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WASHINGTON, D.C. 20460

OFFICE OF
THE ADMINISTRATOR

May 7, 1990

EPA-SAB-EEC-90-017

Honorable William K. Reilly
Administrator
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Reilly:

The Science Advisory Board (SAB) has completed its research-in-progress review of the Office of Research and Development's (ORD) Toxics Treatability and Toxicity Reduction (TT&TR) Research Program at the Risk Reduction Engineering Laboratory (RREL), and is pleased to submit its final report. This report resulted from a review meeting on June 22 and 23, 1989 at which time Subcommittee members discussed the program with representatives of ORD and from subsequent evaluations. The major findings and recommendations of the Subcommittee's report are as follows:

1) A Research Plan is Needed: The TT&TR Research Program is very important to the mission and responsibilities of the Agency. However, the SAB found it difficult to properly review the TT&TR Research Program, because of the lack of direction stemming from the absence of an available research plan. A carefully constructed and integrated research plan should be developed that clearly states the program's objectives, goals and rationale.

2) Need for a Common and Prioritized List of Toxicants: The biotic and abiotic fate data base should be greatly expanded, primarily from the published literature. The data collection effort and the program as a whole does not work off a common list of toxicants. To most effectively utilize resources, a common, prioritized list should be developed and used to guide data acquisition, experimental, and modeling efforts.

3) The Modeling Area Needs A Directed, Critical Review: The modeling work observed by the Subcommittee is not state-of-the-art. If present modeling efforts continue, the modeling should be augmented with personnel with greater expertise in quantitative

structure-activity relationships and transport and fate processes. Existing models for integration and analysis of available data on the fate of toxicants in wastewater treatment processes should be critically reviewed and used where appropriate. The assistance of other modeling groups within the EPA and of others with demonstrated expertise in the field should be obtained. The in-house laboratory research should be focused to take advantage of special pilot facilities for important projects, such as model verification. The modeling efforts at RREL would benefit greatly from careful consideration of the guidance given in the EPA/SAB modeling resolution (EPA-SAB-EEC-89-012).

4) A Peer Review is Needed on All Bioassay and Genotoxicity Test Methods Before They are Broadly Applied to Wastewater and Treatment Plant Effluents: The basic concepts used in the Toxicity Reduction Evaluation (TRE) program are sound, but need to be developed further in order to cover the wide range of kinds of wastes, treatment processes, operating conditions and local circumstances. The procedures for characterizing, identifying and applying current knowledge of genotoxins in municipal and industrial wastewaters is so rudimentary that further data will be needed in order to begin to refine protocols for TRE related to health effects. Inappropriate use of toxicity tests can lead to false credibility. To keep the TT&TR Research Program at a state-of-the art level and on track, some type of regular external review should be instituted.

5) A Substantial Technology Transfer Program Will be Required: The effective use of TRE procedures in the field will require that a substantial technology transfer program be put in place.

These recommendations are made with the anticipation that the RREL's TT&TR Research Program will be greatly improved in the future, as the SAB views this program to be very important to the fundamental mission and responsibilities of the Agency.

We are pleased to have had the opportunity to be of service to the Agency, and look forward to your response on this report.

Sincerely,

Raymond C. Loehr

Raymond C. Loehr, Chairman
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EPA U.S. Environmental Protection Agency Washington, DC
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Report of the Toxics Treatability Subcommittee, Environmental Engineering Committee

Review of ORD's Toxics Treatability And Toxicity Reduction Research Program

A SCIENCE ADVISORY BOARD REPORT May 1990

EPA-SAB-EEC-90-017

REPORT OF THE TOXICS TREATABILITY SUBCOMMITTEE OF THE ENVIRONMENTAL ENGINEERING COMMITTEE SCIENCE ADVISORY BOARD

REVIEW OF THE OFFICE OF RESEARCH AND DEVELOPMENT'S TOXICS TREATABILITY AND TOXICITY REDUCTION RESEARCH PROGRAM

NOTICE

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ABSTRACT

The Toxics Treatability Subcommittee (TTS) of the Environmental Engineering Committee (EEC) of the EPA Science Advisory Board (SAB) has prepared a Research-In-Progress report on the Agency's Toxics Treatability and Toxicity Reduction (TT&TR) research program. The goals of the TT&TR research program are to develop protocols to 1) assess the fate of toxicants through wastewater treatment plants, and 2) assess the integrated toxicity of wastewater treatment effluents by use of selected bioassays. The program is organized into three work areas: toxicants treatability, toxicant modeling, and toxicity reduction evaluations. The TT&TR research program is considered by the SAB to be critically important in meeting National water quality goals and to have many excellent elements.

The SAB's findings and recommendations relate to the program research plan, toxicants treatability, toxicant modeling, toxicity reduction evaluations and bioassay and genotoxicity testing. Highlights of the SAB recommendations are that:

1) A carefully constructed and integrated research plan should be developed,

2) A common and prioritized biotic and abiotic fate data base and list of toxicants should be greatly expanded, primarily from the published literature,

3) The modeling area needs a directed, critical review,

4) A peer review is needed on all bioassay and genotoxicity tests before they are broadly applied to wastewater and treatment plant effluents,

5) A substantial technology transfer program will be required.

