Report on Ocean Dumping R and D Pacific Region Department of Fisheries and Oceans 1985-1986

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DISCLAIMER

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RESUME

Woods, S.M. (ed.). 1987. Report on Ocean Dumping R and D Pacific Region. Department of Fisheries and Oceans, 1985-86. Can. Contract. Rep. Hydrogr. Ocean Sci. 27. 39p.

La recherche sur l'immersion de déchets en mer menée dans la région pacifique en 1985 et 1986 a été examinée au cours d'un atelier de travail tenu le 5 décembre 1986 à l'Institut des sciences de la mer; le compte rendu en est publié sous forme de longs résumés. Les études financées par le RODAC présentées au cours de l'atelier comprennent l'évaluation de la faisabilité de tests de toxicité des sédiments qui soient adéquats pour la révision de l'application de la Loi sur l'immersion de déchets en mer (LIDM), la révision et l'analyse de données environnementales historiques obtenues au site de déversement de Point Grey, une étude des documents publiés sur l'échantillonnage et le sous-échantillonnage représentatifs des sédiments, et la mise au point et l'essai d'une plate-forme expérimentale autonome (le Benthic Lander). L'étude visant à examiner et à évaluer les procédures de vérifications biologiques pour l'évaluation des incidences toxiques de produits chimiques libérés de matériau de dragage immergé en mer a révélé que, malgré la nécessité d'autres données, la vérification biologique est possible et plusieurs tests appropriés peuvent être utilisés immédiatement en laboratoire et sur le terrain. L'étude du site de déversement de Point Grey a révélé d'importants problèmes dans l'analyse et l'interprétation des tendances spatiales et temporelles des paramètres de contrôle environnemental établis pour ce site; plusieurs recommandations ont été offertes afin d'assurer la création d'une base de données fiables et compatibles pour les méthodes d'évaluation future. L'examen de documents publiés sur l'échantillonnage et le sous-échantillonnage représentatifs de sédiments a souligné le besoin d'autres données sur la distribution du cadmium et du mercure dans les sédiments marins à des sites de dragage caractéristiques; on a fait des recommandations afin de pallier à ce manque de données. Quoique les essais avec le Benthic Lander ne soient pas terminés, les résultats initiaux sont assez encourageants. Dans une présentation sur le triade des facteurs de qualité des sédiments, on a indiqué que cette approche peut être utilisée pour élaborer des critères de qualité des sédiments, critères jugés nécessaires à la protection de la vie aquatique car les sédiments marins absorbent les produits chimiques toxiques et rémanents jusqu'à des teneurs plusieurs fois supérieures aux concentrations de la colonne d'eau. Une révision sommaire du programme de recherche relevant de la LIDM a permis de dégager les priorités de recherche qui devront être observées afin de réaliser, à court terme, la clarification et la mise à jour des besoins en données et des normes liés à ladite loi. A long terme, la recherche vise une meilleure compréhension des relations de cause à effet liées à l'immersion de déchets en mer.

Mots-clés: immersion de déchets en mer, incidence environnementale.

ABSTRACT

Woods, S.M. (ed.). 1987. Report on Ocean Dumping R and D Pacific Region. Department of Fisheries and Oceans, 1985-86. Can. Contract. Rep. Hydrogr. Ocean Sci. 27. 39p.

Ocean dumping research conducted in the Pacific Region during 1985-1986 was reviewed at a workshop held on 5 December 1986 at the Institute of Ocean Sciences; the proceedings have been summarized in extended abstract form for publication. RODAC-funded studies presented at the workshop include feasibility assessment of sediment toxicity tests suitable for ODCA application review, review and analysis of historical environmental data from the Point Grey ocean dumpsite, a literature review of representative sediment sampling and sub-sampling, and development and testing of a free-vehicle experimental platform (the Benthic Lander). The study to review and evaluate biological testing procedures for assessing toxic effects of chemical releases from marine dredge-spoil disposal indicated that, although additional information requirements exist, biological testing is feasible and several specific tests can be implemented immediately for field and laboratory use. The Point Grey review revealed extensive difficulties in both the analysis and interpretation of spatial and temporal trends in the environmental monitoring parameters established for the dumpsite; several recommendations were offered to ensure that a reliable compatible data base is created for future evaluation procedures. The literature review of representative sediment sampling and subsampling indicated that more information is required on the distribution of cadmium and mercury in marine sediments from typical dredgesites; recommendations were made to enable these data gaps to be filled. Although experimentation with the Benthic Lander is still underway, initial results have been relatively successful. In a presentation on the Sediment Quality Triad, it was indicated that this approach can be used to develop sediment quality criteria; criteria deemed necessary to protect aquatic life since aquatic sediments sorb persistent and toxic chemicals to levels many times higher than water-column concentrations. A summary review of the ODCA research programme outlined the research priorities to be addressed in order to achieve the short-term research goal of clarifying and updating ODCA information requirements and standards; the long-term research goal is to better understand cause/effect relationships associated with ocean disposal.

Key Words: Ocean dumping, Environmental effects.

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ACKNOWLEDGEMENTS

I would like to express my gratitude to the speakers and other workshop participants who contributed to the successful outcome of the day's proceedings and to the contents of this report. Special acknowledgement is accorded to R. Kussat (EPS West Vancouver), M. Waldichuk (DFO West Vancouver) and R. Wilson (DFO - IOS) for chairing the workshop and to our guest speakers - P. Chapman (E.V.S. Consultants) and J. Karau (EPS Hull). My appreciation is extended also to L. Giovando (DFO - IOS) for his review of the report manuscript, to S. Thomson (DFO - IOS) for her assistance with the workshop mailing list and review of the manuscript, and to M. Tate (Double T Typing) for word-processing the report.

1. SUMMARY AND CONCLUSIONS

RODAC-funded research contracts for 1985-86 were reviewed at a workshop held on 5 December 1986 at the Institute of Ocean Sciences, Sidney, B.C. The studies included feasibility assessment of sediment toxicity tests suitable for ODCA application review, review and analysis of historical environmental data collected at the Point Grey ocean dumpsite, a critical literature review of representative sampling and subsampling, and development and testing of a free-vehicle experimental platform (the Benthic Lander). Guest speakers presented an approach, the Sediment Quality Triad, to develop sediment quality criteria and a review of national ODCA research priorities. The discussion which concluded the workshop dealt with the proposed ODCA research submission/review schedule, with ODCA research-fund concept-submission and detailed proposal forms and with Pacific Region research priorities for 1987-88. This report summarizes the material presented at the workshop.

The review and evaluation of biological testing procedures for assessing toxic effects of chemical releases from dredge-spoil disposal in the marine environment indicated that biological testing is feasible and that several specific tests can be implemented immediately for field and laboratory use. These are lethal and sublethal toxicity bioassays and bioaccumulation studies. However, to adequately address the suggested ODCA evaluation procedure for dredged materials, information and other requirements need to be fulfilled. These include improvement of toxicity data bases, further efforts in the development of sublethal toxicity tests, definition of minimum controls for bioassays, definition of proper sediment handling and storage practices, provision for ongoing review of the sediment evaluation protocol, and a need for proper recognition of chemical dynamics during evaluation protocols.

In the review and analysis of existing data on the environmental effects of dredged-material disposal at the Point Grey dumpsite, it was realized that the numerous modifications made in the implementation of the monitoring programme have created extensive difficulties in both the analysis and the interpretation of spatial and temporal trends. Several recommendations were put forward to produce the data reliability and compatibility necessary not only to evaluate the existing condition of the environment but also to permit an evaluation of changes. A set of 20 permanent sampling stations (17 dumpsite and 3 controls) needs to be designated and all components of the monitoring programme need to be implemented together at each of these stations. The programme should include routine physiological testing, benthic infaunal sampling, routine sampling/analysis of physical/chemical parameters, compilation of data in a standard computer format to which information can be routinely added, and analysis of data to relate the three major study components (bioaccumulation, benthic infauna, and physical/chemical parameters) to provide insight into spatial and temporal trends.

