UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

SAB-EEC-87-013

January 15, 1987

OFFICE OF
THE ADMINISTRATOR

Honorable Lee M. Thomas
Administrator
U.S. Environmental Protection Agency
401 M St., SW
Washington, DC 20460

Dear Mr. Thomas:

The Science Advisory Board's Environmental Engineering Committee has recently completed its review of the reports on landfilling and land application as alternatives to ocean disposal of sewage sludges, that were developed by the Office of Policy Planning and Evaluation for the Office of Marine and Estuarine Protection. We are pleased to forward to you the Committee's report for your consideration.

The Committee believes that the reports do not provide adequate documentation to justify the choice of methodology and selection of models. The Committee also recommends that the Agency conduct sensitivity analyses to evaluate the importance of variables and uncertainties in the models. In addition, the methodology should use data distributions rather than subjectively defining "representative" conditions.

The Committee appreciates the opportunity to conduct this scientific review. We request that the Agency formally respond to the attached report.

Sincerely,

Raymond C. Loehr

Raymond C. Loehr, Chairman
Environmental Engineering Committee
Science Advisory Board

Norton Nelson

Norton Nelson, Chairman
Executive Committee
Science Advisory Board

Attachment

cc: Terry Yosie, SAB
Larry Jensen, OW
Tudor Davies, OMEP
Milt Russell, OPPE

NOTICE

This report has been written by the Science Advisory Board, a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The Board is structured to provide a balanced, expert assessment of scientific matters related to problems facing the Agency. This report has not been reviewed for approval by the Agency, and hence, the contents of this report do not necessarily represent the views and policies of the Environmental Protection Agency. Nor does mention of trade names or commercial products represent endorsement or recommendation for use.

SAB-EEC-87-013

REVIEW OF REPORTS ON

LANDFILLING AND LAND APPLICATION ALTERNATIVES TO THE OCEAN DISPOSAL OF POTW SLUDGES

REPORT OF

THE ENVIRONMENTAL ENGINEERING COMMITTEE

U.S. Environmental Protection Agency
Science Advisory Board
Washington, D.C.

January, 1987

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I. EXECUTIVE SUMMARY

In late 1985, the Environmental Engineering Committee of the Science Advisory Board was asked by the Office of Marine and Estuarine Protection (OMEP) to review technical documents supporting revisions to the Agency's ocean dumping regulations. The two main issues were: 1) technical justification for the different regulatory treatment of the disposal of dredged materials and 2) the consideration, in the ocean disposal of publicly owned treatment works (POTW) sludges, of both the need for ocean dumping and the availability and impacts of land-based alternatives. This report deals with the second of these issues only. Specifically, this report presents the Science Advisory Board review of the methodologies developed by EPA's Office of Policy Planning and Evaluation (OPPE) to analyze POTW sludge landfilling and land application as alternatives to ocean disposal of POTW sludges (1,2).

The Committee was provided with two separate documents: one dealing with landfilling alternatives to ocean disposal of POTW sludge and the second dealing with land application alternatives to the ocean disposal of POTW sludges. Because the methodology used for these options was so similar, and because the documents are nearly identical in their draft form, the Committee opted to present one combined review of the documents. Furthermore, the Committee recommends that the OPPE land application and landfilling reports be combined into a single report.

In general, the Committee finds that the reports do not provide adequate documentation to justify the choice of methodology and the selection of simulation models proposed.

The following summary outlines the Committee's principal findings and recommendations. Details on each of these will be found in Section III of this report.

A. The reports do not provide adequate documentation to support the use of the models proposed. Although reasons for the selection of the Pesticide Root Zone Model (PRZM) to describe transport in the unsaturated zone are made clear, the model has been tested in the field only for pesticides and has not been tested for applications of POTW sludge to land, nor for transport of metals and other potentially harmful chemicals of the type which occur in POTW sludge. In addition, PRZM has not been tested for landfilling and cannot simulate nitrogen dynamics in the unsaturated zone. There is no discussion of any validation or the reasons for choosing the Analytic Transport 1,2,3-Dimension (AT123D) Model in the saturated zone or the Exposure Analysis Modeling System (EXAMS) Model for transport in surface water. The Committee recommends that such information be included in the report.