Key Words: toxics treatability, toxicity reduction, toxics treatability and toxicity reduction research

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1.0 EXECUTIVE SUMMARY

A research in progress review of the Agency's Toxics Treatability and Toxicity Reduction (TT&TR) Research Program was conducted at the Risk Reduction Engineering Laboratory (RREL) on 22-23 June 1989 by the Toxics Treatability Subcommittee (TTS) of the Environmental Engineering Committee (EEC) of the Science Advisory Board (SAB). The stated objectives of the TT&TR Research Program are to develop protocols to 1) assess the fate of toxicants through wastewater treatment plants, and 2) assess the integrated toxicity of wastewater treatment effluents by use of selected bioassays. The program is organized into three work areas: toxicants treatability, toxicant modeling, and toxicity reduction evaluations. The TT&TR Research Program, considered by the SAB to be critically important in meeting National water quality goals, has many excellent elements. Some findings and recommendations for improvement of the program follow.

1.1 Program Research Plan

The SAB found it difficult to properly review the TT&TR Research Program because of the lack of an available research plan. A carefully constructed and integrated research plan should be developed that clearly states the Program's objectives and goals, the rationale for each, the interactions and interactiveness of program components, and the responsiveness of the program to Agency and National needs.

The lack of an available research plan does not indicate that the research that has been performed and is in progress is not appropriate or worthwhile. However, since the SAB places such great importance on this area of research and the topic is so broad and interconnected with other Agency research and policy making efforts, it is essential that there be a research plan for the program to keep it focused and on budget.

1.2 Toxicants Treatability

The SAB believes that past and ongoing biodegradation work on single compounds, if properly analyzed and interpreted, will suffice to support current program needs, and that more laboratory work in this area by the EPA should not be of high priority. The treatability data base on single compounds should be expanded based on data in the existing literature and updated as new information is published. The fate of mixed substrates in treatment processes should receive greater attention. Since the RREL has unique capabilities in the Agency for pilot plant work with mixed substrate raw wastewaters, the TT&TR Research Program should pursue mass balance studies for specific chemicals and classes of chemicals including all applicable abiotic and biotic fate mechanisms, not with the view of getting closure, but rather to point the way to key mechanisms of removal. These studies

should be complemented with suitable analyses for assessing reductions in toxicity throughout the various stages of the treatment processes being evaluated. Studies on the fate of specific chemicals in mixed soluble substrates in aerobic treatment systems seem appropriate; however, the fate of sorbed or particle-bound toxicants should be given special emphasis in anaerobic systems, since these processes are used mostly for sludge digestion. The procedure of adding spiked compounds to wastewater streams can lead to erroneous results, since the added compounds may fail to enter into the waste matrix in a representative fashion.

1.3 Toxicant Modeling

The RREL is developing a modeling approach for estimating fate-in-treatment of organic toxicants in primary/activated sludge wastewater treatment systems. It is understood that this model is to be used by consultants and regulators for 1) guidance on how to treat toxic organic compounds, and 2) guidance on whether RCRA and CERCLA liquid streams may be disposed in a POTW. The modeling effort, at the present time, is not intended to provide guidance in the assessment or prediction of residual toxicity in POTW effluents.

Some of the primary concerns of the SAB about current modeling efforts in support of the TT&TR Research Program include 1) the need for assessment of the extent to which a new model needs to be formulated versus the adaptation of existing, and perhaps simpler, models, 2) the need for model confirmation and sensitivity and uncertainty analysis, 3) the need for improved coordination and interaction between process and transport and fate scientists/engineers and modelers, 4) the serious need for peer review at an early stage of model development, and 5) the adequacy of the data base on reaction rate constants.

TT&TR modeling efforts at RREL would benefit greatly from careful consideration of the guidance on selection and use of models given in the EPA/SAB modeling resolution (EPA-SAB-EEC-89-012). It also appears that existing, simple models could be adapted, calibrated, and used for prediction of chemical fate in wastewater treatment plants. If present modeling efforts continue, the modeling team should be augmented with personnel with greater expertise in quantitative structure activity relationships and transport and fate processes. In addition, immediate attention should be given to sensitivity analyses to determine when, to what extent, and at what level each parameter being considered influences or significantly affects the transport and fate predictions for specific chemicals. Results of model predictions, during early stages of model development, should be compared to data obtained in parallel, coordinated pilot plant experiments in the toxicants treatability research initiative.

A directed, critical review of existing models that could be used for toxicant modeling should be undertaken immediately by those skilled in the art. Current in-house and contractor expertise at RREL in modeling appears inadequate to support the needs of the TT&TR Research Program.

1.4 Toxicity Reduction Evaluations

The objective of the Toxicity Reduction Evaluations (TRE) area is to determine the toxicity of wastewaters before and after treatment in order to determine the reduction in toxicity by treatment processes and thereby to devise ways to adjust the treatment processes (or influent waste streams through elimination or pretreatment to remove specific types of contaminants not effectively treated) or incorporate additional treatment processes to achieve toxicity reduction goals. The general methodology involves use of bioassays for determining the toxicity of complex mixtures of organic compounds and/or metals which contribute to the toxicity without chemical analysis of specific elements or compounds. The basic concepts used in the TRE program are sound, but need to be developed further in order to cover the wide range of kinds of wastes, treatment processes, operating conditions, and local circumstances at operating publicly-owned treatment works.

