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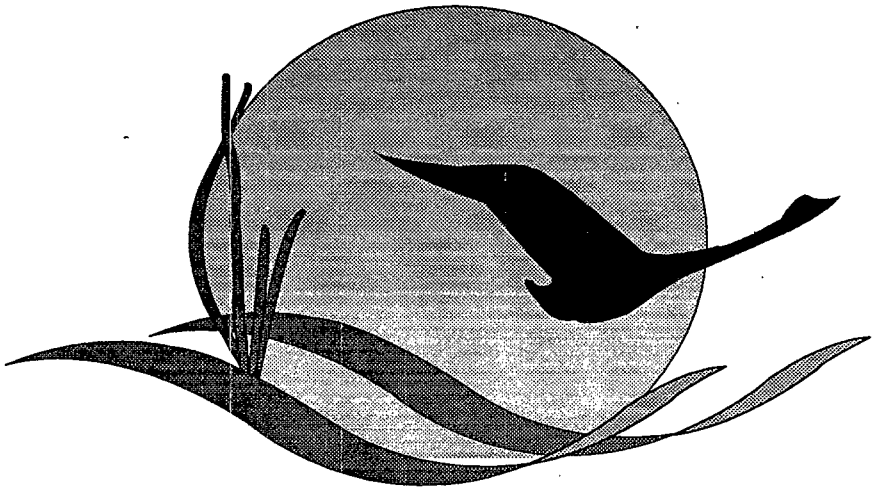
Chesapeake Bay Contaminated Sediments Critical Issue Forum Proceedings

Basinwide Toxics Reduction Strategy Reevaluation Report



Chesapeake Bay Program

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Proceedings of the Chesapeake Bay Program Toxics Subcommittee Sponsored

Chesapeake Bay Contaminated Sediments

Critical Issue Forum

December 10, 1992

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PROCEEDINGS OF THE CHESAPEAKE BAY PROGRAM
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CHESAPEAKE BAY CONTAMINATED SEDIMENTS CRITICAL ISSUE FORUM

U.S. EPA Chesapeake Bay Program Office
Chesapeake Bay Information and Conference Center

December 10, 1992

1. CRITICAL ISSUE FORUM OBJECTIVES/PROCESS

Dave Velinsky convened the forum and described the forum objectives and process. A written summary of the forum proceedings, discussions and findings will be prepared by the Chesapeake Bay Program Office and the forum co-chairs and distributed for review by the forum speakers. The forum findings will be presented to the Toxics Subcommittee in January.

As an integral part of the ongoing reevaluation, the Chesapeake Bay Contaminated Sediment Critical Issue Forum was structured to seek a technical consensus on the following series of questions:

- From the critical review of available data, have we defined/can we define the relative magnitude (concentration) and extent (geographical distribution) of contaminated sediments within Chesapeake Bay?

- Does this definition of the magnitude and extent of contaminated sediments within the Bay give us reason to believe this identified (potential) toxics issue is causing or can cause an impact (e.g. bioaccumulation, toxicity) on Chesapeake Bay system, on either a Baywide, regional or local scale?

- How does the magnitude and extent of contaminated sediments within Chesapeake Bay compare with other coastal systems (e.g. Puget Sound) or large water bodies (e.g. Great Lakes)?

- What direction should the Toxics Subcommittee recommend the Chesapeake Bay Program agencies take with regards to addressing contaminated sediments?

  - Denoting Regions of Concern (with contaminated sediments as one of the parameters for delineation)
  - Recommending to the jurisdictions general/specific source reduction/remediation actions
  - Undertaking a structured set of applied and basic studies in specific Regions of Concern to determine the source, fate and effects of sedimentary metals and organics
  - Other directions...

- If there is insufficient data or information to answer the above questions, identify the additional data/research required to answer the questions.

2. EPA CONTAMINATED SEDIMENTS MANAGEMENT STRATEGY

Tom Armitage described the events leading up to development of EPA's Contaminated Sediment Management Strategy. He explained that national EPA surveys in 1985 and 1987, concerned mostly with bioaccumulative toxic compounds such as PCBs, pesticides, PAHs, and metals, showed that the extent of sediment contamination might be national in scope. A 1989 National Academy of Sciences report, "Contaminated Marine Sediments - Assessment and Remediation", recommended the EPA take specific actions to address sediment contamination issues.

A map from the "Overview of Sediment Contamination in the U.S." report showed sites across the country where available data show levels of sediment contamination which may be harmful to benthic and other aquatic communities. The sites displayed were associated with drinking water restrictions, fish kills, fish advisories and recreation use restrictions. The Great Lakes region shows a proliferation of these sites, which may be indicative of sediment contamination problems in that region but is probably due to a greater amount of sediment contaminant data.

Based on present data, sources of contaminants in sediments have been identified as: industrial discharges, municipal waste water treatment plants, combined sewage overflows, stormwater runoff, hazardous waste disposal sites, and atmospheric deposition.

Tom Armitage pointed out that efforts to develop a national "Contaminated Sediments Management Strategy" were initiated in 1989 by then EPA administrator Lee Thomas. Testimony on the scope of contaminated sediment problems was presented at a number of Congressional hearings throughout 1989-1991 as a result of increased legislative interest in the issue. EPA's proposed sediment management approach was presented at national conferences in 1991 and a draft strategy outline was released for public review in March 1992. Three national forums on the proposed strategy were also held in April-June, 1992. The forums proceedings were published in September 1992. A revised strategy will be distributed for comment in March 1993 with a final strategy to be available in late summer or early fall 1993.

The goals of the draft "Contaminated Sediment Management Strategy" are to:

- prevent future contamination of sediments;
- manage existing sediment contamination using:
  - pollution prevention
  - source controls
  - natural recovery where appropriate (Natural recovery refers to limiting bioavailability of contaminants through processes such as natural sedimentation. Active remediation may be preferable to natural recovery when toxics are moving off site. Criteria are being established for determination of when to use active remediation.);
- remediate high-risk sites where natural recovery is not acceptable; and
- ensure environmentally sound management of sediment dredging and the disposal of dredged materials.

Specific elements of the strategy include:

- Assessment: a national inventory to identify and rank geographical areas for targeted pollution prevention, source controls and remediation, coupled with consistent tiered testing methodologies employed as part of expanded sediment monitoring programs.
- Research: the EPA Office of Research and Development has a contaminated sediment research plan which encompasses development of sediment assessment methods, sediment quality criteria, and new remediation technologies.
- Prevention: applications of existing authorities to prevent point and nonpoint sources of sediment contamination and prevent introduction of new compounds which may contaminate sediments.
- Remediation: use existing authority and statutory provisions under CWA, CERCLA (superfund), RCRA, and TSCA, which can be focused on sediment quality.
- Dredged material: A new testing manual for dredged material is being developed which will reduce the list of test species to include only the most sensitive ones, and will provide mixing zone models for use in shallow water. The applicability of RCRA to dredged material and the appropriate use of sediment quality criteria in dredged material assessment and management is also being addressed.

Outreach activities concerning contaminated sediments include a quarterly newsletter, "Contaminated Sediment News", and publication of the national Sediment Strategy Forums proceedings. Tom Armitage distributed a handout from the EPA Office of Water's Office of Science and Technology which outlined the responsibilities of various EPA program offices for sediment toxicity testing.

Tom Armitage described the results of the most recent EPA Science Advisory Board review of the proposed sediment quality criteria for 3 PAHs and 2 pesticides. The Science Advisory Board recommended EPA provide guidance on how each program office will apply the sediment quality criteria in their regulatory processes. EPA is performing an economic impact analysis for the application of the criteria. Sediment quality criteria for 4 metals - nickel, lead, zinc, and cadmium - are also being developed and the metals criteria development methodology will undergo a Science Advisory Board review this summer.

