Proceedings of the Environmental Protection Agency
PUBLIC MEETING ON WASTE LEACHING

Due to the critical importance of protecting the nation's ground water resources, laboratory leaching of wastes is a valuable tool for making waste management decisions. Leaching test methods are used to assess: (a) whether a waste should be classified as a hazardous waste, (b) waste treatment process effectiveness, and c) whether land disposal is an appropriate means of managing particular wastes. Leaching tests and data also serve as the source terms for the subsurface fate and transport modeling that is a key component of the risk assessment process on which waste management decisions (such as listing and de-listing) are based. They form the basis for decisions on assessing the effectiveness of waste stabilization processes and for assessing the long term impact that treatment residues will have on the environment.

Current EPA leachability test methods have only been scientifically validated for very limited applications (i.e., hazardous waste characterization and land ban). They have not been shown to be valid for making waste-site specific risk assessments. In addition, even for the waste characterization and land ban applications, the current test procedures have known weaknesses. As a result of these limitations, the Agency does not have the tools necessary to perform the quantitative risk assessments needed to give waste disposers credit for site- and waste-specific factors that might act to reduce the risk to human health and the environment. Such a situation may result in over-regulation. The lack of appropriate testing protocols to adequately evaluate treated wastes may also be acting as a barrier to the use of innovative waste treatment processes.

Recognizing the importance of leaching science, EPA's Office of Solid Waste held a public meeting to address these issues on July 22-23, 1999. The meeting was held in Crystal City, VA, in conjunction with EPA's 15th Annual Waste Testing and Quality Assurance symposium, and provided a forum for Federal and State regulators, research scientists, and the regulated community to:

- discuss issues related to estimating the leaching potential of wastes and contaminated materials,
- discuss the history of the Agency's leachate estimation tests,
- review the state-of-the art with respect to leachate estimation, and
- solicit input on how the issues can be addressed.

This document provides a summary of these discussions, organized in the order in which technical presentations were made. From the agenda, you may select the proceedings of each speaker's presentation, and, where available, a copy of their presentation materials, as well as a list of the attendees: attendees.pdf.

Importance of this Meeting (Greg Helms EPA/OSW)

Greg Helms of EPA's Office of Solid Waste, Hazardous Waste Identification Division, reviewed some of the issues related to the current leaching tests and their application in the Resource Conservation and Recovery Act (RCRA) program. A copy of Mr. Helms' presentation materials is available through the following link: helms1.pdf. During his presentation, he summarized the issues associated with the Toxicity Characteristic Leaching Procedure (TCLP), noting that the test is based on a codisposal mismanagement scenario where the waste in question is assumed to be disposed of in a sanitary landfill. For many large volume wastes (e.g., mining residuals, utility ash) such a mismanagement scenario is not a plausible one. He also noted that the TCLP is designed to replicate leaching in an acidic environment, however, in some waste management situations, the waste is subjected to leaching at high pH. For those materials that pose their greatest hazard when exposed to alkaline leachate, use of the TCLP will underestimate leaching potential. Mr. Helms posed several questions to the group, to provide focus and context for the discussions over the next two days:

1. Given the large uncertainties associated with both the fate and transport models and the health impact values, how accurate and precise do the leaching tests which serve as the source terms for the models, have to be?
2. Can the deficiencies with using the TCLP for the various RCRA applications (e.g., assessing the hazard posed by alkaline wastes, determining leaching potential in monodisposal situations) be fixed with minor changes or does the Agency need to adopt a totally different approach?
3. The Toxicity Characteristic (and the TCLP) is based on assuming improper management in a sanitary landfill. Given the changes that have taken place in the past 20 years, is this still an appropriate mismanagement scenario to employ in the characteristic? If not, what would be the appropriate scenario or scenarios to use?
4. How can time dependent processes (biodegradation, oxidation, reduction, washout, physical stressors) which can act to both lessen and increase leachability be incorporated into the estimation procedure?
5. Is there an existing test or tests that should be considered as replacements for the TCLP to characterize wastes?
6. How can changes in the existing tests or a new test be validated?
7. Can measurement of fundamental properties of the waste be used to replace leaching tests or to overcome test limitations?
8. The current scenario assumes that the hazard posed by the waste is contamination of ground water and subsequent ingestion of the contaminated water. Should the Agency be concerned about other routes of exposure (e.g., volatilization of the waste and subsequent breathing of contaminated air)?
9. How should the Agency balance the tradeoffs between test accuracy, test time, and cost?
10. Should the waste characterization process be waste type specific (e.g., different tests and scenarios depending on the type of waste)?
11. Where should mobility testing end and modeling begin?

During the question and answer period, a participant asked how the Agency would use the results of the conference. Mr. Helms said that the Agency will issue a report describing actions that the Agency may take, and detailing the science behind any changes to testing protocols that may be implemented.

Background of Toxicity Characteristic leaching Procedure (TCLP)

In 1982, as an employee of the EPA, Todd Kimmell (currently with the Argonne National Laboratory) played a key role in the development of the TCLP. Mr. Kimmell presented an overview of the intent of the TCLP, reviewed the process used to develop the test, and discussed some of the current concerns with the test procedure. A copy of Mr. Kimmell's presentation materials is available through the following link: kimmell1.pdf.

Mr. Kimmell described the TCLP as the second generation of leaching tests at EPA, replacing the Extraction Procedure (EP). The TCLP was developed in response to the 1984 Hazardous and Solid Waste Amendments (HSWA), which directed EPA to examine the EP and make changes to ensure that it accurately predicts leaching potential of wastes when mismanaged. Congress was specifically concerned about the:

- ability of the EP to accurately represent mobility under a wide variety of conditions, and
- fact that existing characteristics did not identify wastes that were hazardous due to organic constituents.

The Resource Conservation and Recovery Act (RCRA) directed EPA to establish characteristics that identify wastes that pose a threat when improperly managed. One of the characteristics established was the Toxicity Characteristic (TC), which was developed to identify those wastes which might result in contamination of ground water if improperly managed. EPA was faced with the task of choosing one or more mismanagement scenarios for the TC. Several options were evaluated, with codisposal in a municipal waste landfill chosen as the single scenario to be applied to all wastes. This scenario was believed to be the most appropriate reasonable worst case. The EP was a batch extraction leaching test, based on the municipal waste co-disposal scenario, which presented operational difficulties, including problems with generating a reproducible leachate, questionable applicability to organic contaminants, and it was inappropriate for analysis of volatile organic compounds (VOCs).