B. The hydrologic and chemical transport models used in the landfilling and the land application methodologies are of the type commonly employed to simulate area-averaged, long-term behavior at the field or catchment scale. Individual events at individual sites may differ significantly from model predictions. Because of these limitations, among others, the Committee recommends that the reports include a sensitivity analysis to evaluate the precision by which each parameter in the model must be known to avoid an erroneous output.

C. The OPPE reports propose that the analysis be done on a regional basis by defining representative conditions for coastal areas which can be considered alternatives for ocean dumping. The entire coastline of the United States cannot be represented with respect to the variation in soil, climatic, hydrologic, and POTW sludge disposal conditions by six coastal sites. The Committee recommends that the Agency develop a more scientific approach using data distributions to assess the range of conditions which may be encountered at any candidate site for alternative land disposal.

D. The documents do not consider the co-disposal of POTW sludges in landfills with other municipal and industrial wastes. The Committee suggests that an analysis of co-disposal in landfills be included (see specific comment, p. 7).

E. The Universal Soil Loss Equation (USLE) Model was developed to predict soil movement within a field. Its validity to predict sediment yield to a stream is not demonstrated. The Committee recommends that the report consider other models and adequately justify the use of USLE for the calculation of runoff and erosion if it remains the model of choice (see specific comment, p. 8).

II. INTRODUCTION

In late 1985, the Office of Marine and Estuarine Protection (OMEP) requested that the Science Advisory Board (SAB), review technical documents supporting revisions to the Agency ocean dumping regulations, which implement the Marine Protection, Research, and Sanctuaries Act (MPRSA). The documents were to be divided into two categories addressing, respectively, ocean disposal of publicly owned treatment works (POTW) sewage sludges and ocean disposal of dredged materials.

At the same time, the Science Advisory Board was also asked by the Office of Water Regulations and Standards (OWRS) to review technical documents supporting the development of regulations to be proposed (under Section 405(d) of the Clean Water Act) for the disposal/reuse of POTW sludges. Both of these reviews were assigned to the Environmental Engineering Committee, which decided to conduct the reviews simultaneously, since the subject material was very similar and since, in fact, the same methodology was being used in some cases to support both regulatory efforts.

The Environmental Engineering Committee accepted the task, and augmented its members with a number of consultants, including three members of the Environmental Advisory Board of the U. S. Army Corps of Engineers; three members of the SAB's Environmental Effects, Transport and Fate Committee; one member of the SAB's Health Effects Committee; and others. The Committee organized itself for the reviews by creating a number of subgroups, each dealing with one or more options/documents. A listing of the Committee membership, which includes the subgroup breakdown, is provided in Appendix A. The Committee decided that, rather than issue one large report covering all reviews, it would issue three separate reports on the ocean disposal of dredged materials, on the disposal/reuse of POTW sludges, and on the landfilling and land application alternatives to ocean disposal of POTW sludges]. This document presents only the third topic. The specific charge for this review appears in Appendix B.

Revisions to the MPRSA relate to two separate issues. First, the Agency must, as a result of a lawsuit brought by the National Wildlife Federation, provide adequate technical justification for current regulations permitting different regulatory treatment for the disposal of dredged materials. Second, the Agency must make revisions to the portion of the regulations dealing with the disposal of POTW sludges. These revisions, mandated by a second lawsuit brought by the city of New York, will require that consideration be given to the need for ocean dumping and to the availability and impacts of land-based alternatives (whereas the current regulation considers only marine impacts). This last issue is subject of this report.