Results of EPA Sponsored Workshop on Tiered Sediment Toxicity Testing Protocols

Beverly Baker summarized the results from the September 16-18 workshop on Tiered Sediment Toxicity Testing Protocol held in Washington D.C. The workshop, co-sponsored by the Office of Water and the Office of Research and Development, was held to provide an opportunity for experts in sediment toxicology and staff from EPA's Regional and Headquarters program office to discuss and prioritize the development of standardized freshwater and marine sediment bioassay procedures. As part of EPA's Contaminated Sediment Strategy, EPA's program offices have agreed to use consistent tests for the assessment of sediment quality. As a result of the workshop, the following test organisms have been selected for development of standardized sediment toxicity test methods in FY93:

- Freshwater acute toxicity tests - *Hyalella azteca*, and *Chironomus tentans*.
- Freshwater bioaccumulation test - *Lumbriculus variagatus*.
- Marine/estuarine acute toxicity tests - *Rhepoxynius abronius, Ampelisca abdita, Echaustorius estuarius*, and *Leptocheirus plumulosus*.
- Marine bioaccumulation tests - *Neries sp.* and *Macoma nasuta*.

By the end of FY93, EPA approved protocols on sediment collection and handling and sediment spiking will be published and sediment toxicity test protocols will be available for the above mentioned species. As additional funds become available, work will be conducted on chronic toxicity test methods development and sediment toxicity identification evaluations. Copies of the workshop proceedings are available through the EPA Office of Science and Technology Resource Center.

Rich Batiuk mentioned that there is a need for chronic as well as acute toxicity tests covering the full range of Bay salinity. Beth McGee mentioned that chronic toxicity tests had been conducted by the state of Maryland on *Leptocheirus plumulosus* and have been recommended for standardization through the ASTM process.

National Sediment Contamination Data Inventory

Catherine Fox distributed outlines of the "Framework for the Design of the National Inventory of Contaminated Sediment Sites". A draft of the inventory framework will be available by the end of December with the final framework available in February 1993. The purpose of the national inventory is to obtain the best possible near-term assessment of the national extent and severity of sediment contamination. The inventory will be used to determine whether contaminated sediments are a pervasive national-scale problem or more of a localized "hot spots" issue. The inventory will also be used by EPA Program Offices in targeting assessment, pollution prevention, source control, remediation, and dredged material management activities.

Based on a review of regional sediment contaminant data inventories, EPA decided to include data from individual samples (as opposed to data averages or summaries) in the national inventory. Individual data, to be stored on an EPA mainframe computer, will be grouped and rated for quality: high (good QA/QC), moderate, or no information.

3. NOAA NST/EPA EMAP SEDIMENT CONTAMINANT FINDINGS

Tom O'Connor described findings from the analysis of the combined sediment contamination data from the NOAA National Status and Trends Program (NS&T) through 1989 and from the 1990 EPA Environmental Monitoring and Assessment Program (EMAP) for Chesapeake Bay. The NS&T Program has chemical data from 274 sites distributed throughout the coastal United States. The EMAP Program, for 1990, has data for 152 sites in the Virginian Province. There are 17 NS&T sites and 62 EMAP sites in Chesapeake Bay.

Tom presented the data in several ways, all of which pointed towards three more contaminated areas in the Chesapeake Bay: Baltimore Harbor, Anacostia River, and Elizabeth River. When combined data were adjusted for grain-size and compared with "high" concentrations as derived from the national NS&T data set, those three areas were the only areas in Chesapeake Bay where 3 or more chemicals were at "high" sediment concentrations.

Concentrations of sediment contaminants above which there is the potential for biological impacts have been published by Long and Morgan (1990). Effects range-median (ER-M) and effects range-low (ER-L) values are based on an analysis of data sets containing coincident measures of chemical concentrations and some biological effect. The ER-M is the median of concentrations for which there

was a biological effect. The ER-L is the 10th percentile of those values. It should be recognized that these values are only guidelines because (1) they are based on data from field-collected sediments with no assurance that a biological effect is caused by any particular chemical, and (2) there are many instances listed by Long and Morgan where sediments with concentrations in excess of ER-L's had no corresponding biological effect (this was less so with the ER-M values).

In Chesapeake Bay, there were a number of NS&T/EMAP sites where sediment concentrations of at least one chemical were in excess of an ER-L value. However, with one exception, all the sites with >80% sandy sediments and 21 of the 57 sites with fine-grained sediment had no concentration exceeding an ER-L value. These sites were almost all in the southern portion of the mainstem Bay. Exceedances of ER-M values were found only at sites within Baltimore Harbor, the Anacostia River and the Elizabeth River, and at sites in the northern mainstem Bay.

At the EMAP sites, sediment toxicity was tested using 10-day survival of amphipods. Sediment at a particular site were considered in the "toxic" category if survival on test sediments was less then 80% and statistically less (0.05 level) than control survival. Sediments were found to be toxic at 17 of the 142 EMAP sites in the Virginia Province. Four EMAP sites in Chesapeake Bay were characterized as "toxic" - three in Baltimore Harbor and one in the Elizabeth River.

A final comparison was made between the NS&T/EMAP sediment contaminant data and the EPA proposed sediment quality criteria for trace metals and selected neutral organic compounds. The metal sediment quality criterion assumes toxic conditions if total concentrations of sulfide-insoluble metals (except iron and manganese) exceed the concentration of acid-volatile sulfide (AVS). If it is assumed that all sediments have at least 10 μM/g of AVS, there are only seven Chesapeake Bay sediment samples that might be toxic due to metals contamination. Even in those samples, all from Baltimore Harbor, Anacostia River, and the Elizabeth River, the metals criterion may not be exceeded because AVS could well exceed 10 μM/g. No Chesapeake Bay sediment samples exceeded proposed criteria for four neutral organics - dieldrin, phenanthrene, fluoranthene, and acenaphthalene (where the sediment quality criteria are based on assumed equilibria with pore water and application of water quality criteria to pore water).

In summary, sites in Baltimore Harbor, the Elizabeth River, and the Anacostia River are distinguished from other sites in Chesapeake Bay in terms of:

- Numbers of chemicals with "high" sediment contaminant concentrations;
- Magnitude of the sediment contaminant concentrations;
- Sediment contaminant concentrations in excess of ER-M values thought to be associated with sediment toxicity; and
- Measured sediment toxicity (at sites in Baltimore Harbor and Elizabeth River).

Tom stated that there is a connection between toxicity and contaminated sediment in the Elizabeth River and Baltimore Harbor.

Sediment Core Analyses

Nathalie Valette-Silver presented a summary of findings from previous contaminant analyses of Chesapeake Bay sediment cores. She explained that determining temporal trends through sediment core analyses is useful in evaluating changes in contamination due to anthropogenic activities. Trends in sediment contamination can also be examined through analysis of surface sediments or shellfish tissue data records.

Sediment cores are used in the determination of long term trends by finding background, or baseline, concentrations and constructing a chronology of sediment contamination levels over time. The reconstruction of historical sediment contamination trends requires collection of samples in areas where sediments have been undisturbed during and after their deposition (i.e. limited or no physical or biological mixing).

Dating of sediment layers is crucial to insure a reliable chronology of a core. The integrity of the core must be checked by using x-ray radiography. Slices of the core are then dated using pollen or radioactive isotopes such as Pb^{210} and Cs^{137}.

Results from previous sediment core work in the Chesapeake Bay show that there is a peak in the 1970s in the concentrations of Cu and Pb in the southern mainstem Bay, followed by a decrease in the early 1980s. In the northern mainstem Bay, concentrations of Pb and Zn were still increasing in the 1980s. For the organic compounds, increases were observed through 1982. The sediment core contaminant data from the early 1980s is the most recent.