The review of literature on representative sampling and sub-sampling of heterogeneous sediments revealed a number of glaring information gaps not only concerning spatial distribution of cadmium and mercury in the sediment matrix but also in the area of sampling constants for these metals. It pointed out that the importance of frequency distributions depended very much on the objective of the particular statistical analysis being used and concluded that the most suitable null hypothesis to test was $H_o = \bar{x} \geq L$ (i.e., the sediment is contaminated). A formula was suggested for calculating the optimum number of analytical replicates that should be analysed. To provide the requisite information, it was recommended that a number of sampling sites be chosen and enough samples collected to determine the frequency distribution by sediment-size class and the Visman sampling constants for cadmium and mercury in the sediments at each site.

The Benthic Lander is intended to be an economical and efficient means to determine the mechanisms and rates of biological processes at ocean dumpsites and other areas which, because of depth or other hazard, are beyond ordinary access by SCUBA. During the period from 14 February 1986 to 3 December 1986, Lander prototypes were deployed a total of five times in water depths of 90-250 m. Four retrievals were relatively successful; one Lander was lost when the recovery buoy failed to surface. Design modifications were carried out over this time period to improve reliability of the vehicle with reduced cost. Experimentation will resume in early 1987 as the weather improves at the Point Grey dumpsite.

The Sediment Quality Triad was presented as an approach to fulfill the need to develop criteria that can be used to assess sediment quality. These criteria are considered necessary to protect aquatic life as aquatic sediments sorb persistent and toxic chemicals to levels many times higher than water-column concentrations. The Triad incorporates three essential components: bulk sediment chemistry to determine the presence and degree of anthropogenic contamination, sediment bioassays to demonstrate that substances in the sediment can interfere with the normal functioning of at least some biological organisms tested in the laboratory, and measures of benthic infaunal community structure/histopathological abnormalities in resident biota to assess *in-situ* alteration of resident biological communities. The Triad can be used to determine pollution-induced degradation both areally and temporally for a large number of sites by generating indices that represent individual aggregate characterizations of the respective chemistry, bioassay and *in-situ* data. Studies to date have indicated the effectiveness of the Triad and it was recommended that this approach be pursued.

The role of the ODCA research programme was reviewed with regard to issuance of dumping permits, development of policies and standards, and basic monitoring and research for the purpose of studying the possible long-range effects of pollution. The effectiveness of the research undertaken is assessed on an annual basis. The short-term (5-year) goal for the ocean-dumping research programme is to clarify and update ODCA information requirements and standards by addressing the following research priorities: sediment toxicity tests, management of physical impacts, quality-assurance requirements for generating data, schedule-substances review, and dumpsite assessments. The long-term research goal is to better understand cause/effect relationships associated with ocean disposal.

The workshop ended with a discussion during which the following research priorities for 1987-88 Pacific RODAC funding were presented:

- A monitoring programme for the Point Grey dumpsite including sediment chemistry, identification of benthic infauna and sediment bioassays.
- Amphipod bioassays on sediments along the B.C. coast containing heavy metals and organic contaminants.
- Benthic community bioassays at ocean dumpsite(s) using planktonic larvae of benthic invertebrates.
- Development of sediment sample processing guidelines.

Extended abstracts of the RODAC studies contracted in 1985-86 are contained in this report. Inquiries regarding the information presented and further publications should be directed to the appropriate scientific authorities at their associated institutes. Appendix I lists the abbreviations and addresses of these institutes.

A list of those who attended the workshop is contained in Appendix II. Appendix III outlines contracts for 1985-86 while studies contracted for 1986-87 are listed in Appendix IV.

Copies of this Canadian Report of Hydrography and Ocean Sciences are available from the Institute of Ocean Sciences, Sidney, B.C.

This report was prepared by S.M. Woods Consulting under contract to the Institute of Ocean Sciences (Ref. SSC File No. 06SB.FP941-6-1899).

2. FEASIBILITY ASSESSMENT OF SEDIMENT TOXICITY TESTS SUITABLE FOR ODCA APPLICATION REVIEW

D.E. Konasewich, E.R. McGreer and H. Sneddon

Contractor: ENVIROCHEM Services
COASTLINE Environmental Services Limited
Scientific Authority: R. Kussat, EPS West Vancouver

This study reviewed and evaluated biological testing procedures for assessing the toxic effects of chemical releases from dredge-spoil disposal in the marine environment. The test procedures were evaluated on the basis of criteria defined by the Ocean Dumping Programme of Environment Canada as part of the contract terms of reference. Our review indicates that biological testing is feasible, and several specific tests can be implemented immediately for field and laboratory use. These are:

Lethal toxicity bioassays

- Amphipod *Rhepoxinius abronius* 10-day sediment bioassay, and
- Benthic community recruitment bioassay.

Both of the recommended bioassays have been shown to be sensitive to "polluted sediments". Verification is required to assure that the procedures are sensitive to a broad range of toxic actions.

Sublethal toxicity bioassays

- No recommendation is made, and further work to define life-cycle tests is suggested.

Bioaccumulation

- Sediment-phase tests with the clam, *Macoma balthica*.

This species occurs on all three of Canada's coasts, and "good" correlations between laboratory studies and field observations have been reported.

Figure 2.1 presents a suggested ODCA evaluation procedure for dredged materials. Although additional information requirements exist, the requirements should not delay the initial implementation of a test protocol. The additional requirements include:

- Improvement of toxicity data bases to assure that the selected test species will respond to a spectrum of chemicals representing various toxicity mechanisms;

- Further efforts in the development of life-cycle tests for assessment of sublethal toxicity;

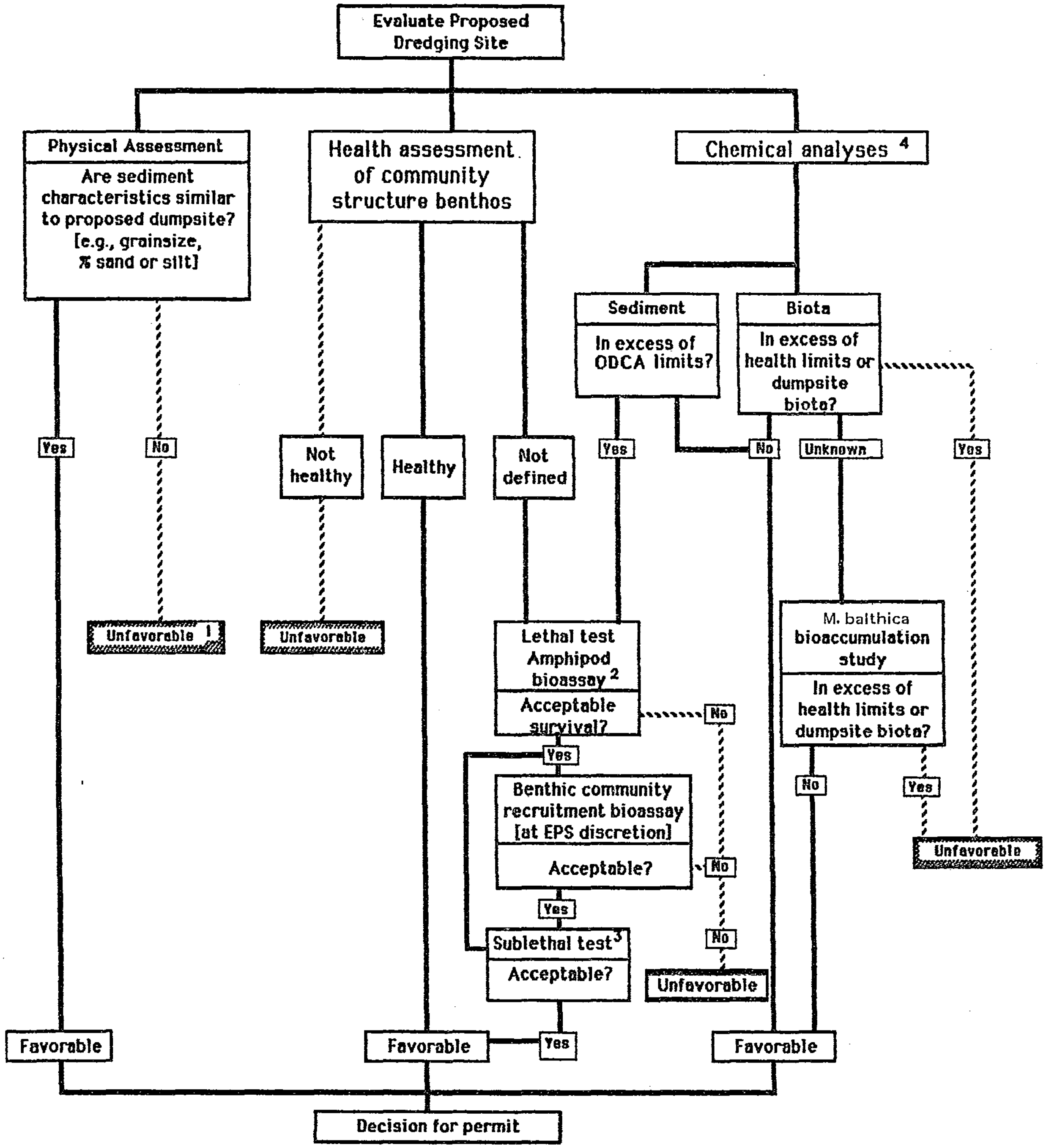
- Definition of minimum physical and chemical controls which must be in place during the bioassay sequence; and

