersey |
| ABWJ | Anaheim Bay | West Jetty | California |
| APCP | Apalachicola Bay | Cat Point Bar | Florida |
| APDB | Apalachicola Bay | Dry Bar | Florida |
| ABHI | Aransas Bay | Harbor Island | Texas |
| ABLR | Aransas Bay | Long Reef | Texas |
| ABOB | Atchafalaya Bay | Oyster Bayou | Louisiana |
| BBSD | Barataria Bay | Bayou Saint Denis | Louisiana |
| BBTB | Barataria Bay | Turtle Bay | Louisiana |
| BBMB | Barataria Bay | Middle Bank | Louisiana |
| BPBP | Barbers Point | Barbers Point | Hawaii |
| BIBL | Barnegat Inlet | Barnegat Light | New Jersey |
| BBSM | Bellingham Bay | Squalicum Marina | Washington |
| BBPC | Biscayne Bay | Princeton Canal | Florida |
| BIBI | Block Island | Block Island | Rhode Island |
| BBBE | Bodega Bay | Bodega Bay Entrance | California |
| BHDI | Boston Harbor | Deer Island | Massachusetts |
| BHDB | Boston Harbor | Dorchester Bay | Massachusetts |
| BHHB | Boston Harbor | Hingham Bay | Massachusetts |
| BHBI | Boston Harbor | Brewster Island | Massachusetts |
| BRFS | Brazos River | Ferrport Surfside | Texas |
| BSBG | Breton Sound | Bay Garderne | Louisiana |
| BSSI | Breton Sound | Sable Island | Louisiana |
| BBRH | Buzzards Bay | Round Hill | Massachusetts |
| BBAR | Buzzards Bay | Angelica Rock | Massachusetts |
| BBGN | Buzzards Bay | Goosebury Neck | Massachusetts |
| CLCL | Caillou Lake | Caillou Lake | Louisiana |
| CLLC | Calcasieu Lake | Lake Charles | Louisiana |
| CLSJ | Calcasieu Lake | Saint Johns Island | Louisiana |
| CAGH | Cape Ann | Gap Head | Massachusetts |
| CFBI | Cape Fear | Battery Island | North Carolina |
| CKBP | Cedar Key | Black Point | Florida |
| CHFJ | Charleston Harbor | Fort Johnson | South Carolina |
| CHSF | Charleston Harbor | Shutes Folly Island | South Carolina |
| CBBI | Charlotte Harbor | Bird Island | Florida |
| CBFM | Charlotte Harbor | Fort Meyers | Florida |
| CBMP | Chesapeake Bay | Mountain Point Bar | Maryland |
| CBHP | Chesapeake Bay | Hackett Point Bar | Maryland |
| CBHG | Chesapeake Bay | Hog Point | Maryland |
| CBIB | Chesapeake Bay | Ingram Bay | Virginia |
| CBCC | Chesapeake Bay | Cape Charles | Virginia |
| CBDP | Chesapeake Bay | Dandy Point | Virginia |
| CBCI | Chincot. Bay | Chincot. Inlet | Virginia |
| CBSP | Choctawatchee Bay | Shirk Point | Florida |
| CBSR | Choctawatchee Bay | Off Santa Rosa | Florida |
| CRSJ | Columbia River | South Jetty | Oregon |
| CBTP | Commencement Bay | Tahlequah Point | Washington |
| CBCH | Coos Bay | Coos Head | Oregon |
| CBRP | Coos Bay | Russell Point | Oregon |
| CBCR | Copano Bay | Copano Reef | Texas |
| CCBH | Corpus Christi | Boat Harbor | Texas |
| CCIC | Corpus Christi | Ingleside Cove | Texas |
| CCNB | Corpus Christi | Neuces Bay | Texas |
| DBFE | Delaware Bay | False Egg Island Point | Delaware |