The NOAA National Status and Trends Program has been supporting sediment core analysis studies for the last few years. A sediment core study was initiated in Chesapeake Bay in 1992 (first year only). Five of the six study sites are located in the mainstem of the Bay, and one is located at the mouth of the York River. When completed, the study will yield information on six sediment core contaminant chronologies for trace metals and nutrients and three sediment core contaminant chronologiies for organic compounds.

Nathalie Valette-Silver concluded that some problems exist with sediment core samples. In particular, chronology of the sediment must be good and several dating tools must be used at the same time to achieve this objective. Remobilization of some of the contaminants can occur after deposition of the sediments due to diagenetic processes. With these problems accounted for, sediment cores can keep a reliable record of contamination changes over time. This type of study can then be a very useful tool for managers in reconstructing the historical contamination in Chesapeake Bay.

Nathalie Valette-Silver went on to describe results from short term trends analyses of surface sediment contaminant data collected through the NOAA National Status and Trends Program Benthic Surveillance Project in Chesapeake Bay for the period of 1984-1986. These results show almost no trends except for Zn, which did increase in the northern mainstem Bay.

She explained that there are some problems associated with the use of surface sediments for establishing short term trends. In particular, it is difficult to determine the exact age of the surface sediment collected at a site. Sedimentation rates can vary due to changes in erosional and depositional processes both temporally and from site to site. The only way to check this is by using a radionuclide with a short half life, such as Be^7 with a half life of 54 days, to determine if the sediment has been

deposited within the last year.

Another method for evaluating short term temporal trends is to look at trends in bivalve tissue chemistry. Oysters and mussels are good indicator organisms for detection of short term contamination trends because their chemical body burden responds rapidly to chemical changes in their environment.

4. BAYWIDE SEDIMENT CONTAMINANT MONITORING PROGRAM FINDINGS

Rich Eskin presented findings from an ongoing effort to synthesize, analyze and interpret sediment contaminant data from the Maryland and Virginia components of the Chesapeake Bay Sediment Contaminant Monitoring Program. This baywide monitoring program was established to characterize sediment contamination in Chesapeake Bay and its tidal tributaries. A draft report presenting more detailed descriptions of the findings below will be distributed for review in late March.

For summary purposes, the station specific sediment contaminant data have been aggregated by Chesapeake Bay segment. Rich Eskin emphasized that this summary format gives a very broad overview and that the data need to be reviewed in greater detail before any decisions can be based on it. Aggregates of the available data, however, are useful in highlighting geographic areas, focusing on potential sources, and making comparisons between areas or stations.

General Patterns of Distribution

Rich Eskin presented several graphs with ERM values as reference lines, when relevant, to indicate areas that need closer examination. ERLs were not used because it was felt they are more arbitrary and because the report is not attempting to make a strong statement about the relationship of the ERL and ERM to actual toxicity in the field.

Mainstem

In the Bay Mainstem, metal concentrations are distributed in a pattern similar to that of silt/clay content. The highest metals concentrations were found, along with the highest silt/clay content, in segment CB3. Mainstem patterns of specific metals and organic contaminants were summarized as follows:

- Organic carbon and organic contaminant concentrations were highest in segment CB2.
- Lead: Follows the general pattern of silt/clay content with the highest concentrations and ranges in segment CB3. All values were below the ERM value of 110 ppm. There is a decrease in concentrations from west to east with similar median values at river mouths.
- Nickel: Highest concentrations in segments CB2 and CB3 with a wider concentration range in segment CB3 than in segment CB2 (note there are different numbers of observations in the two segments). Some values exceed the ERM value of 50 ppm. Concentration ranges were similar across all the river mouths.
- Zinc: Follows the general pattern described for silt and clay with the highest concentrations found in segment CB3. Some values exceeded the ERM value, indicating that a closer look would be worthwhile. Concentrations decreased from west to east. According to published information, zinc levels are naturally high in the Bay.

- Chrysene: Follows the pattern of organic carbon with the highest concentrations in segment CB2. This suggests diffuse sources, and that concentrations occur where natural physical/chemical conditions are most relevant. All values were well below the ERM value of 2800 ppm.
- Total PCBs: Not analyzed for in earlier mainstem samples, but may be representative of chlorinated compounds, which seem to distribute more like metals than PAHs. PCB concentrations at all locations were well below the ERM value of 400 ppb.
- Arsenic: The only substance with a clear pattern of temporal changes in the mainstem. The Baywide median for arsenic was 8.5 ppm. The highest segment median was 13 ppm in the aggregated Western mainstem segment, well below the ERM value of 85 ppm. An apparent increase of arsenic was documented, but it is likely a function of analytical method differences.

Tributaries

Rich Eskin showed a map of Chesapeake Bay tributary segments, explaining that only the Maryland tributaries had metals data. Tributary trends of specific metals and other toxic substances were summarized as follows.

- Chromium: Concentrations were generally below the ERM value. The Sassafras River and some of the Western Shore tributaries (Back River) have elevated concentrations relative to other tributaries, but values are still below the ERM. Low levels were reported in the southern Eastern Shore tributaries.
- Lead: Similar pattern to chromium; elevated concentrations in Back River.
- Zinc: The ERM was exceeded in several locations - Back River, Magothy, Severn and South rivers. Recent estimates of urban runoff reported relatively large zinc loadings, but an anthropogenic enrichment factor has not yet been calculated for this data.
- Nickel: Elevated levels were reported for the Back, Elk, and Northeast rivers.
- Benzo(a)anthracene: Concentrations were generally well below the ERM value. Levels were low in Back River but slightly elevated in the Western Shore tributaries. Low concentrations were reported in the southern Eastern Shore tributaries.

Pesticides were sampled for at 38 stations in Maryland. Carbofuran was found in only one location. Hexachlorobenzene was only found at 6 of the 9 stations in Baltimore Harbor. Curtis Bay and Back Creek were shown to have high concentrations of pesticides in sediments.

In the Baltimore Harbor, the central channel stations generally show the lowest concentrations. Rich Eskin suggested that further investigation of sediment contamination from lead, chromium, nickel, and zinc was warranted by the existing data. Pesticides reported in the Baltimore Harbor sediments were mostly chlorinated compounds.

Sediment data for the Elizabeth River comes from many different programs with different stations often monitoring for different purposes. Though the data has been aggregated into five general geographic regions, final results await further discussions with Virginia. Rich Eskin noted that although concentration ranges spanning almost 6 orders of magnitude were observed, the median concentrations are much less variable. Even in the Southern Branch of the Elizabeth River, which has the highest concentrations, the median concentrations were often right around the ERM value. These findings have significant implications for identification of Chesapeake Bay Regions of Concern, suggesting very high

levels of resolution may be necessary to clearly define "hot spots".

5. UPPER TIDAL POTOMAC RIVER SEDIMENT CONTAMINANT FINDINGS

Dave Velinsky summarized findings from a sediment study of the sections of the Potomac and Anacostia Rivers within Washington D.C. The objectives of this study were 1) to define the extent of chemical contamination in the sediments around selected areas of the District of Columbia; 2) to determine the extent and possible controlling factors of sediment toxicity to the amphipod *Hyalella azteca*; and 3) to elucidate possible source area(s) of organic and inorganic contaminants to sediments in this area.

A total of 54 samples were collected from Potomac River, Anacostia River, Tidal Basin, Washington Ship Channel and Kingman Lake. Direct sampling of 14 major storm and combined sewer outfalls in the Tidal Basin, Washington Ship Channel, and the Anacostia River was carried out as well. In addition, bottom sediment material was collected from inside selected storm and combined sewers that directly discharge into these areas. The outfall and sewer sediment samples were used to indicate source areas for anthropogenic chemicals to river sediments around the District of Columbia. Sediment chemistry data was combined with benthic macro-invertebrate abundance, diversity, and toxicity data to identify areas of biological and chemical impacts.