- Definition of sediment handling and storage practices prior to bioassay testing.

Provision for ongoing review of the sediment evaluation protocol is required. For example, subsequent monitoring of resident infauna at dumpsites will determine the extent to which the test protocol is successful in the evaluation of contaminated sediments. Such monitoring feedback will enable proof of prediction and, furthermore, lead to refined test protocols which will be acceptable to all parties involved.

A major concern is the apparent lack of proper recognition of chemical dynamics during many existing sediment evaluation protocols. The effects of parameters such as pH, dissolved oxygen, redox conditions, organic content of sediment, etc. should be recognized throughout the evaluation protocols. The absence of recognition of chemical dynamics may result in poor correlations between laboratory results and field evaluations.

Detailed discussions are found in the following technical report: Konasewich, D.E., E.R. McGreer and H. Sneddon. 1986. Feasibility assessment of sediment toxicity tests suitable for ODCA application review. Prepared for the Regional Ocean Dumping Advisory Committee, EPS-Pacific Region, West Vancouver, B.C. 79p.



1. Unfavorable implies a "red flag" for consideration of permit applications. Final decision is dependent upon regulatory review.
2. Other lethal tests may be required pending completion of additional toxicity testing.
3. Sublethal tests yet to be determined.
4. Chemical analyses should be used to define conditions for bioassay.

FIGURE 2.1 Suggested ODCA evaluation scheme.

3. REVIEW AND ANALYSIS OF HISTORICAL ENVIRONMENTAL DATA COLLECTED AT THE POINT GREY OCEAN DISPOSAL SITE.

S.F. Cross[1]

Contractor: E.V.S. Consultants Limited
Scientific Authority: H. Nelson, EPS West Vancouver

Dredging activities in the lower mainland of British Columbia are concentrated within the Fraser River, where millions of tonnes of sediment are removed annually from navigation channels by Public Works Canada. Private commercial dredging companies remove river silt and woodwaste from proposed or existing foreshore developments and from industrial sites, i.e., those associated mainly with the forest industry. Dredging activities located elsewhere in the lower mainland include maintenance dredging around industrial sites, e.g., pulpmills, sawmills, harbour wharf excavations and sporadic dredging requirements such as those related to B.C. Place and Expo '86 developments in False Creek.

Dredged material has been disposed of annually at a number of designated disposal sites adjacent to the lower mainland. These sites include Sandheads, Fraser River (South Arm), and Point Grey. The latter two receive primarily clean dredge material comprised of silt, mud, sand and clay derived largely from maintenance dredging conducted within the main arm of the Fraser River. The Point Grey dumpsite, in contrast, receives dredged organic material from the Fraser River, Burrard Inlet and False Creek, as well as construction debris, woodwastes, and contaminated sediments removed from Vancouver's waterways.

The routine assessment and monitoring of impacts associated with ocean-dumping activities at designated ocean dumpsites are performed by the Environmental Protection Service (EPS). The stated objective of these routine monitoring activities is to identify large-scale impacts on the marine environment and to document trends in the chemical composition of sediments at the dumpsite.

The present study was initiated through the Pacific Regional Ocean Dumping Advisory Committee (RODAC) and was intended to

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review and analyse existing data on the environmental effects of dredged-material disposal at the Point Grey dumpsite. Application of these results to modification of present monitoring-programme design criteria was also to be considered.

Numerous environmental studies have been carried out at the Point Grey dumpsite since the initial survey conducted by Hoos in 1975. These have included bioaccumulation studies, benthic infaunal studies, physical/chemical studies, and 'other' studies which include Pisces (submersible) observations, wave monitoring programmes, etc. Using the following criteria, numerical data produced in each study were evaluated in terms of the study design and the sampling/analytical methodologies employed:

- Statement of hypothesis (objective);
- Number of stations;
- Degree of replication (field or laboratory);
- Parameters estimated;
- Appropriate reference or control;
- Expression of variability - precision estimates;
- Quality control - accuracy estimates;
- Between-survey compatibility;
- Summary/comparative statistics; and
- Presentation of data.

Implementation of the environmental monitoring programme at the Point Grey ocean dumpsite over the past decade has undergone numerous modifications, the combination of which has led to extensive difficulties in both the analysis and interpretation of spatial and temporal trends in established environmental monitoring parameters. Examples of the problems encountered include the lack of any sample replication in either the field sampling or laboratory analyses, inconsistent selection of sampling stations from one year to the next, inconsistent selection in the group of parameters chosen for monitoring from one year to the next, lack of quality control procedures applied to analytical procedures (particularly benthic infaunal analyses), and the failure to review past survey reports in planning current monitoring efforts. The primary objective of routine monitoring should be not only to evaluate the existing (present) condition of the environment, but also to permit an evaluation of temporal changes through incorporation of past data.

To successfully address these objectives, a good basic study design must be followed rigorously to achieve the key elements of the monitoring programme: data reliability and compatibility. In the present evaluation of the Point Grey monitoring programme numerous problems have been identified which should be corrected if these basic design criteria are to be met.

The original Point Grey study design, initially implemented in 1975, incorporated three major study components: bioaccumulation, benthic infauna, and physical/chemical parameters. Each component provides a very useful index to the impact of the dumped material on the environment. Physical/chemical parameters (e.g., grain-size sediment chemistry) directly establish the extent of the impact on the area. Benthic infauna community structure illustrates the indirect effect of the disposed material on the biotic component of the environment, largely as a result of both the subtle, chronic effects of the material and the direct physical effect of the material. Bioaccumulation studies serve to link the measured physical/chemical impact to any observed biological impact, by demonstrating direct effects on selected resident organisms. All three study components are considered important, and should be reinstated into a revised routine monitoring programme.

Since the Point Grey environmental evaluation started in 1975, the programme has experienced a reduction in both the number of stations sampled and the environmental parameters estimated. In fact, in the last study (1984), only five chemical parameters were measured at 24 of the original 50 stations. These data were supported only by semi-quantitative bioaccumulation results obtained from selected trawl species. This apparent need for a reduction in programme size could, however, be accommodated in a defensible study design. On the basis of our evaluation of the existing monitoring design and associated problems, the following modifications to future Point Grey monitoring assessments are recommended:

- Reduction in the number of monitoring stations from 50 to 17, eight located within the dumpsite area and nine outside the area (see Figure 3.1).