In response to HSWA, the TCLP was developed to correct the deficiencies of the EP. Leaching tests are but one component of the TC, which also uses a groundwater transport model to set regulatory levels against which concentrations in the TCLP extract are compared. The regulatory levels in the TC represent a back-calculation from an acceptable chronic exposure level in a receptor well, through the unsaturated and saturated zones, back to the source, the bottom of the landfill. In addition to the groundwater transport model, the EPA Composite Model for Landfills (EPACML) is a key component of the TC.

The TCLP was intended to be a laboratory test designed to simulate leaching in a municipal landfill. During the development of the TCLP, the Agency considered whether the:

- mismanagement scenario upon which the test is based is appropriate for all waste types,
- test protocol can be applied to site-specific risk assessment, and
- individual elements of the test are applicable to specific waste types

Scientists from EPA and the Oak Ridge National Laboratory (ORNL) embarked upon a research effort, using large-scale lysimeters to generate municipal waste leachate (MWL). The MWL was used to leach a variety of wastes under simulated landfill conditions (column leaching). Laboratory-based leaching tests, both batch and column mode, were also used to leach the same waste. The results of these experiments were analyzed statistically to determine which of the laboratory tests best matched the lysimeter data. This research program resulted in a test that:

- Retained the EP's batch extraction format as the basic mode of the test, because it was shown to be more accurate than column extraction.
- Employed an acetate buffer leaching fluid to simulate the effect of decomposing municipal waste.
- Was shown to be more accurate than the EP and other available laboratory leaching tests.
- Was suitable for assessing the leachability of organic compounds.
- Met the HSWA mandate.

The TCLP is operationally similar to the EP, and comprises the following elements:

- An initial separation of liquid and solid phases
- Particle size reduction of monolithic materials.
- Batch-wise extraction (using a rotary apparatus) of the solid phase with a simulated leaching fluid (leachant) for an 18-hour period.
- Separation of the liquid and solid phases, resulting in a liquid extract.
- Combining the extract (leachate) with any original liquid phase.
- Analysis of the combined sample for target constituents.

While the two tests have similarities, the TCLP development team was given the task of addressing the shortfalls of the EP. They developed the zero-headspace extractor to minimize the loss of VOCs during extraction. Operational problems were minimized by using a pre-determined recipe for the extraction fluid and specifying glass fiber filters for liquid/solid separation. Precision and ruggedness were improved by controlling test variables, and practical considerations were addressed, such as ensuring that the test produced sufficient extract for subsequent analyses. Although the TCLP has been promulgated for nine years, concerns with the test remain:

- Is the municipal waste co-disposal mismanagement scenario the right one to model?
- Is the test sufficiently accurate and precise?
- Does the test evaluate the impact of physical stabilization and monolithic wastes.
- The test presents operational difficulties with some waste types (e.g., oily wastes).
- Is the infinite source assumption inherent in the EPACML model, and modeled by the TCLP, valid?
- Is the TCLP end-point (concentration in leachate compared to regulatory threshold) appropriate, or should the end-point reflect a mass of constituent leached over time?

Since the purpose of the meeting is to obtain stakeholder input into EPA deliberation on future directions, and in that vein, Mr. Kimmell felt that any future directions should consider:

- The more complex the situation(s) being modeled, the more complex the model.
- The more accurate the target for the model, the more complex the model.
- The more information you want your model to provide, the more complex the model.
- The more complex the model, typically, the higher the associated effort and cost.

While good science must be the primary consideration, practical constraints must also be considered.

EPA Science Advisory Board (SAB) Reviews of Waste Leachability

Dr. Ishwar Murarka, of ISH Inc., is a soil scientist who served on EPA's Science Advisory Board (SAB) Environmental Engineering Committee during the time that the SAB reviewed the status of leachability estimation methodology. He provided a summary of the SAB's findings and recommendations. A copy of Dr. Murarka's presentation materials is available through the following link: murarka1.pdf.

In 1992, the SAB released the report "Leachability Phenomena - Recommendations and Rationale for Analysis of Contaminant Release", recommending that the Agency conduct a review of its waste leachability procedures. Specifically, the SAB recommended that the Agency study and better understand the mechanisms controlling leachability; and develop better conceptual models for waste management scenarios with special emphasis on:

- redox potential
- leaching fluid composition and properties
- matrix in which waste resides
- type of management unit (pile, landfill)
- contact conditions (cover, cap, liner, effects;)

The SAB report also recommended that the Agency :

- study the effect of long term stresses on the waste and management unit and how they will affect waste properties and leachate release;
- develop a variety of contaminant release tests and test conditions to assess potential release of contaminants from different types of sources of concern,
- improve mathematical models to complement laboratory tests of leachability,
- field validate leach tests before broadly applying them.
- define the controlling mechanism prior to developing or applying any leaching tests or models.
- understand how the controlling mechanisms influence, either directly or indirectly, the release and environmental fate.
- refrain from applying any extrapolation of a set of conditions or stresses appropriate for one purpose to another without reasonable verification of relevance.

The latest SAB Environmental Engineering Committee (EEC) commentary "Waste Leachability: The Need for Review of Current Agency Procedures" (EPA-SAB-EEC-COM-99-002, available at www.epa.gov/sab/reports) was aimed at drawing the Administrator's attention to the need for review and improvement of the TCLP, because:

- the TCLP is broadly applied;
- leach tests can be improved by accounting for additional parameters; and
- the Agency's reliance on a single mismanagement scenario has caused difficulties.

The difficulties cited in the commentary include the issues raised in Edison Electric vs. EPA (1993), where the Court ruled that the Toxicity Characteristic rule must bear "some rational relationship to mineral wastes in order for the Agency to justify the application of the toxicity test to those wastes" as well as Columbia Falls Aluminum Co. vs. EPA (1998), where the Court ruling cited the language in the earlier Edison Electric case and vacated the application of the TCLP to the characterization of aluminum smelter wastes. In this case, the court believed that the high alkalinity of the waste, monofilling of waste, and very low liquid-to-solid ratios were important variables not accounted for in the TCLP. The SAB/EEC recommended that EPA:

- improve leach test procedures and conduct a field validation before implementing new procedures;
- study the various applications of the TCLP, and then generate improved leach test procedures.