The protocols for Toxicity Identification Evaluation (TIE) developed by the EPA Duluth Laboratory seem appropriate for use in assessing and identifying sources of toxicity in the TRE program. The procedures for characterizing and identifying genotoxic substances also need further development. Current knowledge of genotoxins in municipal and industrial wastewaters is so rudimentary that further data will be needed in order to begin to refine the protocols for TRE related to health effects. Analysis of genotoxins in wastewater treatment plant effluents is needed and appropriate, and we concur with RREL personnel that strong caution must be exercised in any attempt to translate results obtained to human health risk analysis.

Basically, TRE relies on detective work supported by a variety of direct and indirect analytical tools, procedures, and protocols. If TRE is properly exercised by very knowledgeable personnel, sources of toxicity may be identified and reduced. A substantial technology transfer program will be required to support the effective use of TRE procedures in the field.

2.0 INTRODUCTION

A research in progress review of the Agency's Toxics Treatability and Toxicity Reduction (TT&TR) Research Program was conducted at the Risk Reduction Engineering Laboratory (RREL) on 22-23 June 1989. The review was conducted by the Toxics Treatability Subcommittee (TTS) of the Environmental Engineering Committee (EEC) of the Science Advisory Board (SAB). Extensive written documentation on the program's projects was provided to the Subcommittee as background before the review (Appendix D). The format for the review consisted of 1-1/2 days of formal presentations by laboratory and program management and by both in-house and contractor technical personnel, followed by informal discussions which included representatives from EPA headquarters in Washington, D.C. (Appendix B).

Program Goals and Tasks

RREL Director Mr. E. Timothy Oppelt opened the review by succinctly stating that the goals of EPA's TT&TR Research Program are to:

(1) Assess the fate of toxicants through wastewater treatment plants, and

(2) Assess the integrated toxicity of wastewater treatment effluents by use of selected bioassays.

To accomplish these goals, the program is currently organized into three major work areas:

(1) Toxicants Treatability - development of experimental protocols for and generation of relevant data on the abiotic (sorption and volatilization) and biotic (aerobic and anaerobic biodegradation) components of the fate of toxicants in biological wastewater treatment processes.

(2) Toxicant Modeling - development of a modeling approach for estimating fate-in-treatment of organic toxicants in primary/activated sludge wastewater treatment plants based on experimental data and the chemical and structural molecular properties of toxicants.

(3) Toxicity Reduction Evaluations - development of protocols for a) systematically conducting Toxicity Reduction Evaluations at municipal and industrial wastewater treatment plants to determine the efficacy of the treatment process, and b) Toxicity Identification Evaluations to separate and identify the sources (discharges) of toxicity to wastewater treatment plants.

Information and evaluation tools are intended to provide support for regulatory decisions on:

(1) Pretreatment requirements for specific toxicants and wastewater treatment plant effluent toxicity,

(2) Treatment needs for wastewater discharges into "open" oceans,

(3) Water quality suitability of aqueous discharges from treatment, storage and disposal facilities (TSDF) used in controlling listed aqueous RCRA wastes,

(4) Banning or restricting production of new or existing chemicals, and

(5) Efficient use of waste minimization and waste prevention techniques to support the national initiative on pollution prevention through identification of specific industrial sources of toxicants and/or toxicity.

One highly visible, immediate need for output from this program was voiced in question form by a representative of the EPA Office of Water Programs: "Can I take a liquid stream from a Superfund Site and put it into a wastewater treatment plant?" The fact that extant knowledge on the fate of toxicants in wastewater treatment processes, after decades of study and operation, is inadequate to provide acceptable guidance on this question, clearly demonstrates the need for appropriate effort in the Agency on Toxics Treatability and Toxicity Reduction.

3.0 RESEARCH PLAN

The SAB-EEC Toxics Treatability Subcommittee (TTS) was hindered in this review of the TT&TR Research Program by the lack of an available Research Plan. Without the plan, it was difficult to assess how the research projects that were presented would be utilized to satisfy the program goal: to assess the fate of toxicants and their toxicity through wastewater treatment.

For example, it was not clear if the Toxicity Identification Evaluation (TIE) work was intended to supplant the toxics treatability laboratory studies. The toxics treatability studies are compound specific and deal only with single compound situations, while the TIE work deals with a characteristic that may be exhibited by a wastewater. While it is true that a toxic compound will exhibit the characteristic of toxicity, in the real world it is difficult, if not impossible, to break down the toxicity characteristic into its component parts. That being the case, it seems only logical that more attention needs to be paid to identifying those compounds that contribute to the toxicity of a given wastewater. Further, how do the TIE and Toxicants

Treatability efforts fit into the Research Plan?

Likewise, it was unclear how a compound-specific mathematical model relates to the TIE work. The fate of compound "x" through a wastewater treatment plant is only of academic interest. The real issue is how does the toxicity of a complex wastewater decrease through wastewater treatment?

This is not to say that the research that has been performed and is currently underway is not worthwhile. This is an extremely important research area that is well worth the Agency's effort. However, since the research topic is so broad and there are so many significant interactions both within this program and with other Agency research and policy making efforts, it is essential that there be a research plan for the program to keep it focused and on budget.

A research plan is a roadmap and as such has many benefits, not the least of which are:

- establishing resource needs,
- setting priorities,
- delineating interactions, and
- setting milestones.