- Selection of an appropriate reference area (e.g., Howe Sound), and establishment of three control stations within the reference area, stratified by depths comparable to the range sampled at Point Grey. Establishing a set of reference stations a considerable distance from the Point Grey dumpsite will ensure that all possible dumping effects are eliminated. Since the areal impact at this dumpsite is presently not defined, and in fact has been suggested to reach well into the northeast quadrant of the original sampling grid, collection of control samples from an area known to be free of such effects is an essential consideration in the proper design of such a monitoring programme.

- Implementation of an appropriate "routine" physiological test to replace bioaccumulation studies. In view of the lack of an appropriate bioaccumulation test organism, it is recommended that sediment bioassays be performed to establish a comparable 'direct' link between impact wastes and the biotic component.

- Re-incorporation of benthic infaunal sampling. A minimum of three whole replicate grabs should be analysed for each of the 20 stations. Complete taxonomy (species level) should be applied to all samples. A thorough quality-control procedure for both sorting and identification/verification should be implemented.

- Routine sampling/analysis of physical/chemical parameters, including depth, sediment characteristics, organic content, Cu, Pb, Hg, Cd, and Zn for each of the 20 stations (minimum three replicates). Analytical quality-control procedures should be strictly applied, and precision/accuracy estimates reported.

- Compilation of data in a standard computer format specifically developed to permit routine additions to the data base, thus allowing easy manipulation and comparison with all historic data.

- Analysis of data to relate all three major study components to provide insight into the areal extent of impact at the Point Grey dumpsite, as well as to establish temporal trends and determine how they are related to dumping activities. Analytical methodology employed should consider stratification by variables which could have an influence on any statistical interpretation.

The foregoing recommendations for modification of the Point Grey monitoring programme require that a set of permanent sampling stations be designated, and that all components of the programme be implemented together at each of these stations. Implementation of such a defined monitoring programme will ensure that a reliable, compatible data base is created, so that all subsequent evaluation procedures are utilizing a consistent basis for meaningful interpretation of environmental condition.

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4. A CRITICAL LITERATURE REVIEW OF REPRESENTATIVE SEDIMENT SAMPLING AND SUBSAMPLING

M.B. Yunker

Contractor: Dobrocky SEATECH Limited
Scientific Authority: R. Macdonald, DFO-IOS

INTRODUCTION

In the final planning stages, the terms of reference for this critical literature review were expanded to include a state-of-the-art review of the literature on representative sampling and subsampling of heterogeneous substances. The results of this literature review were then summarized and conclusions reached on the application of the information obtained to sediment sampling.

Initially, relevant work was accessed by a key-word literature review and by assembling relevant papers. When synthesizing the results of the literature review, attention was paid to the following key aspects:

- Spatial distribution of the analyte in the matrix;
- Random sampling error due to heterogeneity of particles; and
- Influence of point sources and stratification of pollutants on sampling.

RESULTS

When the results of this literature review were examined, a number of glaring information gaps were observed. Most obvious was the fact that there was very little relevant data of documented high quality on the spatial distribution of the metals cadmium (Cd) and mercury (Hg) in the sediment matrix. In many cases, total metal concentrations have been reported along with grain-size distribution, but almost no data were available on the variation of metal concentration within each size class. As a result of this lack of information, it was not possible to state whether (a) large enough samples or (b) sufficient samples were being analysed to satisfy the goals of the Ocean Dumping Control Act (ODCA). Furthermore, the lack of information on the frequency distribution of Cd and Hg in sediments may imply that the statistical tests used to test conformance of a sediment to the Act (before ocean dumping) may not be valid.

The general literature review pointed out that the importance of frequency distributions depended very much on the objectives of the particular statistical analysis at hand. In the case of estimating total quantity of a contaminant dispersed over the area being sampled, the shape of frequency distributions may largely be ignored. If, however, statistical tests were in order (as they are for ODCA administration), then it may become essential to consider the form of the frequency distribution. The review also pointed out that a judgemental choice of "representative" or "typical" sites can almost always be expected to lead to erroneous results. The best known "descriptive" survey technique was reported to be stratified random sampling. A grid scheme was noted as not being as efficient in estimating total quantities of a contaminant; however, it was usually considered necessary for contouring.

For ODCA purposes, it was concluded that the most suitable null hypothesis to test was $H_o = \bar{x} \geq L$ (i.e., the sediment is contaminated). When H_o was stated in this way, it was possible to specify exactly what risk was taken in testing H_o, since it was possible to give a known probability of falsely rejecting the null hypothesis and concluding that the sediment was not contaminated. If the alternative hypothesis was put forward (i.e., $H_o = \bar{x} \leq L$, the sediment is not contaminated), it was only possible to specify the probability of prohibiting ocean dumping unnecessarily.

Based on the costs of collecting and analysing a sample and on a knowledge of sampling and analytical variances, a formula was suggested for calculating the optimum number of analytical replicates that should be analysed. It was found that, in most cases, the formula would predict one replicate. Essentially then, once an analytical procedure had been demonstrated to be in a state of statistical control, it was concluded that it would be best to concentrate resources on determining the sampling variation (i.e., to analyse samples from different grab or core samples as opposed to analytical replicates). This assumed that an adequate number of quality assurance samples would also be analysed concurrently. The Geological Survey of Canada reported essentially the same approach (with an inverted nested sampling design) where most of the samples analysed were from different sampling locations.

For ODCA testing, enough representative samples of marine sediment need to be collected from the area being examined so that a valid test could be made of the null hypothesis (that the sediment is contaminated). From a knowledge of the mean and the variance, it was possible to calculate the number of samples required to determine any minimum detectable difference from the ODCA limit. It was not possible, however, to optimize the number of samples to be collected for any given total cost of a programme. It was concluded that the decision on the number of samples to be analysed needs to be based on the magnitude of difference from the ODCA limit desired (i.e., the minimum detectable difference), the risk and consequences of an incorrect decision, and the cost of the programme. Once these decisions had been made, the formulae and examples shown allowed this number of samples to be calculated easily.

The results of this literature review also indicated an information gap in the area of sampling constants for the analytes of interest to ODCA (i.e., Cd and Hg). A knowledge of Visman sampling constants was considered necessary to allow the calculation of the weight of individual samples and the number of samples to hold the sampling standard deviation to a given level. Alternatively, the sampling constants were shown to allow an assessment of what the sampling deviation would be for a given weight of sample and a given number of samples (based on both the calculated number of samples given above and the cost).

Sampling theory demonstrated that, for a material of 60 µm diameter (approximately 250 mesh), the test-portion size required to hold the sampling error to 5% relative could vary widely depending on the assumptions made as to the fraction of the total particles that contained high levels of contaminant and on the concentrations of contaminant in the two types of particles modelled. The overall conclusion was that, if the metal contamination being studied (e.g., Cd or Hg) was present at concentrations of about 1 µg/g (1 ppm), then very large subsamples were required if the metal was present in only a limited number of particles.

RECOMMENDATIONS

From the above discussion, it follows that more information is required on the distribution of Cd and Hg in marine sediments from typical dredgesites. It is recommended that a number of sites be chosen on each coast and enough samples be collected to determine the frequency distribution by sediment-size class and the Visman sampling constants for Cd and Hg in the sediments at each site. It is expected that significant cost savings would be realized in this work by making collection and analysis concurrent with the ODCA application process at as many of the sites as possible.

ACKNOWLEDGEMENTS

The author would like to thank Dr. Byron Kratochvil of the University of Alberta in Edmonton for his contribution to this review. He assisted with the update of the literature review and contributed the section on sampling constants and sampling theory. The author would also like to thank Dr. Rob Macdonald of the Institute of Ocean Sciences, Sidney, B.C. (the Scientific Authority) for his helpful comments and suggestions throughout the course of the review.

