Reference Sediment Approach for Determining Sediment Contamination

Norman I. Rubinstein
U.S. Environmental Protection Agency, Office of Research and Development
Atlantic Ecology Division, Narragansett, Rhode Island

One of the more contentious and highly publicized regulatory programs capturing headlines today is the dredging and dredged material disposal program, which is jointly administered by the U.S. Army Corps of Engineers (USACE), the U.S. Environmental Protection Agency (EPA) and, in inland waters, the respective state and local authorities. Within this regulatory program, one of the more controversial issues is the identification and use of reference sediments to facilitate the permitting process for dredged material disposal.

The application of a reference sediment approach to identify sediment contamination in dredged materials was developed more than twenty years ago for the ocean dumping program. In this discussion, which reflects my personal views and should not be construed as Agency policy, I will review the statutory basis for the dredged material program, the rationale used to develop this reference-based regulatory approach, and the operational definition of reference sediment as described in the current testing manual. I will also identify how the reference approach is applied today, how it can be improved, and what future research is needed to support the program.

Program Statutes

Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) stipulates that all operations involving the transportation and dumping of dredged material into ocean waters must be evaluated to determine the potential environmental impacts of these activities. Similar legislation in Section 404 of the Clean Water Act (CWA) addresses dredging and disposal operations in inland waters. There is a pending rule change that will make program operations and use of reference sediments consistent for both ocean and inland waters. This discussion, however, will focus on the existing requirements in the ocean dumping regulations.

The Green Book

The testing manual for Section 103 of the MPRSA is commonly referred to as the Green Book (USEPA/USACE, 1991). It was first developed in 1977 and later revised in 1991 by a joint USEPA/USACE technical committee. The Green Book provides specific guidance for conducting the evaluative protocols used to assess the suitability of dredged materials for open water disposal. It also defines test materials, reference sediments, and control treatments, and specifies details on test methodologies and provides guidance for the interpretation of data generated by these tests. Much of the remaining discussion will be based on material from this manual.

Reference Sediment Approach

In 1976 the ocean disposal regulatory program adopted the reference sediment comparison approach because at that time it was considered the most direct and pragmatic way to satisfy the requirements of the MPRSA. The statutory language of the MPRSA prohibits dumping of dredged materials containing certain constituents as other than trace contaminants unless they are "rapidly rendered harmless." This regulatory language comes directly from the London Convention which represents international agreements on ocean disposal activities. The reference comparison approach provides a mechanism that allows regulators to make decisions that take into account existing background or baseline conditions in the vicinity of the disposal site as defined by the specific test endpoints selected. The rationale as originally applied viewed dredging and disposal activities not as remediation activities aimed specifically at improving existing condition, but as activities that at a minimum must be conducted in a manner that would not further degrade environmental conditions at the disposal site.

Evaluation of benthic impacts for the dredged material program employs sediment toxicity tests and bioaccumulation tests (Green Book). The benthic sediment toxicity tests consist of 10-day whole sediment exposures conducted with appropriately sensitive species and focuses on mortality as the test endpoint. The standard bioaccumulation test involves a 28-day exposure with tissue residue contaminant levels in selected biota as the test endpoint.

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The reference sediment is the key to making regulatory decisions concerning dredged material disposal (Figure 1). Results from benthic toxicity and bioaccumulation tests using representative biota and reference sediments are compared to results from tests using dredged sediments (test material). These comparisons serve as the basis for determining the potential for adverse ecological impacts resulting from dredged material disposal at the environs of the disposal site.

Initiating the Dredging Process

The dredging process begins with identifying the need for dredging a navigation channel. The decision on whether or not to dredge is based primarily on economic and societal issues. Navigation channels must be maintained to support marine transportation, which is the primary mode for global trade, currently estimated at about three trillion dollars annually. The management of dredged material, however, is an environmental issue that is further defined by applying the federal standard which stipulates that disposal occur according to the least cost option that is environmentally appropriate. Once the need to dredge is determined, a disposal site is identified (USEPA, 1990).

The next step in the process is to identify and collect appropriate reference sediment. There are two approaches for identifying the reference material. One approach is to physically locate a reference site, define its location and boundaries, and collect sediments from the site. The other approach, referred to as the reference area approach, involves collecting sediment samples using a grid overlay which provides a composite of sediments representative of the disposal site. The reference material represents the existing benthic environmental conditions in the vicinity of the disposal site. The reference material must satisfy the definition in the Green Book, particularly with respect to three critical requirements (Figure 2). Reference sediment should be: (1) substantially free of contaminants; (2) as similar as possible to the grain size of the sediment in the dredged materials and at the disposal site; and (3) reflective of conditions that would exist at the disposal site if no dredged material disposal had taken place and that represent all other influences on sediments in the area. The test material (dredged material) is then collected in a manner representative of the sediments from the reach and depth of the project area to be dredged. Finally a control sediment is identified which is free of contaminants and known to satisfy the physical requirements (i.e. grain size) of the test organism. This material serves as the laboratory control treatment.