Geographical and spatial trends for trace metals and organics in sediments reveal several specific areas of concern. High concentrations of lead, cadmium, and zinc, as well as PAHs, PCBs, chlordanes, and DDT (sum of DDT+DDE+DDD) were observed in many areas. Since DDT was banned 20 years ago, its presence in the storm and combined sewer samples is of concern. The highest concentrations were found at sites located close to the Washington Navy Yard in the Anacostia River. The lowest concentrations (dependent on the constituent) were found either in the Washington Ship Channel, near Green Leaf Point, or in one of two Potomac River sites near Hains Point. Trace metals and other organics often exhibited the same geographical trend.

Analysis of the sediment data suggests that numerous storm and combined sewers are a major source of sediment contamination to the Anacostia River. This is especially noted at the station near the Washington Navy Yard. The extreme concentration gradient between the sewer, outfall, and river sediments at this location (and others) indicates urban runoff as a source. Past and present activities at the Washington Navy Yard and possibly the U.S. Botanical Gardens could also contribute to the contamination of the area.

Sediment toxicity testing and macro-invertebrate community analysis results matched with chemical results in the lower Anacostia River stations (i.e., from the Pennsylvania Arc Bridge to the South Capital Street Bridge) which exhibited the most severe degree of biological impairment. Two Kingman Lake stations also exhibited toxicity. Both the Washington Ship Channel and Tidal Basin stations showed no sediment toxicity, moderate benthic community parameters, and levels of sediment contamination below levels present in the Anacostia River. The Potomac River site presented a perplexing situation in that *H. azteca* survival was lowest of any site, while benthic community results were equivocal. Sediment contaminant levels were some of the lowest of any station, however. Sediment toxicity results may be the result of high concentrations of porewater ammonia.

Sediment concentrations of trace metals and specific organics from the 15 biological stations were compared to the proposed EPA sediment quality criteria for metals and selected organics. SEM/AVS

molar ratios at all sites were less than one, indicating that trace metals were not bio-available in the porewaters of the sediments. Measured sediment concentrations did not exceed the proposed sediment quality criteria for dieldrin, endrin, acenapthene, flouranthene, and phenanthrene. Sediment concentrations of total chlordane, normalized to the organic carbon content, exceeded the calculated sediment quality criterion. These preliminary results suggest that chlordane may be contributing to the impairment of the benthic community. However, comparisons of the sediment quality criteria of individual chemicals does not take into account the possible synergistic effects of all organic and inorganic compounds present.

Sediments of the Anacostia River were substantially enriched for lead, cadmium, and zinc, compared to the other trace metals - copper, chromium, and mercury. Concentrations of lead, cadmium, zinc and other trace metals were higher than those found in the mainstem Chesapeake Bay by a factor of 2-4, depending on the metal. Concentrations of all metals were below concentrations found in Baltimore Harbor and the Schuylkill River (Philadelphia, PA). Metals concentrations were higher in the Washington D.C. area than in the Maryland portion of the tidal Potomac River.

All groups of organics had higher concentrations than those reported in the mainstem Bay, but were lower than those found in Baltimore Harbor. On a chemical basis alone, it appears that specific reaches of the Potomac and Anacostia rivers and other tidal systems within the Washington, D.C. area are contaminated with trace metals and organics (PCBs, DDT, PAH, and chlordane). The most severely impacted area is the reach of the Anacostia River just downstream of the Washington Navy Yard. Outfall sediment distribution indicates a diffuse input for total hydrocarbons and PAHs, related to the ubiquitous nature of their sources (i.e. fossil fuel combustion, crankcase oils, etc.), while other contaminants, such as PCBs, have distributions that suggest a point source input to the area sediments through specific outfalls.

6. CHESAPEAKE BAY SEDIMENT TOXICITY FINDINGS

Ray Alden reviewed previous work on contaminated sediments in the Elizabeth River, presented the Sediment Quality Triad, gave an overview of the sediment portion of the Chesapeake Bay Ambient Toxicity Program and presented sediment toxicity issues relevant to future studies.

The Elizabeth River study evaluated responses of amphipods, urchins, and microtox to sediment contamination. Transects were evaluated and inferential relationships were made in the late 1970s and early 1980s. Two groups were studied; one control group and one group which was close to a lethal effects area (i.e. an area known to be > 50% lethal). The results for this group were close to those expected. However, sublethal and chronic effects found further to the south were unexpected. High levels of phenanthrene, anthracene, and napthalene were found in this area. Chrysene and other 5 ring compounds related to the break down of creosote from oil spills and power plant activities were also found. Characteristics of benthic community, i.e. biomass, depth distribution of biomass, species diversity, etc, with relation to salinity were presented in a series of graphs. Ray Alden stated that the Elizabeth river species diversity levels were below what was expected, and concluded that the area is highly impacted.

Ray Alden briefly discussed the Sediment Quality Triad, which is a graphical representation of the comparison of 3 variables - toxicity, chemistry, and in situ effects - to a reference site. The triad is useful in that it displays the interrelation of these variables. However, it does not show cause and effect relationships and has some statistical problems associated with it.

Ray Alden gave an overview of the Chesapeake Bay Ambient Toxicity Program, now in its third year. The objectives of the program are to:

- Develop a survey program to assess ambient toxicity in living resource habitats and other areas of concern;
- Assess the feasibility of ambient toxicity surveys
  - field test water column toxicity tests, sediment toxicity tests and suborganismal response measures
  - determine the relative sensitivity of these tests to ambient contaminant concentrations; and
- Develop quantitative toxicity indices based upon multiple endpoints.

The water column testing was carried out by Lenwood Hall and the suborganismal tests conducted by Jay Gooch.

The sampling sites, which varied over the three years of the study, were selected to provide a range of sites, including sites with known contamination as well as sites expected to be unimpacted. Additional tidal freshwater sites were included in year 2 and *Hyalella azteca* was added. Ray Alden presented a list of all the organisms used for testing in the three years of the study. For the year three study, summary indices are being developed to allow more direct comparison of the battery of test results among sampled systems.

Specific results from all three years of the studies were not presented, however, some general conclusions were made. Ray Alden suggested that some of the results may be biased because some of the areas studied were those of concern, i.e. known problem areas. Different tests were performed at different sites, as well, and the sensitivities of the tests were not always the same. Ray Alden suggested that a battery of tests is needed to determine actual levels of sediment contamination.

In reference to the Sediment Quality Triad, Ray Alden stated that he had developed a technique to put confidence limits on the sediment triad plot, noting that problems can occur because there is often only one sample per site, so confidence of replicated data is needed.

In a brief summary of results of the Ambient Toxicity Testing program, Ray Alden noted that results for the Wye River station were surprising. This was to be a reference site, but sediment effects were observed. The Wye River results showed less toxicity in Year 2 of the study.

Ray Alden stated that sediment toxicity testing is an embryonic field with a great deal of uncertainty in quantification, and that several issues should be determined for future studies in this area. It is important to determine a "clean" standard for reference sediment criteria, i.e. how uncontaminated it should be, as well as a standard for contaminated sites, i.e. "how dirty is dirty?". In future studies, species selection should take into account phylogenic diversity, life-style considerations, and species availability, as well as possible risks involved in transporting species, and the potential for overharvest of resident species. Consideration should also be given to factors that might cause confounding effects, such as particle size, temperature, salinity and the presence of NH_4 and sulfides. Factors affecting bioavailability - total organic carbon, acid volatile sulfates, light, etc. - must be fully factored into any resultant data analysis.

Other quantification factors to consider for future sediment toxicity testing are: experimental

design, uncertainty and confidence, and the need for comparability studies. It is also important to determine how the results of studies are used. Ray Alden suggested results should be viewed in the context of a broader picture, using EMAP and other available data. Ecological risk assessment factors are also important. Determination of goals (what to protect), techniques, and weighting factors (how do you weight toxicity, mortality,) are all important aspects in how the data generated through sediment toxicity tests will be used in contaminated sediment management.