Dr. Murarka closed by noting that the SAB/EEC anticipates that multiple leaching tests may be needed to meet the multiple uses to which the TCLP is currently being applied.

Stakeholder Perspectives on Leaching Problem

Scott Marris, from EQ Inc. (a waste treatment and disposal firm that deals with the TCLP on a daily basis for waste identification and verification under the Land Disposal Restrictions. program) stated that the TCLP is generally a good predictor of leachability, and acknowledged that, while it is difficult to develop a "one size fits all" test, it is important that the Agency retain the concept of a test that is simple and inexpensive. He also believes that it is important that the Agency maintain the concept of having to only run one test rather than conducting multiple leaching tests on a particular sample, noting that multiple tests/samples are a problem for private industry because of elapsed time while waiting for test results, as well as testing costs.

Mr. Marris said that is critical that industry can get results as quickly as possible due to the economic consequences of having to hold off on management decisions pending test results. He suggested that EPA should consider adding additional compounds, and suggested the TRI list as a source of those additional compounds.

During the question and answer period at the end of the session, participants asked questions of the morning's speakers.

David Friedman, EPA/ORD, asked about the size of the treatment batches and the variability of the testing results. Scott Marris responded, noting that, although different companies treat different size batches, his company treats 200 cubic yard batches. Within a particular waste stream there can be some variability, although pH does not vary too much between batches. His company will not accept a batch for treatment unless it meets their requirements.

Trish Erickson, EPA, asked if a single test procedure would be defined as a single test with a variety of leaching fluids, either on the waste coming in, or in post-disposal. Scott Marris responded that he believed that approach would work, although the practicality of testing post-disposal is questionable. The TCLP already has a break-point for waste pH, for example, if the pH is less than 5 you would use the acetate buffer and if it is greater than 5 use the acetic acid leaching fluid. The problems have been found in higher pHs and perhaps we do need another leaching fluid. Perhaps a buffer or neutral pH or one that more closely matches the average rainfall pH for that specific region of the country. He stated that the pH might depend on the actual landfill to which the material was shipped and that those facilities may already have such information available.

Harley Hopkins, American Petroleum Institute (API) commented on the effect that leachability might have on groundwater, saying that API would like to maintain a simple test and the flexibility to apply knowledge about the waste to get an estimate of the leachability and fate transport of these materials.

Judy Kleiman, EPA Region 5, asked about the pH range of waste leachate at treatment and disposal facilities. Scott Marris responded that the pH at his facility is alkaline, but certainly less than 12.

David Kosson, Rutgers University, asked if there had been a systematic comparison between the TCLP results of the materials going into the landfill and the quality of the leachate that you are observing across the large number of sites? Scott Marris responded that he did not know of such a comparison.

David Sussman, Poubelle Associates, commented that, when the hazardous waste regulations first came out, there was the EP Tox test that caused chaos across the land, and when the TCLP test came out for characterizing all waste, it also caused chaos across the land. But, now 10 years later into the TCLP, he did not believe that any changes in testing procedures will cause chaos. He suggested that a “one size fits all” approach will not work, that instead, we need to have leaching tests that match the materials, the leaching scenario, the management scenario, and every thing else. He went on to say that he hoped that the basic TCLP is not drastically changed and that EPA can come up with leaching procedures for all of the other scenarios.

David Hassett, University of North Dakota, commented that he was concerned about the idea of measuring the pH of the leaching fluid after the test and relating that to a starting pH of the leaching fluid. He believes that the pH of the leaching fluid is usually controlled by the waste itself, and in particular, a highly alkaline leachate is not the result of starting with an alkaline leaching fluid, but rather, having an alkaline waste through which the leaching fluid passes. His concern is in how one could simulate the actual conditions in a landfill in a revised testing procedure. He was specifically concerned about *starting* with an alkaline leaching fluid as a means of modeling the alkaline leachates that have been observed for some wastes.

Hans van der Sloot, Netherlands Environmental Research Foundation (NERF), asked why the target analyte list in the TCLP had been limited to the current list, noting that the European list is much longer. Mr. Marris responded that the list was based on the EP Tox. He said that the individual analytes were chosen because at the time the list was developed, they were the only elements for which the EPA had data and toxicity numbers, noting that the TCLP was developed from drinking water standards. Mr. Marris agreed that the EPA could look into expanding the list of constituents in the TCLP.

Garry Haworth, New Hampshire Dept of Environmental Services commented that multiple leachates for multiple uses would require multiple testing and certification, and if the Agency focuses on the extractant, it still leads to multiple methods.

A participant asked how the science advisory board deals with uncertainty in the TCLP, and is there a maximum level of uncertainty? Dr. Murarka responded, noting that the SAB does not tell the EPA what level of uncertainty to chose to base their policies on, and that there are a number of ways uncertainties and inaccuracies occur and are calculated.

Session II - Modeling and Risk Assessment

Importance of Leachate Tests in the Assessment Process

Dr. Ishwar Murarka, of ISH Inc., provided an overview of how leachate test results are used in modeling and risk assessment. A copy of Dr. Murarka's presentation materials is available through the following link: murarka2.pdf. He enumerated the general types of leaching tests:

- Batch Equilibrium - a single test, this is the approach used by the TCLP
- Column tests - usually a single test, this approach is laboratory-based, and may comprise either complete or partial renewal of the leachant, or no renewal at all
- Partitioning/Distribution Coefficient-based - not a test at all, but a calculation for organic materials based on partitioning coefficients or distribution coefficients between dissimilar liquid phases.
- Solubility-based - not a test at all, but for many metals, there are data available in the literature that describe the activity (concentration) of a given mineral form of the metal at a given pH. Having these data, the concentration in the leachate is simply calculated.
- Field pore water composition - this approach does not really constitute a leaching test. You simply sample and analyze the *in situ* pore water.

Leaching tests serve to quantify the source terms for fate and transport modeling. The purpose of the leaching tests is to obtain aqueous phase concentration(s) of constituent(s) which are released from solids when placed in a land disposal unit(s). The underlying assumption is, if the constituent doesn't leach from the waste, then land disposal of that constituent is not a threat to groundwater. The leachate concentration(s) constitute the source term for the transport and fate modeling which is coupled with the effects information to estimate potential risk. This presents one of the problems with the TCLP - the test does not provide a source term for modeling long-term effects, where long-term may be 6000 - 8000 years of landfill leaching.