The first step in developing a research plan is to clearly identify the objectives. At several times during the review, various TTS members asked what the objective of the research was. Rather than a succinct statement that the presented research was designed so that it would be used for a specific purpose, several ill-defined and hypothetical uses for the work were presented in a fashion that gave the impression that they were developed after the fact to justify having done the research.

It is imperative that program priorities be firmly established. During the discussion of treatability protocols, RREL staff indicated that they were hindered by the lack of available precise analytical tools, yet they plan to continue developing treatability data for various compounds. If they cannot adequately monitor what is taking place in their reactors, then they should cease all future treatability testing until they can measure the necessary parameters to an appropriate level of precision that would allow them to be confident of the quality of the data. Methods development needs to be the top priority. This goes for both analytical procedures as well as bioassay/TRE methodologies.

This program cuts across several Agency efforts and must be coordinated with them in order to avoid duplication of effort and thus the wasting of valuable Agency resources. At a minimum, it should be made clear how the derived information relates to past, current, and planned initiatives in the areas of pollution prevention, air toxics, solid waste, drinking water standards, water

pollution control and model development.

An effective research plan needs to be a dynamic document that is frequently updated at appropriate intervals in response to changes in Agency budgets and priorities. It is acknowledged that national environmental priorities will constantly change and with it the Agency's focus. The program needs to adjust accordingly. Having a research plan in place will allow this research effort to be assigned its rightful priority when it comes time to allocate the Agency's resources.

Once a plan has been developed, it may become evident that significant additional resources must be obtained in order to attain stated objectives by agreed-upon times. This is important to know during the annual budgeting process. For example, adjustments appear to be needed in the research effort to assess mutagenicity caused by chlorinating wastewater effluents. If chlorination does make a wastewater more mutagenic, then a well-documented decision must be made as to what additional work must be undertaken to address the problem.

Another factor that must be given consideration in the research plan is how toxicity should be defined for the purpose of this research. It is apparent that different materials are toxic to different organisms in different concentrations under different conditions. If this research is to focus on toxicity, as the title implies, then a consistent set of toxicity standard measurements should be established to interrelate the projects. Is the objective to reduce toxicity to humans, to selected invertebrates, or to all living organisms? This is a difficult question, but one that must be resolved so that the research can serve as a useful guide for policymakers.

4.0 TOXICANTS TREATABILITY

4.1 Treatability Testing Procedures and Data for Biodegradation in Conventional Wastewater Treatment

4.1.1 Aerobic

The aerobic biodegradation work on single compounds done both in-house and by RREL contractors has resulted in a useful data base on a limited number of chemicals. The approach has been to develop biodegradation protocols that will yield intrinsic kinetic parameters that are independent of the system and biomass concentration. However, kinetic parameters for specific chemicals in treatment processes will be influenced by the type and physiological state of the biota present and by interactions between chemicals in complex mixtures.

The contractor effort in this area to date has been excellent. Past and ongoing biodegradation work on single compounds, if

properly analyzed and interpreted, will suffice to support program needs. Future efforts on single compounds should be directed primarily to greatly expanding the available data base by review and analysis of existing literature. Expansion of the data base for all fate mechanisms should be focused by development of a common, prioritized list of toxicants.

Since the RREL has unique capabilities for pilot plant work and the ultimate objective of the TT&TR Research Program is to assess and predict the fate of single compounds in complex mixtures in wastewater treatment, future in-house biodegradation research should be conducted with mixed substrates at pilot plant scale. Both biotic and abiotic fate parameters should be evaluated in coordinated studies where a mass balance approach is used.

4.1.2 Anaerobic

Low solubility organic compounds tend to sorb and partition to biomass solids during conventional aerobic wastewater treatment processes. Depending on the compound, degradation may be incomplete or may not occur. Hence, significant quantities of toxic organics may be removed from the process in wasted activated sludge solids that require further treatment before final disposal.

Anaerobic biodegradation work currently in progress by contract in support of the TT&TR Research Program is expertly done; however, the protocol employed focuses on soluble substrates and does not simulate actual conditions. Hence, future anaerobic degradation work should be done on particle-bound toxicants to simulate anaerobic sludge digestion. Data collected to date will be useful for predicting the fate of toxicants in processes such as sequencing batch reactors but will be of limited use in assessments of conventional wastewater treatment processes.

In both aerobic and anaerobic biodegradation work, caution is urged in the use of spiked toxicants. If the experimental protocol does not assess the physical state of the spiked chemical in the test system, the assumption that the toxicant has entered into the waste matrix in a manner similar to actual waste streams may be erroneous. Since sorption strongly influences bioavailability, overestimates of biodegradability can result.

4.2 Treatability Testing Procedures and Data for Sorption and Volatilization in Conventional Wastewater Treatment

4.2.1 Sorption

This work is being performed to provide information on abiotic processes affecting removal of organic constituents in wastewater treatment systems. The results from this work will be used for modeling individual removal mechanisms in primary/activated sludge wastewater treatment systems. The sorption studies are focusing on

the partitioning of organic compounds onto activated sludge microbial solids.