Program Testing

As stated above, testing consists of conducting benthic toxicity and bioaccumulation tests on the reference material and the test dredged material with appropriate laboratory controls and comparing the results of each test. Interpretation of the benthic toxicity test data is fairly straightforward. Dredged material is predicted to be acutely toxic to benthic organisms when mean test organism mortality is statistically greater than the reference sediment and exceeds mortality in the reference sediment by at least 10 percent. Statistical differences between test and reference treatments can be greater than 10 percent depending on the inherent variability measured in specific test species (e.g., a 20 percent value for mortality can be used for amphipods).

Interpretation of the benthic bioaccumulation test results is more complicated. Comparisons between the test material and the reference treatments do not provide pass/fail criteria, but rather serve as a screen for a more comprehensive analysis. Results are compared initially to determine whether there are statistically significant differences in contaminant residue levels between the test treatments and the reference treatment. This comparison indicates that contaminants are present in greater than trace quantities with the potential for bioaccumulation and possible trophic transfer. A more comprehensive analysis involves comparisons of tissue residue levels to FDA action levels and consideration of the toxicological properties of the contaminants of concern. If tissue concentrations of one or more contaminants of concern are statistically greater than the FDA action levels, then the test dredged material is predicted to result in benthic bioaccumulation of contaminants. If tissue concentrations are either statistically less than FDA action levels or there are no FDA action levels for the contaminants of concern, the information is considered insufficient to reach a conclusion about the potential for bioaccumulation. In these cases further evaluation, including assessment of additional factors such as the magnitude of bioaccumulation relative to biota indigenous to the disposal site, may be necessary to address the potential for biomagnification and trophic transfer and associated health risks.

The test endpoints (percent mortality and level of contaminant bioaccumulation), as measured in laboratory tests with reference sediment, serve as de facto standards in making regulatory decisions regarding the disposal of dredged material. Obviously, the selection of appropriate reference sediment is of paramount importance if the goals of environmental protection are to be realized.

Reference Site Selection

Current practice in selecting a reference site inevitably requires some degree of compromise to meet the somewhat ambiguous requirements of a reference material (i.e., “substantially free” of contaminants, yet “as similar as possible” to the dredged material and disposal site sediments, and reflective of conditions “had no disposal occurred”). In some areas of the country, groups responsible for dredging and dredged material management are exploring ways to insure consistency and suitability of reference materials selected for dredged material evaluation. This is a function, in part, of the open process employed by the USACE and USEPA to solicit and promote involvement of the states, the local communities,

and stakeholders in establishing what they believe represents environmentally appropriate and acceptable reference material for their localities.

A review of data generated by benthic toxicity and bioaccumulation tests in reference sediments from major dredging projects in New York, Boston, San Francisco, and Puget Sound (personal communication with regional ocean disposal coordinators) indicate that the reference sediments employed in these areas reasonably reflect baseline conditions characteristic of minimally impacted environments Amphipod survival in the 10-day acute toxicity tests averaged around 90 percent in the first three areas (Figure 3). Survival was slightly lower in Puget Sound where a more regionally integrated approach is applied. Tissue residue data from bioaccumulation tests conducted on reference material in all four areas using the polychaete *Nereis virens* and the clam *Macoma nasuta* for polychlorinated biphenyls (PCBs), cadmium, and mercury are shown in Figure 4. PCB tissue concentrations measured 20 to 30 ppb, and mercury and cadmium tissue concentrations measured less than 0.05 ppm on a wet weight basis. These concentrations also approximate current background levels typically measured in minimally impacted aquatic systems (USEPA, 1997). These data support the contention that selection of reference sediments in these major U.S. ports are serving their intended purpose of providing appropriate levels of environmental protection for the dredged material disposal program. However, given the subjectivity inherent in the reference sediment selection process, I believe establishment of national criteria for identification of appropriate reference material would further promote greater consistency in regulatory decision making, and perhaps enhance the margin of environmental protection provided by the current regulatory protocol.

Future Needs

Criteria which define the minimum requirements for reference material selection that will maintain environmental integrity and sustainability at the environs of the disposal site should be developed as additional guidance for the dredged material evaluation process. An example of where this is already happening is Puget Sound where regulators have developed an extensive database that accurately represents background conditions. This database provides the basis for selecting reference materials and establishing statistically based criteria used for dredged material evaluation. Although development of such databases is expensive and time consuming, this approach could serve as a model for insuring appropriate reference standards are employed for dredged material evaluation.