There are many laboratory leaching tests that have been reported in the literature. ASTM has developed standard leaching tests which use alternate leaching fluids with very little additional difference in the test methodology. EPA has one regulatory test for the classification of solid wastes under RCRA; the TCLP (Method 1311). EPA also has the Synthetic Precipitation Leaching Procedure (SPLP) (Method 1312). The TCLP is expected to simulate leaching of solid wastes placed in a municipal landfill, while the SPLP is designed to simulate a monodisposal situation. The TCLP and SPLP have been widely used to generate leachate concentrations for all types of solids for both inorganic and organic constituents.

At this point in his presentation, Dr. Murarka deferred to David Friedman of EPA for an explanation of the origins of the composition of the leaching fluid and the liquid-solid ratio in the TCLP. Mr. Friedman explained that there was an assumption that potentially hazardous wastes would comprise at most 5% of the volume of the material deposited in municipal solid waste (MSW) landfills. The municipal waste was assumed to degrade and produce the acidic liquid to which the waste was exposed. Thus, this 5%/95% relationship lead to the specific composition of the acetic acid solution used in the TCLP. With respect to the 20:1 ratio of extraction fluid to waste, Mr. Friedman explained that some early leaching work performed by ASTM indicated that while the volume of leaching fluid relative to the amount of waste (e.g., the L/S ratio) did play an important role in determining the concentration of many chemicals in the leachate, there was a plateau in the L/S range around 10-20. Because there was concern with the assumption that the waste provides an infinite source of contaminants over time, using a higher L/S of 20 was seen as one way in which the TCLP could address this concern. However, as Mr. Friedman pointed out, the fact that the L/S ratio could also be expressed as "5%" was serendipitous and unrelated to the assumption that 5% of the volume of a MSW landfill was hazardous waste.

Dr. Murarka thanked Mr. Friedman for his input and pointed out that these assumptions were some of the reasons that he felt that the present consideration of leaching tests must determine if other L/S ratios may be more appropriate for other wastes or waste disposal scenarios.

Dr. Murarka stressed that he has no disagreement with the use of the TCLP in its original regulatory context, e.g., for waste classification. His concern is that there are many instances when the TCLP is used outside of that context and that many users are not familiar with the resulting limitations in the data. Over the last ten years or so, issues have arisen because of the much broader use of the TCLP and SPLP test methods. He noted that the leaching potential of a given constituent can be quite different, depending on a number of factors, such as the characteristics of the leaching fluid, the form of the chemical in the solids, and the disposal conditions. The factors that affect the leaching potential of inorganic constituents are:

- pH - the pH of municipal solid waste (MSW) landfill leachate is usually in the range of 4.8 to 5.2, however, leachate from monofill or stabilized wastes is not.
- Redox conditions
- Liquid-to-solid ratio
- Solubility

Different factors affect the leaching potential of organic constituents. They are:

- Partitioning or Solubility - since organic compounds are rarely available in the landfill as crystalline solids, partitioning is the predominant consideration
- Presence of organic carbon - this factor will impact the concentration of the organic constituents in the aqueous phase
- Liquid-to-solid ratio
- Non-aqueous phase extraction

Dr. Murarka presented graphs depicting the concentration of constituents in the leachate vs. the pH of the leachate. He presented data for several metals, including selenium and arsenic, as well as organics such as PAHs from coal tar. The data for metals show that the overall final pH of the leachate is much more important than the pH of the actual leaching fluid itself in determining the actual metal concentration in the leachate. Thus, which leaching fluid you start with is not as important as knowing the pH of the final leachate, and attempts to predict leachate concentrations should rely on the pH of the leachate, not the original leaching fluid.

At the end of his presentation, Dr. Murarka addressed questions from the audience. Hans van der Sloot, Netherlands Energy Research Foundation (NERF), provided extensive comments on Dr. Murarka's presentation. He began by pointing out that new landfill construction methods are in common use now, thus the original assumptions in the TCLP method may no longer be applicable. Dr. Murarka replied that this was one of the factor that he felt needed to be considered when applying leaching tests to situations other than waste classification.

Dr. van der Sloot continued, noting that based on field data, the pH versus concentration data presented by Dr. Murarka fit those data very well, and that pH could be used as a good predictor of metal concentrations in many cases. He noted that the focus on organic content should be placed exclusively on the degradable organic matter. He noted that new European Union regulations have been proposed that will ban placing any degradable organic materials at all in MSW landfills, since the breakdown of these materials lead to the acidic conditions that the TCLP was designed to model, thus keeping them out of the landfills reduces the production of organic acids, etc. Despite his agreement with much of Dr. Murarka's metals versus pH data, Dr. van der Sloot urged Dr. Murarka to be careful in applying the metals data. Dr. Murarka acknowledged that the metals situation was not as simple as it might appear, but noted that he did not have two hours in which to present a detailed discussion of metals speciation, but that he had, in fact, considered the data carefully.

One participant remarked that he had reviewed about two-thirds of the leachate data submitted under the lead paint rule and while there were some pH values as low as 4.8, most were in the range of 6.8 to 7.2, with a small group in the range of 8 to 10. These data came from both old and new landfills, with no clear pH trends apparent thus far, and that some were from MSW landfills while others were from construction debris landfills. Dr. Murarka thanked him for the information and agreed that such data would be useful in his work.

Richard Lesser, of RMRS, noted that regardless of whether EPA determines that either a single test is to be used, or multiple tests are developed for different scenarios, he felt it would be important to develop a rapid approval process for alternative tests, under the performance-based measurement system (PBMS). Otherwise, he felt it would take 8 to 9 years to get a new test considered.

Modeling Overview

Dr. Zubair Saleem, of EPA's Office Solid Waste, presented information on EPA's efforts to model the leaching behavior of wastes. He began his presentation by emphasizing that the TCLP was designed for a specific waste mismanagement scenario and that it works well in the context of that scenario. When applied outside of its original intent, it may not work as well.

Dr. Saleem noted that when wastes are placed in a landfill, they are subjected to various physical, chemical, and biological processes that can result in the creation of new compounds in the waste, changes in the mass and volume of the waste, the creation of different phases within the waste and within the landfill. In order to accurately predict the concentration of the contaminants in the leachate, one must account for these changes.