The present research would benefit from close examination of studies of similar scope on sorption of hydrophobic solutes onto microbial solids and/or soil. Various other research groups have examined sorption of hydrophobic organic solutes onto microbial solids, and this information should be synthesized and interpreted with regard to the results from the current laboratory measurements. This will help confirm the degree of commonality and conformity among the data bases. Also, this integration of experimental results may suggest that sufficient data currently exist for modeling purposes to estimate sorption partitioning of hydrophobic solutes onto microbial solids.

Likewise, the large amount of information on sorption of hydrophobic compounds onto soil is potentially very useful for assessing the extent to which soil-sorption correlations are applicable to microbial solids as well. Current evidence suggests that it may be reasonable to assume that equilibrium sorption partitioning of hydrophobic organic solutes onto bio-solids is analogous to partitioning on soil. For these reasons the current laboratory effort should be focused to determine the connections between the recent laboratory results and the other data bases.

The soil sorption literature also provides an explanation for the "solids effect", and discusses the need to be concerned for separation of suspended micro-particulate matter in order to attain reliable laboratory estimates of the partition coefficient for very hydrophobic (high K_{ow}) solutes. Also, longer equilibration times may be warranted for very hydrophobic solutes than indicated by screening tests for more polar solutes (e.g., methylene blue).

It has been demonstrated for soil suspensions that hydrophobic solutes at low concentrations (e.g., the lesser of about 1 mg/L or one-half aqueous solubility) sorb independently from solute mixtures. This should be evaluated for microbial solids, as modeling and predictions would then be simplified.

An evaluation should be performed in order to understand the effect of wastewater treatment plant effluent containing surface-active material on solute sorption. The objective of this work should be viewed as a screening assessment designed to answer the question of whether there is any significant effect on sorption of hydrophobic compounds owing to aqueous-phase organic byproducts from microbial treatment. A careful literature compilation would suggest the degree of experimentation which may (or may not) be warranted.

4.2.2 Volatilization

The volatilization studies should be directed towards

validating a modeling approach for integrating the contribution of volatilization on removal in primary/activated sludge treatment processes. For this reason, well-controlled laboratory experiments are probably best used to compare the potential influence of wastewater matrix effects in relation to clean water results and to examine biooxidation-sorption-volatilization rate constants under a competitive mode. In general, for volatile solutes ($K_H > 10^{-4}$ atm-m^3/mole) the wastewater matrix effects may not be significant with respect to quasi-equilibrium partitioning between gas and liquid phases. However, surface-active material present in wastewater may affect the rate of mass transfer for certain VOCs during aeration in activated sludge processes. This and other issues related to VOC removal in activated sludge facilities may be addressed by literature assessment and by a few, well-designed pilot plant studies.

The research plan for the TT&TR Research Program should address the proportionality of rate transfer coefficients between selected VOC and dissolved oxygen. In this manner it may be determined if the transfer rates of dissolved oxygen and organic solutes are inhibited approximately to the same degree. Current research suggests this may be the case, and this simplifies modeling. The research should also assess whether gas-phase saturation has an effect on mass transfer from water to air under conditions of activated sludge treatment; this assessment should take into account the differences between mechanical surface aeration and bubble aeration. These issues should be addressed first by synthesis of available literature and, if necessary, modeling to identify which, if any, classes of compounds are sensitive to these issues.

The RREL has unique capability to perform the necessary fate and transport studies with a pilot test and evaluation facility located in Cincinnati, Ohio. Therefore, to the extent possible, it is recommended that research on volatilization of VOCs be incorporated with validation of the modeling approach for integrating removal mechanisms. This work would provide the dual benefit of aiding model verification, while suggesting a focus for laboratory-based volatilization studies through reconciliation of departure between prediction and observation.

The in-house laboratory research at RREL is characterized partly by the execution of repetitive measurements to identify compound properties. In this regard, the RREL is cautioned to prevent its experimental research from becoming preoccupied with routine measurements directed towards developing "more points along the curve". The in-house laboratory research should be focused to take advantage of special pilot facilities for important projects such as model verification.

5.0 TOXICANT MODELING

The TT&TR Research Program has developed a modeling approach for estimating fate-in-treatment of organic compounds in primary/activated sludge wastewater treatment systems. It is understood that this model is to be used by consultants and regulators for: 1) guidance on how to treat toxic organic compounds, and 2) guidance on whether RCRA, CERCLA and industrial liquid streams may be disposed to a POTW.

This modeling effort was the subject of extensive discussion by the Toxics Treatability Subcommittee. Some of the principal concerns include: the need for assessment of existing, and perhaps simpler, models; the need for confirmation and sensitivity and uncertainty analysis; the need for improved coordination and guidance; and the need for peer review.

5.1 Inter-Laboratory Coordination and Adaptation of Existing Models

Various laboratories within the EPA have expertise on development of models to aid prediction of fate and transport of organic compounds. Such models are intended for use by regulators and engineers/scientists. This modeling expertise within the EPA apparently has not been consulted for this project. This expertise may help prevent duplication of effort, as certain components of the model may already exist elsewhere. Indeed, a useful subcomponent model on VOC emissions for an integrated model has been supported by the RREL, but apparently not acknowledged as being employed in the model.

A directed critical review of existing models needs to be undertaken. Other academic and industrial research groups have been working on fate-in-treatment models, and this body of work needs to be consulted in order to determine the extent to which a new model needs to be formulated versus the adaptation of existing, and perhaps simpler, models.