| Code | General Location | Specific Location | State |
|---|---|---|---|
| DBBD | Delaware Bay | Ben Davis Point Shoal | Delaware |
| DBKI | Delaware Bay | Kelly Island | Delaware |
| EBFR | Elliott Bay | Four-Mile Rock | Washington |
| ESSP | Espiritu Santo | South Pass Reef | Texas |
| ESBD | Espiritu Santo | Bill Days Reef | Texas |
| EVFU | Everglades | Faka Union Bay | Florida |
| FIEL | Farallon Island | East Landing | California |
| GBHR | Galveston Bay | Hanna Reef | Texas |
| GBSC | Galveston Bay | Ship Channel | Texas |
| GBYC | Galveston Bay | Yacht Club | Texas |
| GBTD | Galveston Bay | Todd's Dump | Texas |
| GBCR | Galveston Bay | Confed.Reef | Texas |
| GBOB | Galveston Bay | Offats Bayou | Texas |
| GHWJ | Gray's Harbor | Westport Jetty | Washington |
| HHKL | Honolulu Harbor | Keehi Lagoon | Hawaii |
| HRJB | Hudson/Raritan Estuary | Jamaica Bay | New York |
| HRUB | Hudson/Raritan Estuary | Upper Bay | New York |
| HRLB | Hudson/Raritan Estuary | Lower Bay | New York |
| HMBJ | Humboldt Bay | Jetty | California |
| IBNJ | Imperial Beach | North Jetty | California |
| IRSR | Indian River | Sebastian River | Florida |
| JHJH | Joseph Harbor Bayou | Joseph Harbor Bay | Louisiana |
| KAUI | Kauai | Nawiliwili Harbor | Hawaii |
| LJLJ | La Jolla | Point La Jolla | California |
| LMSB | Laguna Madre | South Bay | Texas |
| LMPI | Laguna Madre | Port Isabell | Texas |
| LBNO | Lake Borgne | New Orleans | Louisiana |
| LBMP | Lake Borgne | Malheureux Point | Louisiana |
| LICR | Long Island Sound | Connecticut River | Connecticut |
| LINH | Long Island Sound | New Haven | Connecticut |
| LIHR | Long Island Sound | Housatonic River | Connecticut |
| LISI | Long Island Sound | Sheffield Island | Connecticut |
| LIHU | Long Island Sound | Huntington Harbor | New York |
| LIPJ | Long Island Sound | Port Jefferson | New York |
| LIMR | Long Island Sound | Mamaroneck | New York |
| LIHH | Long Island Sound | Hempstead Harbor | New York |
| LITN | Long Island Sound | Throgs Neck | New York |
| MDSJ | Marina Del Rey | South Jetty | California |
| MBEM | Matagorda Bay | East Matagorda | Texas |
| MBDI | Matagorda Bay | Dog Island | Texas |
| MBCB | Matagorda Bay | Carancahua Bay | Texas |
| MBTP | Matagorda Bay | Tres Palacios Bay | Texas |
| MBGP | Matagorda Bay | Gallinipper Point | Texas |
| MBLR | Matagorda Bay | Lavaca River Mouth | Texas |
| MRCB | Matanzas River | Cresent Beach | Florida |
| MSSP | Merriconeag Sound | Stover Point | Maine |
| MBAR | Mesquite Bay | Ayres Point | Texas |
| MRTP | Mississippi River | Tiger Pass | Louisiana |
| MRPL | Mississippi River | Pass a Loutre | Louisiana |
| MSPB | Mississippi Sound | Pascagoula Bay | Mississippi |
| MSBB | Mississippi Sound | Biloxi Bay | Mississippi |
| MSPC | Mississippi Sound | Pass Christian | Mississippi |
| MBVB | Mission Bay | Ventura Bridge | California |
| MBHI | Mobile Bay | Hollingers Island Channel | Alabama |
| MBCP | Mobile Bay | Cedar Point Reef | Alabama |
| MBSC | Monterey Bay | Point Santa Cruz | California |

| Code | General Location | Specific Location | State |
|---|---|---|---|
| MBTH | Moriches Bay | Tuthill Point | New York |
| NYLB | New York Bight | Long Branch | New Jersey |
| NYSH | Raritan Bay | Sandy Hook Bay | New Jersey |
| NYSR | New York Bight | Shark River | New Jersey |
| NBNB | Naples Bay | Naples Bay | Florida |
| NBDU | Narragansett Bay | Dutch Island | Rhode Island |
| NBDI | Narragansett Bay | Dyer Island | Rhode Island |
| NBWJ | Newport Beach | Wedge Jetty | California |
| NMML | North Miami | Maule Lake | Florida |
| OEIH | Oakland Estuary | Inner Harbor | California |
| OSBJ | Oceanside | Beach Jetty | California |
| PGLP | Pacific Grove | Lovers Point | California |
| PVRP | Palos Verdes | Royal Palms State Park | California |
| PSWB | Pamlico Sound | Wysoching Bay | North Carolina |
| PCMP | Panama City | Municipal Pier | Florida |
| PBSI | Penobscot Bay | Sears Island | Maine |
| PBPI | Penobscot Bay | Pickering Island | Maine |
| PBPH | Pensacola Bay | Public Harbor | Florida |
| PBIB | Pensacola Bay | Indian Bayou | Florida |
| PVMC | Port Valdez | Mineral Creek Flats | Alaska |
| PALH | Point Arena | Lighthouse | California |
| PCPC | Point Conception | Point Conception | California |
| PDSC | Point Delgada | Shelter Cove | California |
| PDPD | Point Dume | Point Dume | California |
| PLLH | Point Loma | Lighthouse | California |
| PRPR | Point Roberts | Point Roberts | Washington |
| SBSB | Point Santa Barbara | PointSanta Barbara | California |
| SGSG | Point Saint George | Point Saint George | California |
| QIUB | Quinby Inlet | Upshur Bay | Virginia |
| RSJC | Roanoke Sound | John Creek | North Carolina |
| RBHC | Rookery Bay | Henderson Creek | Florida |
| SCBR | South Catalina Island | Bird Rock | California |
| JFCF | South Juan de Fuca | Cape Flattery | Washington |
| SSBI | South Puget Sound | Budd Inlet | Washington |
| SLBB | Sabine Lake | Blue Buck Point | Texas |
| SHFP | Salem Harbor | Folger Point | Massachusetts |
| SAMP | San Antonio Bay | Mosquito Point | Texas |
| SAPP | San Antonio Bay | Panther Point Reef | Texas |
| SDHI | San Diego Bay | Harbor Island | California |
| SFDB | San Francisco Bay | Dumbarton Br. | California |
| SFSM | San Francisco Bay | San Mateo Bridge | California |
| SFEM | San Francisco Bay | Emeryville | California |
| SLSL | San Luis Obispo Bay | Point San Luis | California |
| SANM | San Miguel Island | Tyler Bight | California |
| SPFP | San Pedro Harbor | Fishing Pier | California |
| SPSP | San Francisco Bay | San Pablo Bay | California |
| SSSS | San Simeon Point | San Simeon Point | California |
| SCFP | Santa Cruz Island | Fraser Point | California |
| SSSI | Sapelo Sound | Sapelo Island | Georgia |
| SRTI | Savannah River Estuary | Tybee Island | Georgia |
| SIWP | Sinclair Inlet | Waterman Point | Washington |
| SAWB | Saint Andrew Bay | Watson Bayou | Florida |
| SJCB | Saint Johns River | Chicopit Bay | Florida |
| SRWP | Suwannee River | West Pass | Florida |
| TBMK | Tampa Bay | Mullet Key Bayou | Florida |
| TBCB | Tampa Bay | Cockroach Bay | Florida |