The documents describing a procedure for evaluating the landfilling and land application alternatives, respectively, to the ocean disposal of POTW sludges (1,2) were provided to the Committee in May, 1986. Mr. Mike Conti, Office of Policy, Planning and Evaluation (whose office had supervised the preparation of the documents for OMEP), briefed the Committee on their contents at the Committee's meeting on June 10-11, 1986.

Subsequent meetings of the full Committee were held on July 23-24, August 19-20, September 29-30, October 27-28, and December 15-16. The purpose of these meetings was primarily for Committee discussions and drafting of Committee reports. At most of these meetings, Agency staff were present to either brief the Committee or to answer questions and clarify points that were not clear.

This report, while largely drafted by subgroups chaired by Dr. Page and Dr. Ewing, has been contributed to, reviewed, and approved by the full Committee.

III. REPORT ON THE OPPE EVALUATION OF LANDFILLING AND LAND APPLICATION ALTERNATIVES TO THE OCEAN DISPOSAL OF POTW SLUDGE

A. General Comments

The purpose of the landfilling methodology report is to present a method of evaluating the risk of ground water pollution resulting from a POTW sludge trench landfill as an alternative to ocean disposal. The method is based on determination of a unit concentration of contaminant resulting from a unit rate of POTW sludge disposal. The model uses the Pesticide Root Zone Model (PRZM) to determine the rate of input of the contaminant to the ground water aquifer resulting from leaching through the unsaturated zone and then uses the Analytical Transient One-, Two-, and Three-Dimensional Simulation of Waste Transport in the Aquifer System (AT123D) for estimating the concentration of contaminant downgradient in the aquifer at the point of withdrawal.

The land application methodology considers both surface water and ground water as the environmental exposure media, and it couples the PRZM model to describe the transport of chemicals from a land application site to both ground water and surface water with the Exposure Analysis Modeling System (FXAMS) to describe the fate and migration in surface water. Ground water transport in the saturated zone is modeled with the AT123D model.

Because the methodologies used for the landfilling and the land application options are so similar, and because the two OPPE reports are so nearly identical in their Review Draft form, the committee recommends that the OPPE Landfilling and Land Application reports be combined. The Introduction (Section 1) and Model Descriptions (Section 3) of each report, except for interchanging the titles (Landfilling and Land Application), are identical. The Methodology (Section 2), Model Input (Section 4), and References (Section 5) of the two draft reports contain a substantial amount of similar or identical material. Combination of the two reports will eliminate the confusion of having two such similar reports in circulation.

Part of the charge to the Committee was to evaluate the consistency of the approach and assumptions, including the consistency with the Office of Water Regulations and Standards (OWRS) methodologies for assessing the risks of POTW sludge disposal and reuse options. In this regard, the approach used in the documents prepared by OPPE is so much different from that used in the OWRS work that consistency among the documents is not amenable to evaluation. Furthermore, the OPPE documents on alternatives to ocean disposal -- landfilling and land application -- are not nearly as complete as the OWRS methodologies for risk assessment of POTW sludge disposal and reuse options. And as such, evaluations of consistency are not possible. The Committee has, however, noted some major problems below.

The reports do not provide adequate documentation to justify the use of the models proposed. The PRZM model used to describe the transport of chemicals from the landfill or land application site to ground water was developed to describe the fate of land-applied pesticides. The report discusses the previous efforts to validate the PRZM model, which is commendable. The reasons for selection of the PRZM model in the unsaturated zone are made clear. However, the PRZM model has been validated in the field only for pesticides and has not been tested for applications of POTW sludge to land or disposal (of any substance) in landfills. Nor has it been shown to be valid for metals and

other potentially harmful chemicals of the type which occur in POTW sludge. Additionally, a major shortcoming of the PRZM in evaluation of land-based POTW sludge disposal/reuse options is its inability to simulate nitrogen dynamics in the unsaturated zone. These dynamics are critical to the evaluation of the impacts of POTW sludge disposal or application. Modifications required to incorporate nitrogen dynamics into PRZM should not be extensive, and could be implemented.