5.2 Model Organization

The fragment constant and group contribution approach for predicting biological degradation rate is interesting, but not sufficiently advanced for inclusion in a general-purpose model.

Existing information on toxicant degradation rate constants in activated sludge wastewater treatment needs to be compiled and evaluated. The selection of microbial degradation rate parameters in the model should include the versatility to utilize appropriate literature-based rate constants in the forms proposed by the original investigators. It is overly optimistic to presume that a simple, self-consistent data base will suffice for this purpose. Therefore, the modeling approach should permit flexibility for

extraction of appropriate degradation rate constants (i.e., first-, zero-, and mixed-order). Model confirmation, sensitivity and uncertainty analysis will indicate those compounds and rate constants for which the data base may be consolidated, as well as indicate where the data base is particularly weak.

5.3 Model Validation

The model being used in the TT&TR Program is not validated with respect to: 1) EPA RREL pilot plant data, 2) other EPA treatment system data such as the 1982 "40 POTW Study", 3) other field data such as the Chicago MSD and the Seattle metro studies, and 4) other proposed models for either overall fate-in-treatment or submodels for specific processes.

5.4 Model Sensitivity/Simplification

As part of the model verification process, the fate-in-treatment model needs to be tested with various data bases, and assessed in comparison with other proposed models. In this way, the fate-in-treatment model will be evaluated for completeness and inadequacies. This will also provide an appropriate set of case studies to educate potential users on the overall utility of the approach.

5.5 Resources for Model Development and Validation

It appears that the fate-in-treatment model is intended to be one of the principal products of the "toxics treatability" research. However, this model seems to be under-emphasized in terms of programmatic focus and under-funded in terms of available resources.

The fate-in-treatment model is inadequate in its present form. Consideration should be given to allocating this project to a group or team that has expertise in treatment plant operations, as well as being specifically accustomed to the protocols and concerns for development of general-use software for environmental fate assessment. More resources may have to be directed to this task.

6.0 TOXICITY REDUCTION EVALUATIONS

The Subcommittee reviewed three documents which describe the protocols for Toxicity Reduction Evaluations (TRE). These include the Toxicity Reduction Evaluation Protocol for Municipal Wastewater Treatment Plants (EPA/600/2-88/062), the Generalized Methodology for Conducting Industrial Toxicity Reduction Evaluations (EPA/600/2-88/070), and the report by Christian and Cody entitled, "Cytotoxicity and Mutagenesis Methods for Evaluation of Toxicity Removal from Wastewaters."

The objective of TRE is to determine the toxicity of wastewaters before and after treatment in order to determine the

reduction in toxicity by treatment processes which remove toxic substances and thereby to devise ways to adjust the treatment processes or incorporate additional treatment processes which will remove more of the toxicity. The general methodology involves use of bioassays for determining the toxicity of the complex mixture of organic compounds and/or metals which contribute to the toxicity without chemical analysis of specific elements or compounds. The protocols use Toxicity Identification Evaluation (TIE) procedures. After the toxicity source is evaluated, then source reduction or modifications in the pretreatment processes can be investigated with the aim of toxicity reduction. The industrial TREs also put great emphasis on investigation of housekeeping practices because of their importance in toxicity reduction.

6.1 Evaluation of TRE Protocols

The basic concepts presented in all of the TRE protocols reviewed are sound. However, further development is needed in order to cover the wide range of kinds of wastes, treatment processes, operating conditions, and local circumstances. In particular, the procedures for characterizing and identifying genotoxic substances and location of their sources need further development. Current knowledge of genotoxins in municipal and industrial wastewaters is so rudimentary that further data will be needed in order to begin to refine the protocols for TRE involving this kind of toxicity.

6.2 Need for Technology Transfer System

Basically, TRE is detective work: it requires use of very knowledgeable personnel to search for the identities and sources of very elusive substances. Like much detective work, the user must have an intimate knowledge of the system and the basic principles which control its behavior. Otherwise, one may be misled in the toxicity evaluation. But detective work is usually a mixture of science and intuition. TRE procedures seem to be no exception. One danger is that if these protocols are turned over to persons who are not highly competent waste treatment professionals, they may not lead successfully to location of the sources of toxicity and to devising methods of reduction. As a professional gains experience with TREs, intuition may very well sharpen. In order that each person does not have to labor through the experience, or "school-of-hard-knocks", individually, a good technology transfer system should be established so TRE detectives can learn from others' experience as well.

6.3 Need for Realistic Expectations and Continued Refinement of TRE Protocols

A second, and probably greater, danger is that sources of toxic substances cannot be identified because the toxics are ubiquitous or are from such disparate sources that a single source cannot be

isolated. This might occur if a community has many similar industries producing similar mixtures of toxic substances as, for example, a metal plating center or a petrochemical industrial park. This does not obviate the need for the proposed TRE procedures, but it suggests the importance of realistic expectations and the benefits of further refinement of techniques gained with experience.