Ray Alden presented a risk assessment process which involves four steps of identification through risk characterization, which then lead to management actions, or intensified directed research. Directed surveys for damage assessment were also discussed. These should include random stratified surveying of representative areas, surveys of suspected areas, critical habitat areas, and areas of specialized management.

Sediment Toxicity in the Maryland Portion of the Bay

Beth McGee presented sediment toxicity data for the Maryland portion of the Bay. She first emphasized that historical data has helped to characterize sediment contamination, showing that the highest levels of contaminants are found in sediments from urban industrial areas - Baltimore Harbor area including the Inner Harbor, Curtis Creek, Bear Creek, etc. - as well as some areas surrounding Washington D.C. Beth McGee also mentioned that benthic community data collected as part of the long term monitoring of Chesapeake Bay yields some estimate of potential biological effects of sediment contamination. However, because other factors influence the condition of benthic communities, and because of the inherent variability of the estuarine system, it is often difficult to interpret benthic data. The recent use of sediment toxicity tests to quantify biological effects of sediment contamination in the Bay region was used to evaluate the question, "Are contaminated sediments causing a biological impact on a Baywide, regional or local scale?".

The following laboratories were acknowledged for their contribution to this presentation: EPA-ERL Narragansett and Newport, EPA EMAP-Near Coastal (Naragansett), Maryland Department of the Environment, and VERSAR. Most of the data were 10 day amphipod sediment toxicity tests with mortality as the endpoint.

This presentation focused on two different spatial scales: 1) the distribution of sediment toxicity on a broad geographical scale, using EMAP data, and 2) local impacts using other data sets from the Patapsco River and Baltimore Harbor. On a broad scale, the goal is to determine how widespread toxicity is in the Chesapeake Bay, and where, if any, are the toxic "hot spots". On the local scale, the goal is to determine the within-system distribution of toxicity.

In evaluating sediment toxicity data, several questions arise:

- how do toxic sites compare?
- can sediment toxicity tests be used to discriminate among sites?
- do we need sediment toxicity tests, i.e., are they providing additional information?

Beth McGee displayed a map depicting the broad distribution of EMAP stations in the Maryland portion of Chesapeake Bay. The acceptable data (as indicated by mean control survival of >90%) summarized for these sites shows significant toxicity (a significant difference from control and >20%

mortality) for 3 stations in the Patapsco River/Baltimore Harbor sites #81, #82, and #134. Several other stations exhibited between 15 and 20% mortality, but did not fall within the EMAP designation for exhibiting acute toxicity. Beth McGee suggested that because EMAP's tests are conservative, these stations - #130 in the Pocomoke River, #88 in the Anacostia, and #63 in the Chesapeake - may also be of concern. As a case in point, she noted the data presented on the Anacostia River (by D. Velinsky) indicated there is a sediment contamination problem in portions of that river. In addition, EMAP toxicity tests measure only acute lethality as an endpoint, very little is known about the potential sublethal effects of sediment contamination in Chesapeake Bay.

Beth McGee next focused on presenting data for the Patapsco River/Baltimore Harbor system.

Bear Creek Study

Historic data in Bear Creek and surrounding Bethlehem Steel indicate sediments in this area are enriched with metals. Hence, this area was chosen by the EPA Environmental Research Laboratory-Narrangansett as area in which to attempt field validation of the AVS/SEM theory for bioavailability of cationic metal. The EPA lab conducted sediment toxicity tests with the amphipod *Amphelisca abdita* and the clam *Mulinia lateralis*.

The Maryland Department of the Environment conducted tests with the estuarine amphipod *Leptocheirus plumulosus* on samples from a subset of the total stations sampled by EPA. Benthic community structure was also evaluated at select sites. Chemical analyses included measurement of trace metal concentrations in sediments and porewater, as well as acid volatile sulfide determination. Data for *Leptocheirus plumulosus* obtained from a VERSAR study conducted in Bear Creek were also presented. Though the sample locations differed slightly from those of the EPA study, these data were included as an illustration of the relative comparability of the test results.

Results and conclusions for the Bear Creek Study:

- At most sites, results of the sediment toxicity tests were comparable (split samples between MDE, EPA as well as VERSAR data). *Mulinia lateralis* was observed to be generally less sensitive than the two amphipod species.
- On a fine scale, sediment toxicity has a patchy, heterogenous distribution. This observation may be important in the interpretation of the problem. In addition, distribution patterns may give clues as to what the sources of toxicity may also be. It is important to note that vertical distribution of toxicity may be important. Whether underlying sediments are "cleaner" or "dirtier" is important if the purpose of the assessment is for dredging, determining remediation options, etc.
- Predictions of bioavailability have not worked well, i.e., SEM/AVS ratios are >1 at some sites with no significant mortality observed. Whereas at other sites, ratios are <1 and significant mortality is observed, indicating that unmeasured organic chemicals may play a role in toxicity. Porewater concentrations of metals were also less than predicted, suggesting that other sediment components, in addition to AVS, are binding metals.
- Inconsistencies exist between sediment toxicity results and benthic community analysis. This suggests that chemical and benthic community data are not supplying all the information needed to accurately assess the biological impact of sediment contamination.

Curtis Creek

The Maryland Department of the Environment has observed consistent, reproducible, acute toxicity in sediments from a site in Curtis Creek. In fact, dilutions of Curtis Creek sediment, created by mixing Curtis Creek sediment with "clean" sediment, have also elicited toxic effects. Other researchers have indicated the utility of using sediment dilutions to evaluate relative toxicity of contaminated sediments. Data from sediment toxicity test on Curtis Creek dilutions conducted by several laboratories (MDE, EPA-Newport, ODU, and VERSAR) were presented to illustrate the extreme toxicity of these sediments.

Chemical concentrations in sediment from the Curtis Creek site were compared to chemical data from Commencement Bay and Elliot Bay in Puget Sound to evaluate relative levels of contamination. Curtis Creek sediments contained concentrations of metals and PAHs comparable to sediments from Puget Sound, an area well known for contaminated sediment problems.

In summary:

- EMAP sediment toxicity data identified some definitive areas of concern in Baltimore Harbor and the Patapsco River, and some "potential" areas of concern - Pocomoke River (possible pesticide problems), Anacostia River, and the mouth of the Patuxent River.
- Sediments from Baltimore Harbor and the Patapsco River exhibited persistent high toxicity, which had a patchy distribution on a small scale.
- Results of the Bear Creek study to field validate SEM/AVS theory of metals bioavailability suggested deviations from the theory's predictions.
- Sediment toxicity tests may be useful in identifying sources and assessing vertical distribution of sediment contamination. Testing sediment solutions may be used to identify and prioritize sites. For these reasons, and because toxicity tests yield information not attainable through sediment chemistry or benthic community analyses, it is recommended that sediment toxicity tests be incorporated into future monitoring efforts.
- More research involving sublethal effects of sediment contamination in Chesapeake Bay is needed. Existing methods for partial life cycle tests with the amphipods *Ampelisca abdita* and *Leptocheirus plumulosus* are currently being refined and standardized by EPA and could be used to estimate chronic toxicity.

Note on EMAP and Bear Creek data: "Although the data described in this article has been funded wholly or in part by the U.S. Environmental Protection Agency it has not been subjected to Agency review, and therefore does not necessarily reflect the views of the Agency and no official endorsement should be inferred."

Aquatic Sediment Quality Guidelines

Harriette Phelps presented a summary of the report entitled "Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario." The report seeks to provide the basis for determining when sediments are clean, what levels of contaminants are acceptable in the short-term and when contamination is severe enough to warrant significant remedial action. It suggests acute sediment bioassays where sediment concentrations exceed Significant Effect Level (SEL) guidelines. SEL is the sediment concentration of a compound that would be detrimental to the majority of benthic species.