5. DEVELOPMENT AND TESTING OF THE BENTHIC LANDER, A FREE-VEHICLE EXPERIMENTAL PLATFORM FOR STUDYING ENVIRONMENTAL EFFECTS OF OCEAN DUMPING: PROGRESS REPORT

E. Anderson

Contractor: Edward Anderson Marine Sciences
Scientific Authority: C.D. Levings, DFO West Vancouver

OBJECTIVES

The Benthic Lander project will provide for the first time an economical and efficient means to determine the mechanisms and rates of biological processes at ocean dumpsites and other areas which, because of depth or other hazard, are beyond ordinary access by SCUBA. Our present knowledge of biological processes at such sites has been limited to "snapshots" of benthic infaunal community structure, or to extrapolation from laboratory toxicity testing, usually on drastically simplified biological systems.

FIRST PROTOTYPE AND FIRST FIELD TRIAL

The Benthic Lander is basically a box which can carry biological experiments to the ocean floor, incubate them for some time, and return them to the surface with minimal disturbance. It has a pair of hinged doors which are closed when the Lander is suspended (during deployment and recovery), but open when the Lander rests on bottom. At the end of each experiment, the recovery system releases a buoy to the surface so that the Lander may be hauled up. The device in its simplest form is useful for in-situ study of the balance between colonization and mortality in natural and disturbed communities. Later developments may allow the Lander to carry more sophisticated experiments on in-situ rates of chemical or physiological processes.

The first prototype was deployed in Saanich Inlet at 90 m on 14 February 1986. The recovery system incorporated an acoustic release (Interocean 1090) in a design adapted from standard practice in current metering for physical oceanography. The recovery was successful, but the door-closure mechanism proved awkward. Figure 5.1 shows the current version, in which the rubber spring mechanism for door closure is replaced by one operated by one of the Lander's three ballast plates, which each weight 45 kg. Figure 5.2 shows the operating sequence from deployment to recovery.

FIRST FULL-SCALE EXPERIMENT, POINT GREY DUMPSITE

The study area at Point Grey is the highest-volume ocean dumpsite on the west coast of Canada. The dumpsite is about

250 m deep, far beyond ordinary SCUBA access, and is situated in an area of significant ship traffic.

We were unable to insure equipment for deployment at Point Grey. This unexpected twist forced a redesign for affordable loss, which may be a good criterion for experimentation at active dumpsites. We replaced expensive acoustic releases with cheap galvanic releases. These are small mechanical links which corrode in sea water and finally break at a fairly predictable time. The ones we used were of magnesium/nickel and were represented as 30-day releases.

After a successful one-day test, we deployed two Landers at Point Grey: one at a station 0.5 n mi north of dumpsite legal centre and one 3.0 n mi west of centre (W3). Each Lander was loaded with two substrates: a section of natural sediment ecosystem and a similar sediment defaunated by overnight freezing. We wished to measure colonization and mortality rates in natural and dumpsite environments.

We recovered the dumpsite Lander on 7 June. We obtained good samples of the initially azoic side, but the door on the natural ecosystem side was broken and the sample was washed out. The operational limit for safe recovery of the system from a well-equipped 12 m vessel is reached at a 25 kn wind with a 1.5 m sea. The recovery buoy at W3 did not surface. Attempts to grapple the reference Lander failed on several occasions in July and August; in September we accepted that it was lost. Some likely causes for the loss include an accident involving ship traffic, non-release of the galvanic device and fouling of the recovery line.

We took samples from the dumpsites and surrounds as background for interpreting the Benthic Lander experiments. These wild ecosystem samples have been analysed for heavy metals, sediment particle size, meiofauna (100 µm mesh) and macrofauna (500 um mesh).

SECOND PROTOTYPE DEPLOYMENT, SAANICH INLET

The results of the first Point Grey experiment indicated that more development work was required. We modified the Benthic Lander to further improve reliability with reduced cost. The second developmental mooring was deployed at 90 m in Saanich Inlet from 19 October to 3 December 1986. The recovery was completely successful: sediment ecosystems were virtually undisturbed. Meiofauna colonization of substrates defaunated by boiling and freezing were about equal, and both were colonized much more rapidly by meiofauna (chiefly nematodes and harpacticoid copepods) than by the macrofauna of related previous studies.

We will resume experimentation at Point Grey in early spring 1987, as the weather improves.

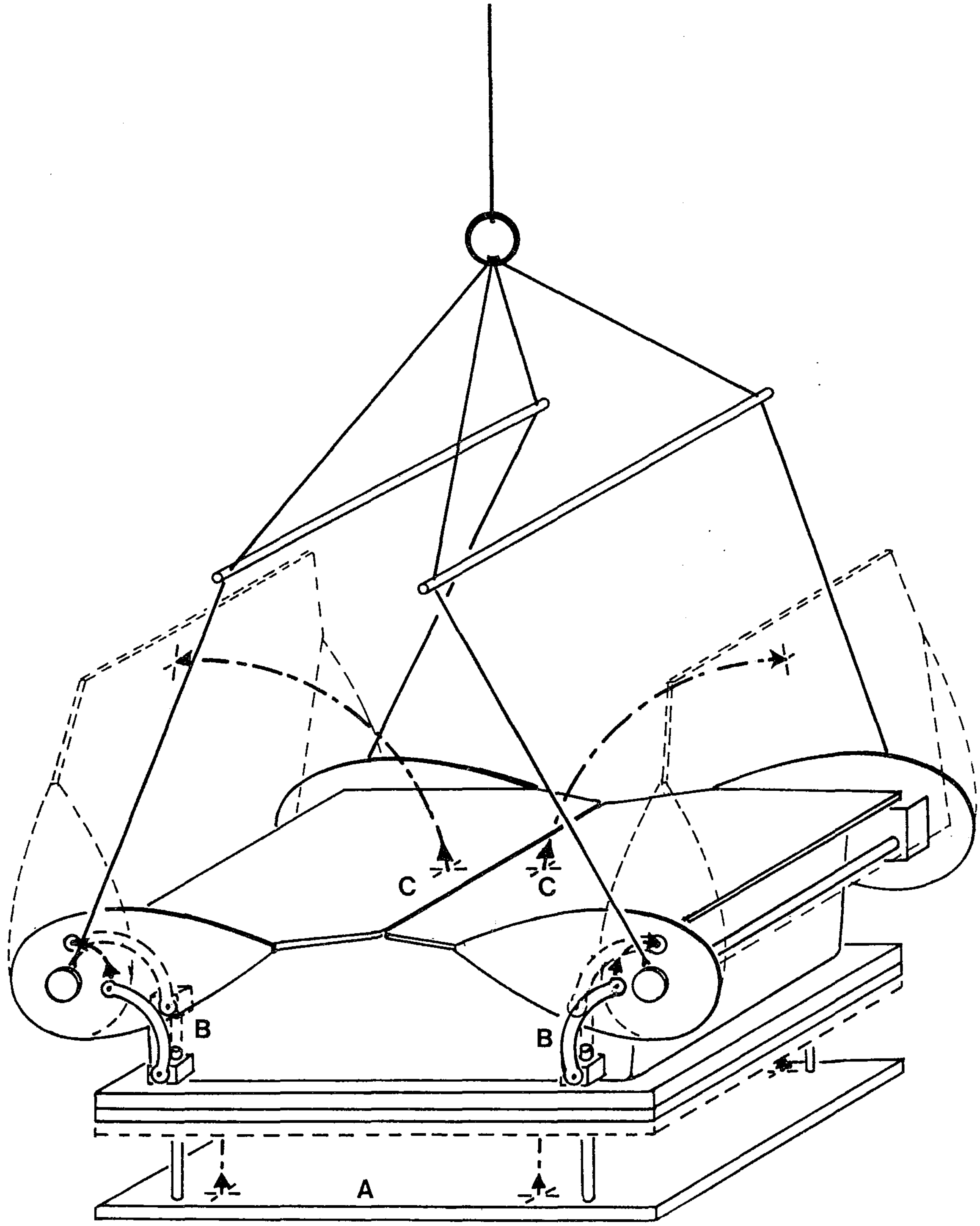

FIGURE 5.1 Diagram of the Benthic Lander. When the Lander rests on bottom (or on deck) the lower ballast plate (A) pushes up the actuating links (B,B) to open the doors (C,C).