Dr. Saleem pointed out that biological transformations can lead to the production of methane, carbon dioxide, water, and various metabolic byproducts. These same biological processes produce heat, which changes the temperature of the waste itself. The temperature changes, in turn, affect the transport of the chemical constituents of the waste, both in terms of the rates of transport and the concentrations that are found in the leachate.

He went on to say that when gases are produced in the landfill, there is an increase in the pressure within the landfill, in both the liquid phase materials and the solid material. If the pressure increases high enough, it can create channels within the landfill, through which liquids may move. Thus, one must also account for factors such as gas production.

Therefore, in order to create a successful model of a landfill, one must account for the flow of water, gases, and non-aqueous phase liquids (NAPLs), and heat conductance, as well as the other physical characteristics of the landfill and the waste.

Computer models need to include all of these factors in their design. Dr. Saleem stated that a good fate and transport model will contain three specific modules covering flow, transport, and reactions. These three modules then interact with one another in the model to predict the concentrations of the constituents across both space and time.

Dr. Saleem indicated that when EPA develops a model, they also attempt to ensure that it is both robust and stable, as well as computationally accurate. EPA uses a Monte Carlo approach for models, which may involve hundreds of thousands of iterations of the model to generate the output. Once a robust, stable, and accurate model has been developed, it may be possible to simplify it to some degree, so that it is easier to use or addresses more generic situations. Such simplifications involve a degree of compromise.

Dr. Saleem explained that EPA has been working for some time on a composite model with transformation products (CMTP) and they are actively seeking field data that can be used to validate the model. The general features of this landfill model include the infiltration of precipitation into the landfill, which passes through the waste, picking up contaminants and transporting them through an unsaturated zone below the landfill and ultimately into the water table.

Dr. Saleem indicated that the three modules (flow, transport, and reactions) are often run with different time steps. The flow module often uses larger time steps than the other modules. The transport and reaction modules typically use smaller time steps, since they are linked to one another and reactions that occur in the leachate or the waste will affect the transport of materials. The reaction module acts as both a source and a sink to the transport module.

A typical model will include a three-phase flow model (water, gas, NAPL) and will account for pressure, velocities of the flows, and the temperature within the landfill. The model includes data on the organic carbon content, various forms of sulfur and sulfides, and metals. Carbon dioxide and methane production are modeled. Organic compounds are considered in two general weight ranges: high molecular weight organics and low molecular weight organics. The transformation products are also included in the CMTP. As each module is run, the model looks for convergence of the outputs and when that occurs, the model moves on to the next time step.

Dr. Saleem indicated that a typical model might run on a high-powered PC for two hours in order to model 1000 days of time in a landfill. He noted that even with a powerful computer, modeling a 100-year period of a landfill will take a tremendous amount of time.

Dr. Saleem noted that EPA had not obtained enough field data to make many meaningful comparisons but that they were working with the data that they have while they solicit data from outside sources. Dr. Saleem concluded his presentation by displaying various outputs of the model and illustrating some of the input data that has been provided by researchers such as Dr. Kosson.

At the end of his presentation, Dr. Saleem addressed questions from the participants. Bart Simmons, Cal/EPA, asked about the uncertainties in the model input. Specifically, using a DQO approach, he asked how accurate a test such as the TCLP would have to be in order to be of comparable certainty to the model. Mr. Simmons noted that modelers deal with coefficients of variation (CVs) in the range of 0.3 to 3, while analytical chemists are upset when the CV is as large as 0.4. Dr. Saleem jokingly replied that once the model was completed, you might not need a test such as the TCLP. Dr. Saleem continued in a more serious vein, noting that while the model would not necessarily replace the TCLP for the waste characterization scenario, it would be useful in many other scenarios to which the TCLP might not apply. Ginny Colten-Bradley, EPA, also responded, noting that some of the model parameters had associated variabilities that are measured in orders of magnitude. These uncertainties are carried through the Monte Carlo analysis. She noted that until one performs the sensitivity analysis of the model, one cannot tell what the DQOs would have to be for a given test such as the TCLP.

John Phillips, Ford Motor Company, asked if the model was based on current landfill construction techniques, such as small cells and caps that limited infiltration, or on older landfill practices, and if the model had to be specific to each landfill. Dr. Saleem responded that the model could include a wide range of landfill designs and construction techniques, and that the model could be landfill-specific, or it could be more generic, such as when EPA wishes to generalize across a range of landfills. Mr. Phillips continued, asking how much information needed to be known about the chemistry of the waste itself. Dr. Saleem indicated that with more data, the model will be more accurate.

David Friedman, EPA, asked how the model handled different forms of the same waste, say a vitrified waste and the original waste material with the same chemical composition? Dr. Saleem responded that the reaction module accounts for the forms of the waste, since the vitrified waste would have different reaction rates then the original waste form.

Hans van der Sloot, NERF, commented that he doubted that any model would ever replace the actual testing of wastes. However, he said that he sees great potential for models in predicting leaching behavior over long time frames. He noted from his own work that often models fail because of some aspect that was not included in the model, but that becomes apparent when the model results are compared to test data. He noted that testing has a purpose, as does modeling. Testing may be quick, in time frames of days to weeks, in order to develop input data for the models. Dr. van der Sloot stressed the need to integrate both aspects of the process. Dr. Saleem agreed.

Organic Modeling Issues and Problems

Chen Chiang, Equilon Enterprises, an environmental engineer and the technology lead for Equilon's fate and transport modeling group, discussed the issues and problems associated with modeling the leaching behavior of organic constituents. A copy of Dr. Chiang's presentation materials is available through the following link: chiang1.pdf. He began his presentation by emphasizing that successful leaching tests must be both practical and site specific, and that successful mathematical models must incorporate time-dependent leachate characteristics and NAPL issues. He suggested that modeling approaches that strive to predict leaching over a 100-year time frame may be unrealistic, and that instead, it may be possible to take a tiered approach to modeling, providing realistic predictions based on critical, fundamental thermodynamic parameters.