Harriette Phelps compared the advantages and shortcomings of current measures of sediment toxicity (sediment background approach, equilibrium partitioning, apparent effects threshold and sediment quality triad) to the two-step screening level concentration approach used by the Ontario Ministry of the Environment. This method is based on co-occurrence in sediments of species and contaminants and does not require a reference site, bioassays, accounting or other environmental factors and it includes the synergistic effects of multiple contaminants. She also presented a case-study and critique of the sediment quality triad approach used in the Netherlands.

7. BAY TOXICS RESEARCH PROGRAM SEDIMENT RELATED FINDINGS

Findings from the sediment related investigations supported under the jointly funded Toxics Subcommittee/NOAA Chesapeake Bay Toxics Research Program were presented. Jeff Cornwell presented findings to date from the ongoing sediment transport flux processes research projects (Appendix A). Linda Schaffner presented findings from the ongoing sediment benthic mixing processes/community effects research projects (Appendix B).

Sediment Transport/Flux Processes

Jeff Cornwell explained that the Chesapeake Bay Toxics Research Program uses an ecosystem approach to looking at toxics. The research emphasis was built on a predecessor program which focused on the effects of low dissolved oxygen on Chesapeake Bay living resources and ecosystem processes. The Chesapeake Bay Environmental Effects Committee decided to keep the ecological processes focus in the initial phases of the toxics research program, but recognized that as the program progresses, more resources will have to be invested in projects dealing with biological effects. The initial goals of the Chesapeake Bay Toxics Research Program were to understand how Chesapeake Bay ecosystem processes influence the transport, fate and effects of toxicants, and to understand the effects that representative toxic substances have upon ecological processes, including trophic dynamics, in the bay.

Jeff Cornwell made several introductory observations. He stated that physical and biogeochemical processes are major controls on the distribution, transformation, and flux of contaminant at the sediment-water interface. Resuspension is also a major source of contaminant particulates in the water column. Redox processes, both chemical and microbial, can have a major impact on contaminant fate. Metal cycling, through mineralization, precipitation as sulfides, and adsorption to oxides, may be strongly affected by redox; organic degradation pathways may be redox-dependent.

Jeff Cornwell briefly reviewed the following ongoing projects:

- Role of plankton in controlling the partitioning and transport of hydrophobic organic contaminants in Chesapeake Bay - Investigators: J.E. Baker, H.R. Harvey and R. Dawson.
- Resuspension and transport of sediment associated toxics in the northern Chesapeake Bay - Investigators: L. Sanford, J Halka, J. Hill.
- Microbial degradation of chlorinated hydrocarbons under alternating redox conditions in Chesapeake Bay. Investigators: D. Capone and J. Baker
- Direct measurements and biogeochemical controls of sediment-water flux of trace metals from estuarine sediments. Investigators: J. Cornwell, D. Burdige, W. Boynton

Major findings of several studies were then presented.

Initial Flux Studies at Mid-Bay Sampling Sites (Sanford et al., Baker er al., Cornwell)

Measurements:

- physical parameters: current velocity, direction, salinity, temperature;
- water/particulate chemistry: suspended sediment, organic carbon, hydrophobic organic compounds (HOCs), metals;
- sediment chemistry: organic carbon, HOCs, metals, pore water solutes, $_{210}Pb$

Results:

- total resuspended mass generally represents less than 1mm of surficial sediment;
- the sedimentation rate is ~ 2100 g/m2/yr;
- burial delay time is ~ 4-17 days;
- small (< 10 um) particles account for the largest fraction of organic carbon, lipids and suspended solids in all seasons;
- lipid distribution among particle size fractions reflects the biological contribution which varies seasonally;
- partitioning of HOCs into particles does not correlate well with organic carbon content;
- neutral lipids may provide better indices of HOC partitioning into particles than either organic carbon or total lipids alone.

Sediment Biogeochemical Transformation -- Organics (Capone, Baker)

The objectives of this study were to characterize the chlorinated hydrocarbon spectra in surficial sediments at one site in the mid-Bay and a heavily contaminated tributary site, and to examine the effect of increasing periods of anoxia on the subsequent aerobic degradation and mineralization of several model chlorinated hydrocarbons in batch sediment slurries.

Measurements:

- chlorinated hydrocarbon concentrations in surficial sediment;
- degradation rates under variable redox conditions.

Results:

- direct evidence that anoxic incubation can enhance degradation under subsequent oxic conditions;
- sulfate reduction appears to be a necessary process for 2,4 dichlorophenol degradation;
- sediments stored for 3 months exhibit complete disappearance of 2,4 DCP in aged, sulfate depleted sediments in less than one month;
- acetate enhanced degradation rates.

Sediment Biogeochemical Transformation -- Metals (Cornwell, Burdige, Boynton)

Measurements:

- rates of microbial/chemical transformation of sulfate, manganese, iron, pore water and

not inert; they can be returned to the water column and the ecosystem by a variety of processes including direct flux and trophic transfer.

- Selected results from the work of Riedel et al. with trace metals arsenic and copper (also investigated effects of various oxygen conditions).

  - Copper flux was highest from oxic sediments and sediments with organisms.

  - Arsenic flux was high from sediments with anoxic overlying water column, slight with oxic water and organisms and zero or negative in oxic sediment without organisms

  - Effects are trace metal and organism specific.

  - Flux rates, averaged annually over the depth of the water column and the area of the bay, are approximately enough to supply all the metals found in the water column; therefore, fluxes likely to be important factor in trace element concentrations in Chesapeake Bay.

- Preliminary Findings from the work of Schaffner and Dickhut with organic contaminants PAHs and PCBs.

  - Macrofauna enhance loss of compounds from the sediment; effect is greatest for compounds with low K_{ow} (relatively less hydrophobic).

  - Possible mechanisms include bioaccumulation and transformation and bioturbation and biosuspension which may directly remove sediments or alter the geochemical environment in a way that enhances desorption processes.

  - Biosuspension is a potentially important process - resuspension by polychaete *Loimia medusa* (common in lower bay) is of the same order of magnitude as flux reported for sediment trap studies.

  - Resuspended material is depleted in the PCB 2-CB, the more hydrophilic compound, but not benzo(a)pyrene, the more hydrophobic compound.

  - Organisms also enhance burial, e.g. benzo(a)pyrene profiles.

  - This rapid burial is associated with biogenic activity; at depth within the sediment column burrow walls contain high concentrations of compounds while ambient sediments contain no compounds (following a pulsed tracer).

  - Bioaccumulation and biotransformation are also likely to be of importance.

  - Organisms exhibit rapid uptake (via ingestion, adsorption, bioaccumulation) of compounds deposited at the sediment-water interface --> this will increase trophic transfer.

Major findings of this research to date are as follows:

- Under 'average' conditions, bioturbation dominates sediment reworking throughout a significant portion of Chesapeake Bay subtidal region - above the pycnocline in upper bay, most of lower bay, high mesohaline and polyhaline tributaries. This means that benthic organisms will have major impacts on the transport, flux and burial of contaminants.
- Benthic organisms influence the cycling and fate of both metals and organic contaminants. Especially important are direct and indirect processes that enhance flux, thereby increasing contaminant residence time within the Chesapeake Bay ecosystem. Direct flux is enhanced via activities such as bioturbation and burrow irrigation. Flux is enhanced indirectly via trophic transfer.
- Mechanisms governing bioaccumulation and biotransformation of organic contaminants are poorly understood, but are presently being investigated. Furthermore, bioaccumulation and biotransformation are highly variable among benthic organisms. 'Model' organisms used in laboratory studies are unlikely to present a representative view of benthic communities which include numerous species comprising various phyla.
- Contaminant exposure increases disease susceptibility in the eastern oyster *Crassostrea virginica*.