There is no discussion of any validation or the reasons for choosing the AT123D model in the saturated zone or the use of the EXAMS model for transport in aquatic systems. Such information should be included in the report.

The hydrologic and chemical transport models used in the landfilling and the land application methodologies are of the type commonly employed to simulate area-averaged, long-term behavior at the field or catchment scale. They use temporally and spatially lumped processes and parameters and, as such, represent more the combined effects of engineering judgment and empirical evidence, rather than either fundamental, mechanistic or statistical concepts. The models for evapotranspiration and runoff and the approach to chemical sorption are good examples; the conceptualizations are simple and constrained by the demands of numerical simulation and the scarcity of available site data. The models cannot describe the full temporal and spatial variability of the transport processes. Individual events at individual sites may differ significantly from model predictions. It is recognized that more fundamental distributed parameter models are primarily used in the research realm, and that parameter estimation for field sites is difficult. Thus, it is unlikely that it will be feasible to use more advanced models in the near future. Because of the limitations of the lumped modeling approach, the reports should include a broader discussion of methods for parameter estimation and a sensitivity analysis to evaluate the precision by which each parameter in the model must be known to avoid an erroneous output.

The report proposes that the analysis be done on a regional basis by defining representative conditions for coastal areas which can be considered alternatives for ocean dumping. This may well be a policy matter which is beyond the purview of this Committee. There are, however, scientific aspects of the approach which need to be considered. The methodology described involves use of simulation models to evaluate the transport processes in this complex environmental system. Some of the input parameters for these models will vary widely within a single region, and will have an impact on the calculated unit contaminant concentration. The six coastal regions will not represent the entire coastline of the United States with respect to the variation in soil, climate, hydrology, and POTW sludge disposal conditions. While the application of the proposed methodology to six sites is a pragmatic and illustrative site-specific method of evaluating the relative risk of alternatives to ocean sludge disposal, it is not the scientific approach needed to assess the range of conditions which may be encountered at any candidate site for alternative land disposal. A formal sensitivity or uncertainty analysis is required to accomplish this.

B. Specific Comments

(Note: Page numbers for specific comments will be referenced to the Land Application methodology report except where indicated otherwise. Many of the specific comments related to the Land Application report will apply also to the Landfilling report since they are nearly identical.)

Page 1: A paragraph or two describing ocean disposal and land disposal methods is recommended.

Page 2: The objective of the study and the audience or intended users should be stated more clearly.

Page 4: The list of contaminants of concern in Table 1.1 is incomplete. Elements such as cadmium, molybdenum, selenium, fluorine, and a number of organics are missing. Contaminants of concern for incineration should be deleted, as the document does not include a treatment of incineration as a disposal option. The table should be accompanied by an explanation for the choice of contaminants and the reasons for inclusion in the land disposal options. The manner in which this list was generated should be explained.

Page 5: The purpose of the report should be more clearly stated. "To evaluate each disposal alternative" should read: "to evaluate the land application alternative..." or "to evaluate the land disposal alternatives" if the two reports are consolidated into one as recommended above.

Page 8: Figure 2.2 shows the representation of the source area, unsaturated zone, and groundwater linkage. The discussion refers to a "standard size source." The meaning of "standard" is not clear. Downgradient aquifer contaminant unit concentrations are computed for various positions in the X-Z plane but only along the centerline of the plume in the direction of flow (Y = 0). If the AT123D model incorporates lateral dispersion, then the selection of the source area would have some effect on the predicted concentrations. The "standard" area and its relationship to the actual area of the landfill should be explained.

Page 9: The assumption that the maximum concentration can be determined from the concentration profiles at different distances downstream in this X-Z plane is dependent on the assumption that this is the plume centerline at all distances downgradient in the plane and that the concentration is maximum at the centerline of the plume. Because the lateral dispersion pattern results in almost uniform concentrations in a region near the centerline (i.e., the curve is flat in the central region), the assumption used is probably satisfactory. Some discussion of this concept should be included.