Dr. Chiang reminded the audience that the goal of a waste leaching modeling exercise is to estimate the concentration of the constituents of interest in the leachate (C_L) or in the waste (C_T) that will give you an acceptable concentration in the receptor (C_R). The model must consider any interaction between leachate and waste concentrations, fate and transport through the groundwater (e.g., biodegradation and dispersion), and derived dilution and attenuation factors. Other parameters and processes that must be considered in the model include volatilization of the waste, infiltration from rainfall, and waste specific issues. One example of a waste-specific issue is the standard practice in the petroleum industry of centrifuging oily wastes before disposal, so at the time of disposal you have a residual NAPL, but not a mobile NAPL. Therefore, the need for multi-phase flow modeling needs to be evaluated. He also pointed out that leachate will preferentially partition into NAPL, so actual leachate, in the presence of residual NAPL, will be small.

Dr. Chiang noted that a lot of fundamental information can be derived from a simple batch for Tier 1 analysis and simple modeling, such as time-dependent leachate concentrations. The current batch testing approach (TCLP) assumes equilibrium partitioning between soil and water, and further assumes that the leachate concentration (C_L) and waste concentration (C_W) are constant over time. An improved approach to this type of finite source modeling might include partitioning between air, soil, water and residual NAPL, and should also consider kinetics, and the movement through the subsurface system.

It is also important to account for the finite nature of the source. For example, one may find temporal changes in the bulk waste as a result of losses due to leaching and volatilization. We can accommodate these factors by employing source zone modeling coupled with groundwater transport modeling, using appropriate measured leaching parameters. Refer to Dr. Chiang's presentation materials for source zone modeling equations.

The question can then be asked, where does a batch test fit in when we are modeling dynamic processes? Batch tests can be used to generate C_{Lo} (the leachate concentration at a leachate/waste ratio extrapolated to zero) and K_w (the partition coefficient.) if equilibrium conditions exist, and for nonequilibrium conditions or when losses (other than leaching) occur, calculations using acceptable default values or separate tests are needed.

Reiterating the original goal of a waste leaching modeling exercise as estimation of the concentration of the constituents of interest in the leachate (C_L) or in the waste (C_T) that will give you an acceptable concentration in the receptor (C_R), Dr. Chiang outlined a potential procedure for determining acceptable C_L and C_T:

- Batch tests for C_{Lo} and K_w for equilibrium leaching (in the absence of other losses).
- Use separate procedure to measure kinetics when important.
- Use default values or separate tests for volatilization, degradation, etc. when important.
- Use default or measured values in coupled source zone & groundwater transport model to determine acceptable C_L and C_T values.

He concluded his presentation by noting that batch tests can be used to obtain equilibrium leaching parameters for organic compounds, but that separate estimation methods/tests are recommended for accounting for other loss processes, such as volatilization and degradation. Kinetics can be accounted for by using default values or separate test methods.

At the end of his presentation, Dr. Chiang addressed a question from Greg Helms, OSW, who asked Dr. Chiang to elaborate on the terms "residual NAPL" and "mobile NAPL". Dr. Chiang responded that he had empirical data that showed that, to mobilize a residual petroleum hydrocarbon, you need to have a hydraulic gradient of 7 (typical hydraulic gradients are usually on the order of 0.001). He conducted a 7-month long pumping test, covering 4 wells; the estimated residual NAPL volume was 5,000 gallons, and they recovered 34 gallons (mobile NAPL).

Inorganic Modeling Issues and Problems

David Brown, EPA/ORD, was scheduled to discuss issues and problems associated with modeling the leaching behavior of inorganic constituents. Mr. Brown could not be present, and his presentation was read by David Friedman, EPA/ORD. The text of that presentation is provided here, in its entirety.

The TCLP or other associated tests are a critical part of implementing some very important regulations that impact many people and many industries as well as the public at large. Because of that there is a great need for setting such methods right. Perhaps too great a need. I wonder if any such tests could be devised to adequately carry such a large load. My own answer to that question is: "Probably not." Considering the specifics of the many hundreds of combinations of waste materials possible, and the many hundreds of potential ideas that might be concocted to defeat any specific test over time, we would indeed be asking a lot from any possible TCLP substitute that might be devised. The waste chemistries are simply too specific and vary too widely to expect to find the test design that 'fits them all' in a satisfyingly defensible way. Having arrived at that conclusion in my own mind, my thinking has strayed toward looking for a set of waste-specific tests, or for finding some other means of satisfying the basic need that incorporates some facility for dealing with the diversity that various wastes now, and in the future, might present.

To develop, test, and adequately apply a sufficiently diverse set of waste category- specific tests to the problem in such a way as to result in a fully defensible position would appear to be a very difficult charge. A charge that might well be outside the realm of do-ability considering time and resource constraints, and the need to extend the battery of tests as new wastes come along and old ones diminish over time. Maintenance of the system of tests so assembled would also be a continuing struggle to assure that proficiency was retained over time in the face of changing waste streams and combinations thereof. Because these difficulties all lead to hands-on efforts in the laboratory in one way or another, I would regard this as a brute force kind of approach with high, long term effort and frequent adjustments involved. For those who might disagree, I offer the following challenge: Give me the complete set of specifications on your metals waste and the test you would apply to it, and 24 hours, and I will put on my waste generator's cap and find a way to defeat it.

If we are to deal with so much diversity in the most efficient way, it seems to me need to put our computers to work on this problem. Rather than devising endless tests and continually revising them to fit a endless stream of new waste combinations, can't we find a way to catalogue what we know about chemistry in our machines and let them do the work? Here, I am suggesting that we do our testing with a model. Then, to adjust our test, or to look at its outcomes, we end up pushing buttons and letting the machines do the work. This too is an admittedly difficult undertaking on the front end. I am not suggesting that all the computer models or the data to drive them are available now, or that I necessarily know anyone smart enough to build them all quickly. What I am suggesting is that it might be an approach with some healthy long term benefits for all concerned. There would also be some side benefits, as discussed in the next bullet.

For sometime now, we have sidestepped the issue of dealing with interactions among mixed wastes in waste management units (WMU). The simple reason for that is that we don't know what combination of stuff is actually in the WMUs that we seek to model with methodologies like HWIR99. This is also why we can have less than great confidence in the applicability of any particular test on a single waste stream when it will actually be disposed in a mixture capable of many complicating' reactions not reflected in the test. This lack of important information is at the heart of some of the uncertainty in the HWIR99 methodology, as well as the the performance of any test (or model substitute) that we might seek to concoct. It is also the area where I think we might best apply some effort. Until we do, we are quite simply attempting to deal with an unknown in a very pragmatic way. How, for instance, do we design a test or modeling protocol that works for an unknown mixture? How do we validate such a test? I can't answer those questions, but would like to challenge those who can.