Linda Schaffner explained the objectives of several individual projects and described the major findings to date.

- Field studies of benthic boundary layers sediment resuspension processes and bioturbation in Chesapeake Bay (e.g. Wright et al., Sanford et al.) demonstrate that:

  - 'Average' physical conditions result in relatively little sediment resuspension, but the resulting flux can be many times higher than inputs of 'new' material.

  - For lower Bay, critical shear stress for sediment entrainment is only exceeded when strong currents interact with moderate waves; currents alone do not resuspend sediments.

  - Critical shear stress is reduced in summer by biological activity.

  - For most of lower bay and many areas of upper bay mainstem regions, bed roughness is predominantly biological and bioturbation dominates sediment mixing processes on long and short time scales.

  - In other areas of the estuary (low salinity regions of tributaries, areas affected by anoxia or high levels of contaminants) the relative importance of bioturbation is less well understood. Available data records often lack evidence of bioturbation, but this does not preclude potential importance of bioturbation on shorter time scales (which may be erased by erosional events) or the potential importance of things like burrow irrigation that alter the biogeochemistry of sediments.

- Laboratory studies (e.g. Riedel et al., Schaffner and Dickhut) are being used to evaluate macrofauna effects on toxicant fate and transport.

  - An important finding of both series of studies is that contaminants in the sediments are

not inert; they can be returned to the water column and the ecosystem by a variety of processes including direct flux and trophic transfer.

- Selected results from the work of Riedel et al. with trace metals arsenic and copper (also investigated effects of various oxygen conditions).

  - Copper flux was highest from oxic sediments and sediments with organisms.

  - Arsenic flux was high from sediments with anoxic overlying water column, slight with oxic water and organisms and zero or negative in oxic sediment without organisms

  - Effects are trace metal and organism specific.

  - Flux rates, averaged annually over the depth of the water column and the area of the bay, are approximately enough to supply all the metals found in the water column; therefore, fluxes likely to be important factor in trace element concentrations in Chesapeake Bay.

- Preliminary Findings from the work of Schaffner and Dickhut with organic contaminants PAHs and PCBs.

  - Macrofauna enhance loss of compounds from the sediment; effect is greatest for compounds with low K_{ow} (relatively less hydrophobic).

  - Possible mechanisms include bioaccumulation and transformation and bioturbation and biosuspension which may directly remove sediments or alter the geochemical environment in a way that enhances desorption processes.

  - Biosuspension is a potentially important process - resuspension by polychaete *Loimia medusa* (common in lower bay) is of the same order of magnitude as flux reported for sediment trap studies.

  - Resuspended material is depleted in the PCB 2-CB, the more hydrophilic compound, but not benzo(a)pyrene, the more hydrophobic compound.

  - Organisms also enhance burial, e.g. benzo(a)pyrene profiles.

  - This rapid burial is associated with biogenic activity; at depth within the sediment column burrow walls contain high concentrations of compounds while ambient sediments contain no compounds (following a pulsed tracer).

  - Bioaccumulation and biotransformation are also likely to be of importance.

  - Organisms exhibit rapid uptake (via ingestion, adsorption, bioaccumulation) of compounds deposited at the sediment-water interface --> this will increase trophic transfer.

- Biotransformation of PAHs is being observed in numerous taxa; biotransformation of a simple PCB (2-CB, 1 chlorine) also being observed, especially in polychaetes

- Experiments to evaluate the mechanisms governing bioaccumulation (e.g. equilibrium partitioning theory vs. sorption-desorption processes) are planned for 1993.

Mechanisms governing uptake for a benthic suspension feeder, the eastern oyster, *Crassostrea virginica*, are being investigated by Weston et al. through work in progress.

Other research focuses on effects on organisms. For example, Chu and Hale are examining relationships between disease susceptibility and exposure to environmental contaminants for the oyster *Crassostrea virginica*. They are finding a dose-related response where higher levels of contaminants lead to increased rates of infection by *Perkinsus marinus*. Effects were also observed at toxicant concentrations an order of magnitude lower than acutely toxic concentrations.

8. DISCUSSION

Rich Eskin led a discussion of the results presented in the forum in an effort to reach a consensus on findings to be reported back to the Toxics Subcommittee for their consideration during the ongoing reevaluation of the Basinwide Toxics Reduction Strategy. The discussion followed the format of the questions outlined in the introduction to the forum.

- **From the critical review of available data, have we defined/can we define the relative magnitude and extent of contaminated sediments within Chesapeake Bay?**

Rich Eskin began by saying that data is available to determine what areas need to be looked at more closely. However, contradictory responses are obtained by different methods. The question arose as to whether we have enough data to determine 3 categories: hot spots, medium intensity spots, and areas that need further identification.

There was general consensus on three "hot spots" - Baltimore Harbor, Elizabeth River, and the Anacostia River. There was also general agreement that there is not a ubiquitous contaminated sediment problem in the Bay. Joel Baker noted, however, that the unexpected case of sediment contamination in the Wye River suggests that problems do exist in areas other than the accepted "hot spots".

- **Does this definition of the magnitude and extent of contaminated sediments within the Bay give us reason to believe this identified (or potential) toxics issue is causing or could cause and impact (e.g. bioaccumulation, toxicity) on Chesapeake Bay systems, on either a Baywide, regional or local scale?**

Determination of scale is another important issue for management and research decisions. The scale of toxics problems will be much different than for the Bay's eutrophication related problems. The spatial scale of resolution is extremely important from a management perspective, i.e., how big does it need to be before it is of concern? Ray Alden suggested that management decisions should be made on

a segment by segment basis. Variability of contamination levels even within highly impacted areas must be addressed.

Another management concern is whether or not there is an overall benefit in reducing contaminated sediments in a given contaminated site. The amount of cleanup that is actually beneficial may vary from one site to the next.

There was general agreement among forum participants that management decisions must start at the broad scale. The presence of different degrees of contamination was reiterated and the question was raised whether there is enough data to characterize sites with varying degrees of sediment contamination appropriately. It was suggested that an effective means of determining where to do future sampling is to overlay grain size content data and critical habitat areas over existing sediment contaminant data. Overlaps of where there are contaminated sediments in habitat areas is where further sampling is required.

- **Comparison of the magnitude and extent of contaminated sediments within Chesapeake bay with other coastal systems (e.g. Puget Sound) or large water bodies (e.g. Great lakes).**

  Forum participants agreed that this comparison was not worthwhile.

- **What direction should the Toxics Subcommittee recommend the Chesapeake Bay Program agencies take with regards to addressing contaminated sediments? Denoting Regions of Concern (with contaminated sediments as a parameter for delineation), etc?**

There is a need to incorporate biological effects, including benthic diversity, into the chemical data in determining which areas are impacted. Human health issues also must be examined and a thorough evaluation of bioaccumulation should be done. Joel Baker suggested that another possible way to look at sediment contamination is through the water column into fish tissue and other food chain contamination and resultant human health effects.

The suggestion was made that enhanced monitoring for toxics in the tributaries is required (e.g. collection of metals data from the Virginia rivers). Others expressed that this is unnecessary because effects on the mainstem would not be elucidated in this way. However, it's possible that effects from tributary contamination are not seen in the mainstem because contaminants are being absorbed by the sediments and therefore being retained with the tributary. Rich Eskin suggested that tributary health in itself is important. There may be numerous small tributaries that have not yet been investigated. The effect to living resources is unknown.

The idea emerged that there is a need to focus research and sampling, because of financial and resource limitations, in areas where a known problem exists. This must be balanced with the need to consider areas of critical habitat. Some areas already have biomonitoring stations in place. Direct sampling for localized effects through directed research should target critical habitat areas that are known depositional areas.