Page 9: The model computes unit concentrations, which are then adjusted by the specific POTW sludge disposal mass, chemical concentrations, and landfill or land application characteristics. Clearly, the contaminant concentrations are linear functions of the mass of contaminant in the POTW sludge disposal site, which is the product of the POTW sludge disposal mass and the contaminant concentration in the sludge. It is not clear what land disposal characteristics are being referred to and whether the contaminant concentration in the ground water is a linear function of all these site characteristics. For example, are rainfall and cation exchange capacity of the soil underlying the site included in the characteristics considered? Is the contaminant concentration a linear function of these characteristics? Information about these questions should be in the report.

Page 10: It is not clear how annual contaminant loadings to the ground water will be distributed during the loading period to establish the loading input to AT123D. The assumption that the entire loading occurs in a four-month period is acknowledged to be conservative and to yield high results, one wonders why unrealistic results are tolerated just for the sake of simplicity. If the differences are not significant, why not use actual seasonal loadings?

Page 11: (of the Landfill report). There must be a more rational reason for not considering co-disposal sludge landfills in this analysis than simply stating that this issue is being addressed by the Office of Solid Waste. A more definitive rationale is needed.

Page 12: (of the Landfill report). No logic is provided to justify that the post-closure period provides greater opportunity for leaching to occur. Justification should be provided since the opposite could be argued.

Page 13: (of the Landfill report). The effect of total landfill area of the trenched landfill on ground water contaminant concentrations is discussed. The conversion of PRZM loadings to ground water loadings can be obtained by multiplying by the ratio of the actual fill area to the total area only if it is assumed that the plumes from each individual trench are laterally dispersed to merge the plumes within the downgradient distance used in the computation. Why is the unit load concept (1000 kg/ha/yr) not used to take care of the total area effect also? The report states that selected area sizes will be used to represent a range of absolute POTW sludge disposal amounts. Earlier (on page 6) reference was made to a "standard" area source; this seems inconsistent. Greater clarification is needed. The procedure will use "predominant" slopes and soil concentrations in each region. In view of the enormous variation in these characteristics within any of the six regions on the entire coastline of the United States, it will be difficult for the user to determine what is "predominant" (see comment above).

Page 13: (of Land Application report). Under the "Land Application Scenario" heading, the document describes key characteristics of a particular type of land application system selected by the authors for simulation in the study. However, no actual simulations are presented. The detail and specificity presented in this section is not necessary. Model input parameters can be presented in more general terms applicable to all land application systems.

Page 16: (of Landfill report). The equation is confusing. The dimensional units for each variable need to be clarified. The unit concentration concept would be more easily conveyed if this factor were withdrawn from the middle of the equation and placed separately outside the parentheses so that all the other factors are multipliers applied to the unit concentration to obtain the adjusted ground water concentration.

Page 19: (of Landfill report). Seasonal distribution of annual rainfall as an input to the PRZM model is not explained.

Page 21: (of Land Application report). Justification for the use of the Universal Soil Loss Equation (USLE) for the calculation of runoff and erosion needs to be provided. It may be a satisfactory predictor of erosion within a field but its validity in predicting transport to the edge of a field and yield to a stream has not been demonstrated. Use of the soil loss information predicted by this model results in a gross overestimate of soil movement to the edge of a field. Since there are several established models currently being used to predict soil movement to the edge of the field, EPA should use one of these more appropriate models. The Soil Conservation Service has been using the "Chemicals, Runoff, Erosion, and Agricultural Management Systems" (CREAMS) model (3) extensively for this purpose. The Office of Surface Mining has recommended the use of "Sedimentology by Distributed Model Treatment" (SEDIMOT II) model (4) for disturbed lands, and this model has been adopted for such use by a number of states. (Within the past year, an improved model called SEDCAD Plus (Sediment, Erosion, and Discharge by Computer Aided Design) (5) has been released. It is based on SEDIMOT II.) Both CREAMS and SEDIMOT II produce, as part of their output, distribution of soil particle sizes. This is extremely useful in evaluating the characteristics of the exported soil material which leaves the field scale area and enters the surface waters. This provides the user with important water quality insights, such as the proportion of various particle-size classes, including small particles on which pollutants could be adsorbed. In light of these comments, we recommend that the Agency consider the use of CREAMS and SEDIMOT II.