That brings me to the bottom line. I say we think about developing models to perform the necessary tests on the computer. To do that, we need detailed data on the waste composition, and we also need detailed data on the how those wastes are actually mixed in the WMU. If we have both those things, we could start making real progress toward developing the sort of predictive models that I am suggesting we develop over time. Once developed, such tools could be easily adjusted to fit changing conditions and waste mixture combinations by simply pushing some buttons, at least in the long haul. The data required to do what I suggest does not exist, and that it might take an act of Congress AND a prodigious amount of effort and expense to get it.) All true of course. Even so, it does seem we are working with an unknown problem until we put the facts on the table. We won't get there until we start, and now seems a good time to do that. If not, we will likely find ourselves asking these same questions a few years form now.

So what I suggest is that we put some thought toward gathering the necessary facts rather than fighting the unknowns any further. We then use those facts in combination with what we know about chemistry, and put some expert systems together that will do the testing for us. It isn't something I would suggest is easy, but it does seem like something reasonable to do because of the long term benefit to be gained, both from the testing perspective and for reducing uncertainty in our risk assessment methodologies. For metals, we have some reasonable starting points available in the variety of metal speciation models and databases that already exist. For organics we have some pretty smart organic chemists around to deal with the reactions. For the metal / organic combinations we have some complexation constants on hand, and know how to get more. There is also a developing field of software design expertise to draw from in developing the sort of expert systems methodologies that would help to make the approach I am suggesting more self-sustaining over time.

How do we do all this? I suggest we start with a three-way partnership agreement between the EPA, the regulated community, and the academic / consulting research community. The EPA and waste generators would work together to help put the needed data on the table (even if it has to be only for a series of well-thought scenarios), and the EPA and outside research community would combine forces to build the modeling tools. All would share in the mutual benefits, that I think could be many. EPA gets a major, and recurring, problem solved, uncertainty of its methods are reduced and public acceptance is increased. The regulated community gets more fair and equitable regulations. The scientific community takes a step forward, and nobody has to stir test tubes.

Session III - Leaching Science

Greg Helms, EPA/OSW, opened the session by reminding the participants that the purpose of the session is to look at the state-of-the-art with respect to leaching science. The questions posed to the group are:

- What range of conditions should be considered for TCLP testing?
- While the TCLP will lead us to make the right decisions most of the time, will the treatment process change the waste in such a manner that a different approach to characterizing the waste is needed?
- How can we assess what is going on at a specific site in order to be able to make site-specific risk assessment?
- How should we characterize wastes if, once characterized, the waste might be disposed of at another site?
- In developing treatment standards, how can the Agency ensure that the potential leachability of a waste, both short-term and long-term, has actually been reduced to the point that it no longer poses a hazard?

He closed his remarks by reminding the participants that any new or revised testing must also be designed to account for the fact that not all waste will go to a municipal facility.

Stakeholder Perspective NJ Department of Environmental Protection

Mike Winka, NJDEP presented the stakeholder perspective from the States. He said that the RCRA and Superfund programs are primarily state run systems, and noted that changes in the test will require changes in those state-run programs, including potential changes in regulatory thresholds. Mr. Winka said that, currently, all the states do not employ the same leaching test, and suggested that one goal of the development program should be to have one or more testing protocols that are used by all states.

He suggested that, should any new or modified tests be developed, EPA should conduct a full-scale demonstration to determine how well the laboratory predicted risks compare to the real world. He believes that it is important that any test used

- yield results in a reasonable time frame (e.g., <90 days),
- not be too expensive, and
- be tied to the end-use of the data.

Inorganic Leaching Science

Dr. William Batchelor, of Texas A&M University, spoke about the state of inorganic leaching science. A copy of Dr. Batchelor's presentation materials is available through the following link: batchel.pdf. He began his presentation by noting that the majority of his research has focused on the leaching of wastes that have been treated by conventional solidification and stabilization techniques. Thus, they tend to be high pH wastes, but the leaching considerations he described can also be applied to other wastes as well.

Dr. Batchelor described leaching in very general terms, stating that when a solid waste is in contact with a fluid, some contaminants will leach from the solid to the fluid. One can look at the process as a continuous one, measuring the concentration of the contaminant in the fluid and the flow rate of the fluid. Alternatively, one can consider a batch process and measure the volume of fluid instead of the flow. Both approaches have uses. Dr. Batchelor noted that the concentration of the contaminants in the leachant becomes a source term for risk assessment models.

The two fundamental issues outlined by Dr. Batchelor are equilibrium and kinetics. When the flow of fluid through the waste is low, there is time for many of the contaminants in the waste to reach an equilibrium with the fluid, and the concentration of a contaminant in the leachant reflects its solubility at equilibrium. Conversely, when the fluid flow is high, the concentration of the contaminants in the leachant is controlled by the rate at which they can dissolve or otherwise be transformed. Dr. Batchelor noted that there are often situations between these two extremes, in which the concentration of a contaminant is a function of both equilibrium process and kinetics. He pointed out that one can design a leaching test to gather information on the equilibrium aspects of the process, the kinetic aspects, or both.

Dr. Batchelor repeated a theme common to many of the presentations at the meeting, that pH controls the leaching on many inorganic contaminants, as well as affecting the speciation of many metals. He showed several graphs of metal concentrations as a function of the pH of the leachant. He noted that for some metal hydroxides, there are maxima in the concentration plots at both high *and* low pH values, with a minimum in the middle of the pH range. This behavior is due to the amphoteric nature of some metal hydroxides, and it can be predicted from first principles.

Dr. Batchelor stated that the sorption of contaminants is controlled to some degree by pH as well, since cations and anions will compete with hydrogen ions and hydroxide ions for sorption sites. He noted that oxidation and reduction reactions are affected by pH as well, and are important in governing the speciation of metals such as arsenic and chromium. The formation of complexes between metals and organic compounds are often controlled by pH as well.

Dr. Batchelor described how the pH of the leachant is determined by the acid neutralizing capacity and the base neutralizing capacity of the waste itself (an important consideration for waste stabilized with alkaline materials such as lime). The pH of the leaching fluid plays a major role in establishing the pH of the leachant, as does the liquid-to-solid ratio. He showed several plots of the solubility of materials leached from a municipal solid waste incinerator ash.