6.4 Status of Knowledge of Genotoxicity

Genotoxin TREs are in the rudimentary stage of development. We agree with the TT&TR Research Program that genotoxic assessment cannot be used for human health risk assessment, because there is no known way with mixtures to link a genotoxic response in a bioassay using lower target organisms to mutagenic or carcinogenic response in humans and the probability of adverse health effects in a human population. The protocol proposed by the TT&TR Research Program is to use genotoxic bioassays to identify wastes which contain genotoxins and those which do not, so that the source of the mutagens can be identified. It is hoped then that the waste from the individual source can be characterized to pinpoint the few suspect mutagenic compounds. Only if adequate epidemiological data are available for these compounds can a human health risk assessment be completed for the specific compounds or mixture of compounds. Nevertheless, the genotoxicity bioassays are useful in evaluating fate-in-treatment and reduction in genotoxicity by treatment or pretreatment modifications.

The use of a variety of different organisms with different genotoxic endpoints in the bioassay is very good. The proposed protocols use the Ames/Salmonella assay, which tests for reverse mutations in bacteria, and induction of sister chromatid exchange in Chinese hamster ovary cells. As more is learned about genotoxic properties of wastes and the genotoxic TREs are refined, other bioassays to identify mutagens which produce forward mutations or frame-shift mutations might be added to the bioassay procedures.

6.5 Interpretation of Genotoxic TRE Results

Wastewater treatment professionals and environmental toxicologists in general are not adequately familiar with genotoxins in wastes; few are able to interpret results of bioassays for mutagenic activity with any confidence. Most do not know what a specified number of revertants reported in an Ames assay means. They have no frame of reference with which to compare it. For this reason, it would be helpful if EPA took steps to determine from the existing literature the mutagenic activity of some common substances for comparison. As results of comparable mutagen assays for drinking water, for surface waters, for common household exposure, etc. are published, these comparisons will facilitate interpretation of bioassays. Then the TRE personnel can know better which tests have priority for further follow-up.

APPENDIX A - THE CHARGE TO THE SUBCOMMITTEEE

SCIENCE ADVISORY BOARD

REVIEW OF THE

TOXICS TREATABILITY AND TOXICITY REDUCTION PROGRAM

The Toxics Treatability and Toxicity Reduction Program in the Risk Reduction Engineering Laboratory (RREL) is developing evaluation tools to support the Agency's regulatory decision processes for management of specific aqueous wastes. The evaluation tools include:

- Experimental protocols and data on representative toxicants for evaluating treatability (biodegradation, inhibition, sorption, and volatilization) in biological wastewater treatment processes.
- Experimental data on fate-in-treatment of representative toxicants for the primary/activated sludge process and for alternate wastewater treatment systems.
- A model for estimating fate-in-treatment of organic toxicants from their chemical and structural molecular properties in primary/activated sludge treatment.
- Case history experimental data for the control of effluent toxicity from municipal and industrial wastewater treatment plants.
- Protocols for systematically conducting Toxicity Reduction Evaluations (TREs) at municipal and industrial wastewater treatment plants.

These evaluation tools provide support for regulatory decisions on:

- Pretreatment requirements for specific toxicants and effluent toxicity.
- Treatment needs for wastewater discharges into "open" oceans.
- Water quality suitability of aqueous discharges from treatment storage and disposal facilities (TSDF) used in controlling listed aqueous RCRA wastes.
- Banning or restricting production of new or existing chemicals.

- The efficient use of waste minimization or waste prevention techniques through identification of specific industrial sources of toxicants and/or toxicity.

The Science Advisory Board in its review of the toxics treatability and toxicity reduction program is specifically requested to evaluate:

- The approaches and methods used or planned in the experimental treatability protocol developed for evaluating aerobic and anaerobic treatability of toxicants in wastewater, and the need for expanded fate-in-treatment data on toxicants in biological wastewater treatment.

- The approaches used for studying and modeling individual removal mechanisms (biodegradation, sorption and volatilization) in primary/activated sludge wastewater treatment, and the modeling approaches for integrating the individual mechanisms into an overall toxicant fate-in-treatment model.

- The level and quality of data needed to establish a satisfactory model for estimating fate-in-treatment of toxicants in primary/activated sludge processes for (a) overall guidance assessment, and (b) treatment plant specific decisions.

- The TRE approaches for municipal and industrial wastewater treatment plants, including the planned TRE health effects study.

- The distribution of available resources in the research program.

The board is requested to provide recommendations for improving the toxics treatability and toxicity reduction program including specific recommendations on:

- The appropriateness of developing fate-in-treatment predictive capabilities for the two application areas described above.

- The technical soundness of the TRE health effects study and possible alternative approaches.