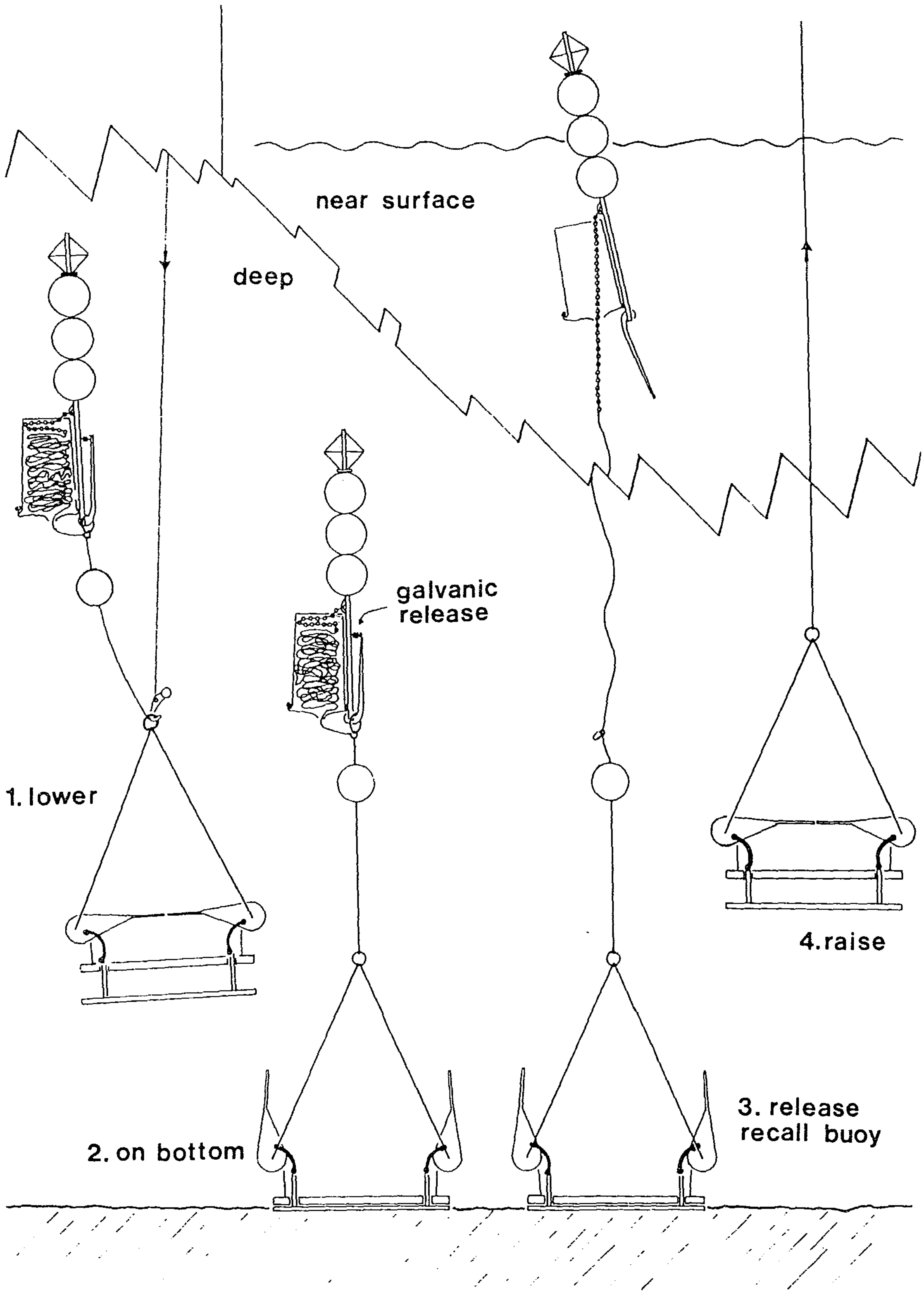

FIGURE 5.2 Benthic Lander field operation sequence.

6. SEDIMENT QUALITY CRITERIA - WATER WE WAITING FOR?

P.M. Chapman

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INTRODUCTION

Aquatic sediments sorb persistent and toxic chemicals to levels many times higher than water-column concentrations, but presently there are no criteria for determining and regulating sediment quality. Almost all toxicological criteria developed to date for the protection of the aquatic environment are based on aqueous chemical concentrations. There is a need to develop criteria that can be used to assess sediment quality. Such sediment quality criteria are necessary to protect aquatic life, and are distinct from present water quality criteria.

The partitioning of sediment contaminants into dissolved and particulate-bound fractions presents a formidable obstacle to the development of sediment quality criteria. Contaminants bound to sediment particles may be more or less available to biota than contaminants in solution, and the effects of partitioning on contaminant bioavailability and toxicity are largely unknown. Contaminant partitioning is a function of sediment characteristics, including grain size and organic content. Moreover, uptake of sediment contaminants by aquatic organisms to toxic residue levels may be by way of the fraction in the interstitial water or by way of ingested sediment.

Because of these complexities, data sets encompassing a myriad of interactions and based on toxicological data derived directly from sediments (i.e., *in-situ* effects and sediment bioassays) offer great promise for the development of sediment quality criteria. This approach, the Sediment Quality Triad, can be used to develop numerical and/or toxicological sediment quality criteria, dependent upon which is realistic and implementable.

THE SEDIMENT QUALITY TRIAD

The use of toxicological data (i.e., the Sediment Quality Triad) to develop sediment quality criteria has been discussed (Chapman and Long, 1983), and subjected to preliminary qualitative testing (Long and Chapman, 1985), and recently to quantitative testing (Chapman et al., 1986, in press a). This approach combines sediment chemistry and sediment bioassay measures with *in-situ* studies to determine and quantify the extent of pollution-induced degradation, and has been used to determine sediment quality criteria based on pollution-induced degradation (Chapman, 1986). Pollution-induced degradation is defined here as a biologically-damaging excess of contamination involving a threat to human life, harm to living resources, or some other deleterious effect.

The Sediment Quality Triad incorporates three essential components: measurements to determine the presence and degree of anthropogenic contamination (i.e., bulk sediment chemistry); measurements which demonstrate that substances in the sediment can interfere with the normal functioning of at least some biological organisms tested in the laboratory (i.e., sediment bioassays); and assessment of <u>in</u>-<u>situ</u> alteration of resident biological communities (e.g., measures of benthic infaunal community structure; histopathological abnormalities in resident biota).

The relative information provided by each component of the Sediment Quality Triad related to a measure of pollution-induced degradation is summarized below:

Parameter		Measurement				Measurement
Bulk Chemistry	→	Contamination		Sediment		Pollution-
Sediment Bioassay	→	Toxicity	→	Quality	→	Induced
<u>In</u>-<u>Situ</u> Bioeffects	→	Alteration		Triad		Degradation

The Sediment Quality Triad can be used to determine pollution-induced degradation both areally and temporally for a large number of sites (and/or stations) by generating indices that represent individual aggregate characterizations of the respective chemistry, bioassay and <u>in</u>-<u>situ</u> data. These indices can be numerical (i.e., numerical sediment quality criteria) or they can be primarily visual (i.e., toxicological sediment quality criteria). For instance, Chapman et al. (1986, in press a) describe a method of plotting the composites from each Triad measure on scales with a common origin such that the value of each unit index becomes the vertex of a triangle. The relative degree of degradation of each site is derived by calculating and comparing the areas of the triangles for each site. In either case, the Sediment Quality Triad provides an objective identification of all sites where contamination is causing real harm, and hence a real-world basis for derived sediment quality criteria.