Additional research needs include improving our ability to predict community, population and ecosystem level impacts from existing effects test endpoints (i.e., acute toxicity), and development of tissue residue-effects linkages for contaminants of concern (Figure 5). What does a whole-body residue concentration mean in terms of the health of the organism, its ability to reproduce, and the propensity for a contaminant to biomagnify? Sufficient data to answer these questions currently do not exist. Predictive models that elucidate residue effects linkages along with the data to validate these modeling efforts should be developed. Efforts to develop tissue residue databases must also continue to ensure effective interpretation of bioaccumulation data.

References

USEPA. 1990. Site designation, monitoring, and management guidance for ocean disposal of dredged material (working draft). U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington, DC.

USEPA. 1997. *The incidence and severity of sediment contamination in surface waters of the United States, Volume 1: National sediment quality survey.* EPA 823-R-97-006. U.S. Environmental Protection Agency, Office of Science and Technology, Washington, DC.

USEPA/USACE. 1991. *Evaluation of dredged material proposed for ocean disposal—Testing manual.* EPA-503/8-91/001. U.S. Environmental Protection Agency, Office of Marine and Estuarine Protection, Washington, DC.

Figure 1.

- Potential adverse impacts are determined on the basis of comparison of test endpoints (benthic toxicity and bioaccumulation) between test and reference treatments

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Figure 2.

- *Substantially free* of contaminants
- *As similar as possible* to the grain size of the dredged material and sediment at the disposal site
- *Reflects conditions at the disposal site that would exist had no dredged material disposal taken place; reflects all other influence on sediments in the area*

Figure 3.

Amphipod Survival in Reference Sediments from Major U.S. Ports

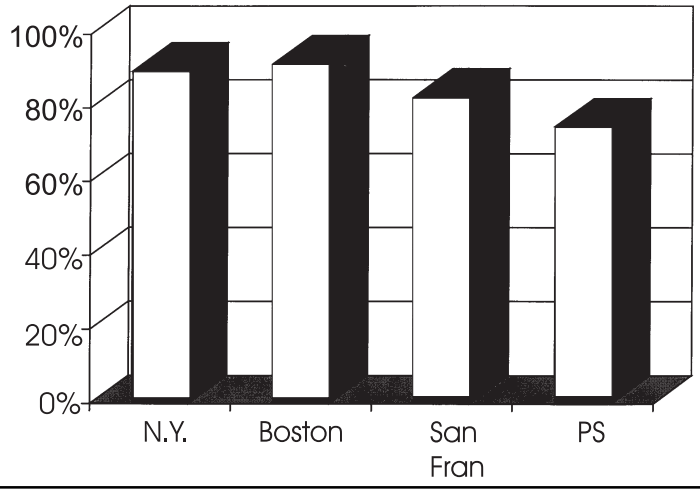

Figure 4.

Bioaccumulation in Reference Sediment (mg/kg wet wt.)

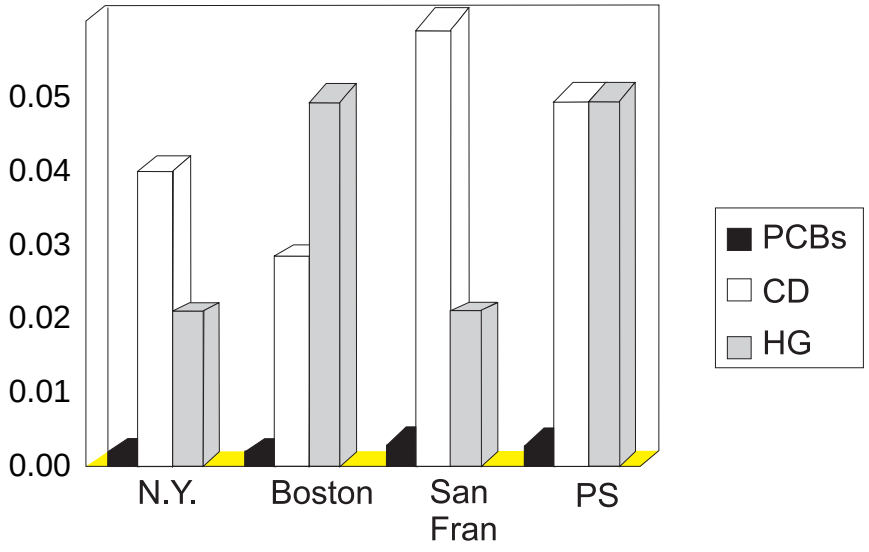

Figure 5.

Reference Approach Suggested Improvements

- Establish minimum criteria for reference site selection that insures environmental integrity and sustainability are preserved (i.e., background database approach used in Puget Sound)

- Develop extrapolation models for single species toxicity endpoints that provide meaningful ecological interpretation at the community and population levels

- Elucidate residue-effects relationships to provide meaningful interpretation of bioaccumulation data.

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