APPENDIX B - TOXICS TREATABILITY SAB SIGN-UP LIST OF ATTENDEES/ GUESTS, JUNE 22 AND 23, 1989

Toxics Treatability SAB Sign-Up List
Attendees/Guests, 22 June 1989

Name	Affiliation/Address
Jack Kooyoomjian	SAB Staff/EPA HQ
Wayne Kachel	Exxon, Benicia, CA (SAB)
Richard G. Luthy	Carnegie Mellon University (SAB)
E. Timothy Oppelt	EPA-RREL
Clyde J Dial	EPA-RREL
Manuel P. Del Pino	Union Carbide Corp.
Kuyen Li	Lamar University
Sheila L. Rosenthal	EPA-OHEA
Rakesh Govind	University of Cincinnati
Richard A. Dobbs	EPA-WHWTRD RREL
Fred Bishop	EPA-WHWTRD RREL
Alden Christianson	EPA-WHWTRD RREL
Sid Hannah	EPA-WHWTRD RREL
James C. Young	University of Arkansas
Ben B. Ewing	University of Illinois (SAB)
C. H. Ward	Rice University (SAB)
Henry H. Tabak	EPA-WHWTRD RREL
Yonggui Shan	EPA-WHWTRD RREL
Eric Cohen	EPA, OMPC-Washington, DC
Atal Eralp	EPA, OMPC-Washington, DC
Ruth Lopez	OWRS/EPA HQ
James M. Lelee	E. G. Jordan, Portland, ME
William Clement	Battelle, Columbus
Michael Jelus	EPA-RREL/TAB, Cincinnati
Richard Brenner	EPA-RREL/TAB, Cincinnati
C. P. Leslie Grady, Jr.	Clemson University
B. Daniel	EPA-HERL
John Meier	EPA-HERL

Toxics Treatability SAB Sign-up List
Attendees/Guests, 23 June 1989

Name	Affiliation/Address
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Kuyen Li	Lamar University
Fred Bishop	EPA-RREL
John Meier	EPA-HERL
C. H. Ward	Rice University (SAB)
Richard A. Dobbs	RREL
James C. Young	University of Arkansas
Yonggui Shan	EPA-RREL
Richard G. Luthy	Carnegie Mellon University
Wayne M. Kachel	Exxon (SAB)
Eric Cohen	EPA-OMPC Washington, DC
Ruth Lopez	EPA-OWRS HQ Washington, DC
Bernie Daniel	EPA-HERL
Ben B. Ewing	University of Illinois (SAB)
Atal Eralp	EPA-OW-OMPC
Clyde J. Dial	EPA-RREL
E. Timothy Oppelt	EPA-RREL
Alden Christianson	EPA-RREL
Henry H. Tabak	EPA-RREL
Kathy S. Clench	EPA-HERL
Sheila F. Rosenthal	EPA-OHEA
Trent R. Lewis	Consultant, Cincinnati, OH

APPENDIX C - GLOSSARY OF TERMS

ACS-	AMERICAN CHEMICAL SOCIETY
AWMA-	AIR AND WASTE MANAGEMENT ASSOCIATION
CERCLA-	COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION AND LIABILITY ACT, or (SUPERFUND)
EEC-	ENVIRONMENTAL ENGINEERING COMMITTEE OF THE SCIENCE ADVISORY BOARD OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
EPA-	U.S. ENVIRONMENTAL PROTECTION AGENCY (ALSO USEPA)
EPA/OMPC-	U.S. ENVIRONMENTAL PROTECTION AGENCY/OFFICE OF MUNICIPAL POLLUTION CONTROL PROGRAMS
EPA/OW/ OMPC-	US. ENVIRONMENTAL PROTECTION AGENCY/OFFICE OF WATER/OFFICE OF MUNICIPAL POLLUTION CONTROL
EPA/OWRS-	U.S.ENVIRONMENTAL PROTECTION AGENCY/ OFFICE OF WATER REGULATIONS AND STANDARDS
HERL/Ci-	HEALTH EFFECTS RESEARCH LABORATORY, CINCINNATI, OHIO OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
HQ-	HEADQUARTERS OF THE EPA, WASHINGTON, D.C.
I&EC-	INDUSTRIAL AND ENGINEERING CHEMISTRY DIVISION, INC. OF THE AMERICAN CHEMICAL SOCIETY
JWPCF-	JOURNAL OF THE WATER POLLUTION CONTROL FEDERATION
MSD-	METROPOLITAN SANITARY DISTRICT
OHEA-	OFFICE OF HEALTH AND ENVIRONMENTAL ASSESSMENT OF THE OFFICE OF RESEARCH AND DEVELOPMENT, U.S. ENVIRONMENTAL PROTECTION AGENCY
OMPC-	OFFICE OF MUNICIPAL POLLUTION CONTROL OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
ORD-	OFFICE OF RESEARCH AND DEVELOPMENT OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
POTW-	PUBLICLY OWNED TREATMENT WORKS
RCRA-	RESOURCE CONSERVATION AND RECOVERY ACT
RREL-	RISK REDUCTION ENGINEERING LABORATORY OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
RREL/TAB, Ci-	RISK REDUCTION ENGINEERING LABORATORY/TREATMENT ASSESSMENT BRANCH, OF THE EPA, CINCINNATI, OHIO
SAB-	SCIENCE ADVISORY BOARD OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY
TAPPI-	TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY
TIE-	TOXICITY IDENTIFICATION EVALUATION
TRE-	TOXICITY REDUCTION EVALUATION
TSDF-	TREATMENT, STORAGE AND DISPOSAL FACILITIES
TTS-	TOXICS TREATABILITY SUBCOMMITTEE OF THE ENVIRONMENTAL ENGINEERING COMMITTEE OF THE SCIENCE ADVISORY BOARD (ALSO REFERRED TO AS THE SUBCOMMITTEE)
TT&TR-	TOXICS TREATABILITY AND TOXICITY REDUCTION
VOC-	VOLATILE ORGANIC CARBON
WHWTRD-	WATER AND HAZARDOUS WASTE TREATMENT RESEARCH DIVISION OF THE RISK REDUCTION ENGINEERING LABORATORY OF THE U.S. ENVIRONMENTAL PROTECTION AGENCY

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