The Sediment Quality Triad provides a broad-scale approach to developing sediment quality criteria; it is based on the assumption that the biological responses observed in sediment bioassays and <u>in</u>-<u>situ</u> studies are a function of the concentration of certain chemicals sorbed to the study area sediments. Because of the possibility of interactions between groups of chemicals, it is probably not possible to determine, in isolation from other contaminants, the no-effect level for a particular individual contaminant in isolation from all other sediment contaminants. Thus, numerical sediment quality criteria determined by this method for one contaminant will be realistically applicable only if concentrations of all sediment contaminants do not exceed their particular criteria concentrations.

WHAT ARE WE WAITING FOR?

Specific numerical sediment quality criteria for three model contaminants [lead (Pb), combustion polyaromatic hydrocarbons (CPAH), polychlorinated biphenyls (PCBs)] have been derived by Chapman (1986) using the Sediment Quality Triad approach. As is apparent from Table 6.1, surprisingly similar values are obtained when variants of this approach are used in different areas, with different data sets (cf. Chapman et al, in press b).

The Sediment Quality Triad (Triad) criteria were determined using bulk sediment chemistry, sediment bioassay and bottomfish liver-lesion data for all of Puget Sound. The Screening Level Concentration (SLC) criteria (Neff et al., in press) were determined by estimating the highest concentration of each contaminant that can be tolerated by approximately 95% of benthic infaunal species, using data for parts of Puget Sound and the New York and Southern California Bights. The Apparent Effects Threshold (AET) criteria (Barrick et al., in review) were determined using very recent bulk sediment chemistry, sediment bioassay and benthic infaunal community-structure data for a few embayments in Puget Sound. Laboratory studies involved sediment bioassays to determine the toxicity of creosote-contaminated sediment containing 13 PAH components, with subsequent use of an additivity model and calculation of the no-effect concentration as the 10-d LC01. Actual bioeffects values for San Francisco Bay (Chapman et al., 1986, in press a) were not included in calculations of the other values, and hence represent a comparison between predicted and actual values.

Comparison of the range of sediment quality criteria shown in Table 6.1 with present EPS ocean dumping guidelines indicates that these guidelines are as much as an order of magnitude too high to be sufficiently protective of the environment (Table 6.2). There is a very real need to develop sediment quality criteria for use in Canadian waters.

The results of studies to date, many of which have involved Canadians, but all of which have been funded in and have taken place in the United States, indicate that sediment quality criteria can be developed, using the approach shown in Figure 6.1. What are we waiting for?

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Chapman, P.M. and E.R. Long. 1983. The use of bioassays as part of a comprehensive approach to marine pollution assessment. Mar. Pollut. Bull. 14:81-84.

Chapman, P.M., R.N. Dexter, S.F. Cross and D.G. Mitchell. 1986. A field trial of the Sediment Quality Triad in San Francisco Bay. NOAA Tech. Memo. NOS OMA 25. 127p.

Chapman, P.M., R.N. Dexter and E.R. Long. In Press a. Synoptic measures of sediment contamination, toxicity and infaunal community structure (the Sediment Quality Triad) in San Francisco Bay. Mar. Ecol. Prog. Ser.

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Neff, J.M., B.W. Cornaby, R.M. Vaga, T.C. Gulbransen, J.S. Scanlon and D.J. Bean. In Press. An evaluation of the screening level concentration approach to derivation of sediment quality criteria for freshwater and saltwater ecosystems. In: Tenth Aquatic Toxicology Symposium. ASTM STP.

TABLE 6.1

Comparison of sediment quality criteria values obtained for three contaminants by four separate approaches, and bioeffects data from San Francisco Bay. (All concentrations as µg/g dry weight of sediment.)

Contaminant	No or minimal biological effects			Significant biological effects	Minimum values for bioeffects San Francisco Bay
	Triad	SLC	Lab. Studies	AET	
Pb	50	-	-	300	130
PAH	3.8	7.6	2.0	5.1; 12.0	9.5
PCBs	0.1	0.06	-	0.13	0.16

TABLE 6.2

Comparison of sediment quality criteria based on biological effects with EPS ocean dumping guidelines. (All concentrations as µg/g dry weight of sediment.)

Contaminant	Bioeffects Sediment Quality Criteria	EPS Ocean Dumping Guidelines	Difference
Pb	50 - 300	500	+ 1.7 - 10.0X
PAH	2.0 - 12.0	none	n/a
PCBs	0.1 - 0.13	1.0	+ 7.7 - 10.0X

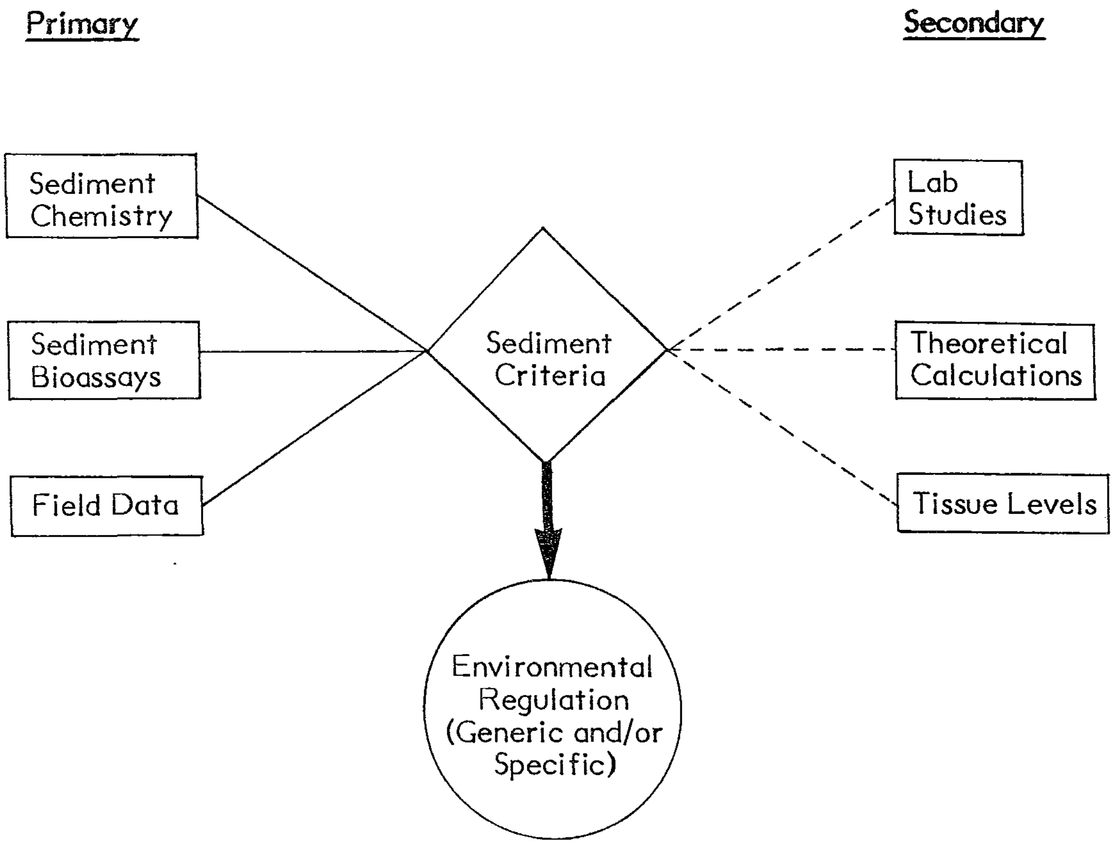

FIGURE 6.1 Recommended approach to developing sediment quality criteria. Primary approach is the Sediment Quality Triad.

7. NATIONAL ODCA RESEARCH PRIORITIES

J. Karau

Environmental Protection Service
Conservation and Protection
Hull, P.Q.