There was a consensus among the forum participants that it is too early to recommend to the jurisdictions general/specific source reduction or remediation actions for contaminated sediments. Undertaking of a structured set of applied and basic studies in specific Regions of Concern to determine the source fate and effects of sedimentary metals and organics follow directly after the identification of

Chesapeake Bay Regions of Concern. Other directions suggested include the collection and synthesis of existing data with an in-depth analysis of current status. Basic research to evaluate recovery times, and formation of predictive models were also suggested.

Appendix A

Ongoing Studies
Sediment Transport/Flux Processes

R/CBT-8 Investigators: J.E. Baker, H.R. Harvey and R. Dawson

Project Title: Role of plankton in controlling the partitioning and transport of hydrophobic organic contaminants in Chesapeake Bay

Objectives: Determine the concentration and distribution of hydrophobic organic contaminants in suricial sediments, sediment traps and 4 size fractions of suspended particles

R/CBT-9 Invesigators: Larry Sanford, Jeff Halka and Jim Hill

Project Title: Resuspension and transport of sediment associated toxics in the northern Chesapeake Bay

Objectives: 1) to investigate the resuspension and transport of fine sediments in the northern Chesapeake Bay, characterizing temporal and spatial variability in resuspension processes, 2) to invesigate the influence of resuspension on the time varying flux of toxics across the sediment-water interface, and to examine how resuspension affects partitioning of toxics between continuously suspended particulates, bottom sediments and dissolution and 3) to relate resuspension and transport of sediment associated toxices to mor easily measurable or predictable sediment and physical forcing characteristics.

R/CBT-11 Investigators: Doug Capone and Joel Baker

Project Title: Microbial degradation of chlorinated hydorcarbons under alternating redox conditions in Chesapeake Bay

Objectives: 1) to characterize the chlorinated hydrocarbon spectra in surficial sediments at one site in the mid-Bay and a heavily contaminated tributary site and 2) examine the effect of increasing periods of anoxia on the subsequent aerobic degradation and mineralization of several model chlorinated hydrocarbons in batch sediment slurries.

R/CBT-12 Investigators: Jeff Cornwell, David Burdige and Walter Boynton

Project Title: Direct measurements and biogeochemical controls of sediment-water flux of trace metals from estuarine sediments

Objectives: To determine 1) direct sediment-water exchange of dissolved trace elements using box fluxes, 2) porewater and solid phase profiles of trace elements, organic carbon, Mn, Fe, S and 3) measure rates of Mn, Fe and S reduction, Soxideation and trace element production using radiotracers and incubation techniques.

Appendix B

Ongoing Studies on Benthic Community Effects

R/CBT-3 Investigator: D. P. Swift

Project Title: Particle-reactive pollutants in Southern Chesapeake Bay: accumulation, resuspension and flux into the bottom

Objectives: to develop computational schemes that will allow estimation of the potential flux of particle-reactive pollutants into the shallow seabed, based on the analysis of hydraulic climate, and on measures of biological activity

R/CBT-4 Investigators: L. D. Wright, J. D. Boon, J. P.-Y. Maa and L. C. Schaffner

Project Title: Dynamics of sediment resuspension: bay-stem plains of lower Chesapeake Bay

Objectives: to improve the ability to model the resuspension of bayfloor sediments by: (a) determining the appropriate, time-varying roughness lengths; (b) determining the corresponding values of the resuspension coefficients; (c) establishing the appropriateness of existing models to the Chesapeake Bay and determining the relative contributions of physical as opposed to biological processes in resuspending sediments

R/CBT-5 Investigators: F.-L. Chu and R. Hale

Project Title: Relationship of pollutants to the onset of disease in the Eastern oyster, *Crassostrea virginica*

Objectives: to examine the influence of an environmentally relevant complex mixture of pollutants on the onset of the disease *Perkinsus marinus* in the eastern oyster, *Crassostrea virginica*

R/CBT-7 Investigators: G. Riedel, J. G. Sanders, R. W. Osman and C. C. Gilmour

Project Title: The role of benthic infauna and fluctuating oxygen concentrations in the flux of toxic trace elements from Chesapeake Bay sediments

Objectives: to understand the processes by which trace elements are transported into and out of sediments, how benthic organisms or activities regulate the transport of such elements between the sediments and the remainder of the ecosystem, and how these processes are altered by periodic changes in the oxygen concentrations of bottom waters

R/CBT-15 Investigators: L. C. Schaffner and R. M. Dickhut

Project Title: Role of benthic communities in sediment-associated toxic organic chemical fate and transport in lower Chesapeake Bay

Objectives: to identify and quantify the role of macrobenthic organisms in sediment-associated organic contaminant (PAH, PCB) transport and fate, including seasonal variation; to evaluate the rates of organic pollutant sorption/desorption and equilibrium distribution on Chesapeake Bay sediment and relate these physical-chemical properties to the uptake and bioaccumulation of organic contaminants

R/CBT-16 Investigators: D. P. Weston, D. L. Penry, R. I. E. Newell and J. Baker

Project Title: Uptake of dissolved and particle-associated toxicants by the eastern oyster

Objectives: to determine how the partitioning of toxic substances among dissolved and particulate phases (including both organic and inorganic particulate matter) affects bioaccumulation by a benthic suspension feeder, and how quantification of this phase-dependent bioavailability could be applied in environmental risk assessment

ROSTER OF ATENDEES
CONTAMINATED SEDIMENT CRITICAL ISSUE FORUM
December 10, 1992
Chesapeake Bay Program Office
Annapolis, Maryland

PARTICIPANT	AFFILIATION
Richard Eskin (Co-chair)	Maryland Department of the Environment
David Velinsky (Co-chair)	Interstate Commission for the Potomac River Basin
Ray Alden	Old Dominion University Applied Marine Research Laboratory
Tom Armitage	U.S. EPA Office of Science and Technology
Beverly Baker	U.S. EPA Office of Science and Technology
Joel Baker	University of MD, Chesapeake Biological Lab
Rich Batiuk	U.S. EPA Chesapeake Bay Program Office
Dean Baudler	Computer Science Corporation/CBPO
Jeffrey Cornwell	Univ. of Maryland/Horn Point Environmental Lab
Cece Donovan	Univ. of Maryland/Eastern Shore
Dan Fisher	Univ. of Maryland/Wye
Bob Foley	U.S. Fish and Wildlife Service, Annapolis
Dana Frye	Chesapeake Research Consortium/CBPO
Mary Jo Garreis	Maryland Department of the Environment
Ian Hartwell	Maryland Department of Natural Resources
Bob Huggett	Virginia Institute of Marine Sciences
Clay Jones	Chesapeake Bay Commission
John Kennedy	Virginia Water Control Board/CBO
Edward Krueger	Potomac Electric Power Company
Robin Laird	U.S. Corps of Engineers, Baltimore District
Beth McGee	U.S. EPA Office of Watershed, Oceans and Wetlands
Deirdre Murphy	Maryland Department of the Environment
Tom O'Connor	NOAA National Status and Trends Program
Harriette Phelps	University of the District of Columbia
Fred Pinkney	Versar, Inc.
Chuck Prorok	Computer Science Corporation/CBPO
Ted Ringger	Citizens Advisory Commission
Jackie Savitz	Chesapeake Bay Foundation
Linda Schaffner	Virginia Institute of Marine Sciences
Lydia Schlosser	USDA Soil Conservation Service
Debra Trent	Virginia Water Control Board
Allyson Ugarte	U.S EPA OSW PSPD
Mike Unger	Virginia Institute of Marine Sciences
Nathalie Valette-Silver	NOAA National Status and Trends Program
Elizabeth Watkins	Chesapeake Research Consortium
Durwood Willis	Virginia Water Control Board