| Code | General Location | Specific Location | State |
|---|---|---|---|
| TBHB | Tampa Bay | Hillsborough Bay | Florida |
| TBPB | Tampa Bay | Papys Bayou | Florida |
| TBOT | Tampa Bay | Old Tampa Bay | Florida |
| TBLB | Terrebonne Bay | Lake Barre | Louisiana |
| TBHP | Tillamook Bay | Hobsonville Point | Oregon |
| TBSR | Tomales Bay | Spanger's Res. | California |
| UISB | Unakwit Inlet | Siwash Bay | Alaska |
| VBSP | Vermillion Bay | Southwest Pass | Louisiana |
| WIPP | Whidbey Island | Possession Point | Washington |
| YBOP | Yaquina Bay | Oneata Point | Oregon |
| YHSS | Yaquina Bay | Sally's Slough | Oregon |
| YHYH | Yaquina Head | Yaquina Head | Oregon |

## NS&T Program Benthic Surveillance Sites

| Code | Location | State |
|---|---|---|
| APA | Apalachicola Bay | Florida |
| BAR | Barataria Bay | Louisiana |
| BOD | Bodega Bay | California |
| BOS | Boston Harbor | Massachusetts |
| BUZ | Buzzards Bay | Massachusetts |
| CAS | Casco Bay | Maine |
| CCB | Corpus Christi Bay | Texas |
| CHS | Charleston Harbor | South Carolina |
| COL | Columbia River | Oregon |
| COM | Commencement Bay | Washington |
| COO | Coos Bay | Oregon |
| DAN | Dana Point | California |
| DEL | Delaware Bay | Delaware |
| ELIE | Long Island Sound | Connecticut |
| ELL | Elliott Bay | Washington |
| END | Prudhoe Bay | Alaska |
| FRB | Frenchman Bay | Maine |
| GAL | Galveston Bay | Texas |
| GRB | Great Bay | New Jersey |
| HER | Heron Bay | Mississippi |
| HMB | Humboldt Bay | California |
| HUN | Hunters Point | California |
| LCB | Lower Chesapeake Bay | Virginia |
| LLM | Lower Laguna Madre | Texas |
| LNB | Long Beach | California |
| LOT | Charlotte Harbor | Florida |
| LUT | Lutak Inlet | Alaska |
| MAC | Machias Bay | Maine |
| MCB | Middle Chesapeake Bay | Virginia |
| MER | Merrimack River | Massachusetts |
| MOB | Mobile Bay | Alabama |
| MON | Monterey Bay | California |
| MRD | Mississippi Delta | Louisiana |
| NAH | Nahku Bay | Alaska |
| NAR | Narragansett Bay | Rhode Island |
| NIS | Nisqually Reach | Washington |
| OAK | Oakland Estuary | California |

| Code | Location | State |
| --- | --- | --- |
| OLI | Oliktok Point | Alaska |
| PAB | San Pablo Bay | California |
| PAM | Pamlico Sound | North Carolina |
| PEN | Pensacola Bay | Florida |
| PNB | Penobscot Bay | Maine |
| RAR | Raritan Bay | New Jersey |
| ROU | Round Island | Mississippi |
| SAB | San Antonio Bay | Texas |
| SAL | Salem Harbor | Massachusetts |
| SAP | Sapelo Island | Georgia |
| SDA | San Diego Harbor | California |
| SDF | San Diego Bay | California |
| SEA | Seal Beach | California |
| SHS | Southhampton Shoal | California |
| SJR | Saint Johns River | Florida |
| SMB | Santa Monica Bay | California |
| SPB | San Pedro Bay | California |
| SPC | San Pedro Canyon | California |
| TAM | Tampa Bay | Florida |
| UCB | Upper Chesapeake Bay | Maryland |
| WLI | West Long Island Sound | New York |



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