The Ocean Dumping Control Act (ODCA) research programme provides scientific information related to:

- Specific ocean-dumping problems with regard to permit issuance;
- Development, modification or appraisal of regional, national or international policies; and
- Possible long-range effects of pollution.

The majority of current ocean dumping and ocean-dumping research in Canada centres on marine disposal of dredged material. The 1987/88 research fund is $150,000 of which approximately $60,000 is dedicated to ocean-dumping research in the Pacific Region.

PERMIT ISSUANCE

A permit for dredge-spoil disposal may be issued if the concentration of any substance in the dredged material does not exceed the ODCA regulated limits for several defined substances or does not exceed the local baseline concentrations at the dumpsite (i.e., like-on-like concept). If the dredged material fails the chemical screening tests, the provision exists to issue a permit if biological tests show that dumping the dredged material will not cause acute or irreversible chronic effects on sensitive organisms typical of the marine ecosystem at the dumpsite. The intent is to maintain compliance with the overall objective of the ODCA and the London Dumping Convention (LDC) which is to ensure that the materials dumped at sea will be "rapidly rendered harmless".

Monitoring, for the purpose of compliance, is designed primarily to document that the magnitude, scale and duration of environmental effects related to a permitted dumping activity do not exceed those expected and accepted as a result of the pre-permit assessments.

POLICIES AND STANDARDS DEVELOPMENT

Substances are allocated to the ODCA Schedules and LDC Annexes if:

- they are, or are proposed, to be dumped, and if
- significant environmental exposure may result, and if
- they possess any combination of the properties listed under hazard potential in significant degree.

Significant environmental exposure is considered to cause acute adverse effects or irreversible chronic effects to representative marine organisms at an ocean dumpsite.

The properties taken into account for evaluating hazard potential include:

1) Persistence/degradability;
2) Bioaccumulation potential;
3) Toxicity to human and marine life;
4) Carcinogenicity or mutagenicity to domestic animals or man; and
5) Ability to interfere with other legitimate uses of the sea.

Prohibited substances for ODCA Schedule I and LDC Annex I classification are those for which dumping will or may result in or contribute to significant environmental exposure on a wide scale, extending far beyond the original location and time of disposal. Restricted substances for ODCA Schedule II and LDC Annex II classification are those suitable for allocation but do not include those already allocated to ODCA Schedule I and LDC Annex I.

A five-stage approach is employed for the development and appraisal of ODCA permit information requirements and standards:

1) Feasibility assessment;
2) Pilot-scale tests;
3) Interpretation guidelines;
4) Workshops/Technology transfer; and
5) Implementation.

This approach is being used to develop sampling guidelines, QA/QC performance requirements and biological tests for the ODCA programme.

BASIC RESEARCH

Monitoring and research for the purpose of studying the possible long-range effects of pollution are designed primarily to increase the knowledge of the processes that control the transport, rate and effects of contaminants released to the marine environment through ocean dumping.

RESEARCH ROLL-UP

The effectiveness of the research undertaken is assessed annually by examining several perennial questions:

1. Is there evidence that ocean dumping has any adverse effects on human health or the environment?

   Concerns exist on a site-specific basis that toxics contained in contaminated sediments may be taken up by biota and potentially endanger marine life or human health. Physical impacts of dredged-material disposal appear to be local and short term in nature.

2. How conclusively do the available results demonstrate the extent or absence of adverse effects?

   The physical impacts of dredged-material disposal are generally well known; however, the predictive capability to assess sediment transport and scale of effects is lacking.

   The remobilization and bioavailability of toxics from dredged sediments are only partially understood. In addition, the resulting bioaccumulation and its toxicological consequences are not well documented.

3. Are the research studies and data adequate to evaluate the effectiveness of current control measures?

   Based on a limited number of monitoring studies, the ODCA controls have proven to be effective in limiting dumping operations to locations where adverse effects to marine environmental quality are minimized.

4. Are the available data on specific substances adequate to prescribe specific control limits?

   The available physical, chemical and ecotoxicological information is considered inadequate to revise the existing control limits which are based on maintaining baseline concentrations for heavy metals and not exceeding 1% of a concentration shown to be toxic for organics.

RESEARCH PRIORITIES

The short-term (5-year) goal for the ocean-dumping research programme is to clarify and update the ODCA information requirements and standards by addressing the following research priorities:

- Sediment toxicity tests;
- Management of physical impacts;
- Quality-assurance requirements for generating data;
- Schedule-substances review; and
- Dumpsite assessments.

Incineration at sea is also being investigated as one of many options which, if properly controlled, could help in the management of hazardous wastes.

The long-term research goal is to better understand cause/effect relationships associated with ocean disposal.

APPENDIX 1

LOCATIONS OF PARTICIPANTS IN 1986

I. GOVERNMENT

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and

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APPENDIX III

1985-1986 CONTRACTS
PACIFIC REGION

1. An experimental simulation of the release of cadmium and lead from contaminated dredge-spoil in sea water. — $15,000

   Scientific Authority: C.S. Wong, DFO/IOS
   Contractor: Seakem Oceanography Limited
   DSS File No.: 06SB.FP941-4-1832

2. Feasibility assessment of sediment toxicity tests suitable for ODCA dredging application review. — $14,400

   Scientific Authority: R. Kussat, EPS, West Vancouver
   Contractor: ENVIROCHEM Services
   DSS File No.: 03SB.KE603-5-0909

3. Review, analysis and application of the current knowledge of environmental effects of dredged-material disposal at Point Grey. — $ 9,500

   Scientific Authority: H. Nelson, EPS, West Vancouver
   Contractor: E.V.S. Consultants Limited
   DSS File No.: 11SB.KE603-5-0415

4. A critical state-of-the-art literature review of representative sampling and sub-sampling of heterogeneous substances. — $ 7,500

   Scientific Authority: R. Macdonald, DFO/IOS
   Contractor: Dobrocky SEATECH Limited
   DSS File No.: 06SB.KE603-5-0971

5. Development and testing of the benthic lander: a free-vehicle experimental platform for studying the environmental effects of ocean dumping. — $12,000

   Scientific Authority: C. Levings, DFO/WVL
   Contractor: Edward Anderson Marine Sciences
   DSS File No.: 03SB.FP941-5-2323

6. Organization of west coast ocean dumping workshop 1985 and preparation of workshop proceedings for publication. $ 4,010

   Scientific Authority: R. Wilson, DFO/IOS
   Contractor: S.M. Woods Consulting
   DSS File No.: 06SB.FP941-5-2240

APPENDIX IV

1986-1987 CONTRACTS
PACIFIC REGION

1. Sediment toxicity tests to address the effects of ocean-dumped material on fertilized eggs of a commercially-important fish species. $16,000

   Scientific Authority: M. Waldichuk, DFO/WVL
   Contractor: COASTLINE Environmental Services Limited
   SSC File No.: 06SB.FP941-6-0897

2. Compilation and assessment of research monitoring and dumping information for active dumpsite on the B.C. coast from 1979 to 1986. $ 5,000

   Scientific Authority: M. Waldichuk, DFO/WVL and R. Kussat, EPS, West Vancouver
   Contractor: D.L. Sullivan
   SSC File No.: KE603-6-0644

3. An assessment of the distribution of cadmium in marine sediments. A core study of elevated cadmium levels in Ucluelet Inlet, B.C. $17,300

   Scientific Authority: H. Nelson, EPS, West Vancouver
   Contractor: R. Waters
   SSC File No.: 09SB.KE603-6-0166

4. Effects of suspended silt on eggs and larvae of three commercially-important fish species in the Strait of Georgia. $17,325

   Scientific Authority: C. Levings, DFO/WVL
   Contractor: E.V.S. Consultants Limited
   SSC File No.: 06SB.FP941-6-1940

5. Organization of west coast ocean dumping workshop and preparation of workshop proceedings for publication. $ 4,050

   Scientific Authority: R. Wilson, DFO/IOS
   Contractor: S.M. Woods Consulting
   SSC File No.: 06SB.FP941-6-1899