Page 31: The assumption in the EXAMS model that bacterial populations neither grow nor decline simply due to the presence of a chemical is incorrect.

Page 32: The rate of absorption and desorption is not necessarily related to the extent or strength of adsorption.

References: The Committee recommends that citations from peer reviewed journals be used whenever possible. Use of information only from EPA contractor reports and papers presented at meetings but not published, should be used with caution.

C. Corrections

Page 10: (of Landfilling report). On line 9, the value of 25 kg/ha should be changed to 20 kg/ha, if 80% of the 100 kg/ha applied annually occurs in four months.

Page 31: The report should avoid use of the designation 1.E-5M ($1x10^{-5}M$) for concentration.

APPENDIX A

U.S. ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL ENGINEERING COMMITTEE
SCIENCE ADVISORY BOARD

COMMITTEE TO REVIEW REGULATIONS ON OCEAN DUMPING AND REUSE AND DISPOSAL OF SEWAGE SLUDGE

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Executive Secretary

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APPENDIX B

Environmental Engineering Committee
Science Advisory Board
U.S. Environmental Protection Agency

REVIEW OF TECHNICAL MATERIAL SUPPORTING REVISIONS TO PORTIONS OF EPA OCEAN DUMPING REGULATIONS RELATING TO THE LANDFILLING AND LAND APPLICATION ALTERNATIVES TO THE OCEAN DISPOSAL OF POTW SLUDGES

Charge to the Committee

To review and advise the Office of Marine and Estuarine Protection (OMEP) on the overall technical and scientific validity of the documents, prepared by the Office of Policy Planning and Evaluation, Integrated Environmental Management Division, providing the methodology for evaluating the landfilling and land application alternatives to the ocean disposal of POTW sludges. Particular attention should be given to:

a. Their scientific validity.

b. Their consistency of approach and assumptions, including consistency with OWRS methodologies for the evaluation of POTW sludge disposal/reuse options.

c. Modeling and data needs.

APPENDIX C

REFERENCES

1. Donigian, A. S. Jr. and R. F. Bicknell, "Environmental Fate of Contaminants from Sludge Disposal Alternatives to Ocean Dumping - Landfill Methodology Report," prepared for the Environmental Research Center, University of Nevada-Las Vegas and for the Integrated Environmental Management Division, U. S. Environmental Protection Agency, March, 1986.

2. Donigian, A. S. Jr. and R. R. Bicknell, "Environmental Fate of Contaminants from Sludge Disposal Alternatives to Ocean Dumping - Land Application Methodology Report," prepared for the Environmental Research Center, University of Nevada-Las Vegas and for the Integrated Environmental Management Division, U. S. Environmental Protection Agency, March, 1986.

3. Knisel, W.G., Ed. "CREAMS: A Field-Scale Model for Chemicals, Runoff, and Erosion for Agricultural Management Systems," U. S. Department of Agriculture (SEA-AR) Report #26 (Volumes 1-3), Tuscon, AZ, 1980.

4. Warner, R.C. et al. "A Hydrology and Sedimentology Watershed Model. Part II: Users Manual." Dept. of Agricultural Engineering, Univeristy of Kentucky, Lexington, 1982.

5. Nebgen, P.J. and R.C. Warner, "Application of Computer Graphics in the Surface Mining Industry," Proceedings of the 19th International Symposium on Computer Applications in the Mineral Industry (APCOM), Penn State Univ., University Park, PA, April 14-18, 1986.