He noted that other factors can play a role, including the presence or absence of surfaces in the waste (e.g., particle size considerations), the presence or absence of ligands (e.g., citrate) within the waste and the leaching fluid, the Eh or redox potential, and the presence of other metals (e.g. $PbCrO_4$).

Dr. Batchelor described the applications of leaching tests for different purposes. For example, the TCLP is what Dr. Batchelor terms a microcosm test. The test developer envisioned a scenario, co-disposal in the case of the TCLP, and designed a test to simulate that scenario. The results of the test are used to predict which wastes pose an unacceptable risk in that scenario.

In contrast, one can also design a leaching test to generate fundamental data about the leaching processes themselves. Such data can include information on the equilibrium processes, the kinetics of the leaching, or both.

Dr. Batchelor said that the important question is "What do you expect to use the test for?" He noted that the two most common answers are to characterize hazardous wastes, and to assess the risk posed by a waste as it interacts with the environment.

In designing an equilibrium test, Dr. Batchelor indicated that one has to decide what leaching fluid to use. Some common choices include:

- distilled/deionized water
- fluids that simulate specific conditions (e.g. TCLP, SPLP)
- a series of acid/base solutions

One then needs to use small particles and long leaching times to achieve equilibrium conditions. In an equilibrium test, a low L/S is needed to avoid dilution of the contaminants with the leaching fluid itself. The L/S ratio is important in cases where the contaminant concentration is limited by its solubility. It is also important when sorption plays an major role, since larger volumes of leaching fluid will affect the desorption of the contaminants by dilution as well. Dr. Batchelor pointed out that if a high L/S ratio is used, then one can look at how much material can be released, in what is essentially an infinite source scenario, as opposed to how much is released in an equilibrium setting.

A third alternative is to look at the acid or base neutralizing capacity of the waste itself. Often, the acid or base neutralizing capacity controls the pH of the leachant, and the concentrations of the contaminants can be predicted from the leachant pH.

The other approach to designing a leaching test is to consider the kinetics as the controlling factor. Dr. Batchelor noted that kinetics is the study of rate processes. The rates of the various processes that occur in the leaching scenario will affect the leachant concentration. The processes include chemical reactions (speciation) and mass transfer (internal/external). This includes the reactions rates of the contaminants, the dissolution rates, and the rate of diffusion of the dissolved contaminants within the leaching fluid and between the leachant and the surrounding environment.

Dr. Batchelor pointed out that the acids and bases within the waste also leach. In many cases, those acids and bases are more soluble that the other contaminants. As a result, they leach into the fluid, changing its pH, in turn affecting the leaching of the other contaminants. The result can be viewed as a series of "fronts" of leachant that pass through the waste and leach contaminants.

Dr. Batchelor noted that the two most common types of kinetic applications are continuous flow tests and semi-continuous (leachant replenishment). In designing a kinetic leaching test, one seeks to determine the observed diffusivity of the contaminants in the leaching test. The variables that can be manipulated in designing the test include Q (the flow rate), the L/S ratio, and the length of the test. One can also use different contaminant concentrations, particularly a low concentration for an "infinite bath" scenario (high Q or high L/S, short time), or a high concentration for a low Q or low L/S, long time, scenario.

Such kinetic leaching tests may run for several months. During the test, one measures the fraction of the material that has leached. In general, the fraction leached is proportional to the square root of the leaching time. From these data, one can calculate the diffusivity or the leaching index for the material. For every contaminant, there is a different balance of Q, L/S, and leaching time.

Dr. Batchelor described experiments that he has run using an anion exchange resin that removes the metals from the leachant before it is cycled back through the waste. This allows him to use a lower L/S ratio to simulate an infinite bath scenario in the laboratory.

Dr. Batchelor summarized his presentation by noting that one needs to consider both equilibrium effects and kinetics. He stressed the importance of pH and noted that the concentration of the contaminant in the leachant links the test results to the field situation. He pointed out that tests designed to measure the leachant concentration include those with equilibrium control - equilibrium test for the concentration of the contaminant at equilibrium with the leaching fluid, and those with kinetic control, designed to examine the leachable concentration (availability) and the observed diffusivity, either through measurement or simulation.

At the close end of his presentation, Dr. Batchelor responded to questions and comments. Paul Bishop, of the University of Cincinnati, asked what Dr. Batchelor suggested was the best pH at which to run leaching tests. Dr. Batchelor replied that there is not a single pH that is best for all leaching tests, or all wastes.

Trish Erickson, of OSW, asked how Dr. Batchelor would approach the leaching of a waste that was very likely to undergo reactions, such as the redox reactions that will occur in a waste containing mercury sulfide. Dr. Batchelor replied that the problem with all leaching tests is that you are measuring the characteristics of the waste at the time that the test is begun and not what will happen months or years down the line. He suggested that it may be possible to simulate the conditions that are likely to occur as the waste interacts with the landfill and then perform tests under those conditions. He noted that the same problem occurs when trying to describe the physical characteristics of the waste over a long time frame.

Dave Hassett, of the University of North Dakota, noted that when dealing with alkaline waste, if one runs the test too fast, one will get different results, primarily as a result of the kinetic effects. Dr. Batchelor replied that most of the common leaching tests are designed as a combination of an equilibrium test and a kinetic test. Thus, if one seeks to identify the kinetic effects, one has to design the test accordingly.

International Perspective of Leaching Science

Hans van der Sloot, Netherlands Energy Research Foundation (NERF), discussed the science of leaching from the international perspective, concentrating on activities in the European Union. He said that the main concerns that we face in the field of waste leaching estimation are:

- there are too many leaching tests addressing the same question,
- the relationship between the test conditions and actual field conditions that we are trying to simulate are too limited, and
- we are not taking advantage of the vast amount of leaching test data that are generated annually in the industry.

The international Network Harmonization of Leaching/Extraction Tests effort has several goals, including:

- Identification of needs in relation to leaching test use and interpretation.
- Comparison of different leaching test methods currently used or proposed in one specific field.
- Horizontal comparison of leaching test methods between different fields.
- Evaluation of leaching test data, interpretation and modeling for environmental assessment.
- Development of cost efficient quality control systems through a hierarchy in testing.

As a result of this effort, a leaching test hierarchy has been adopted by the European Community under standard TC 292. It consists of:

- Characterization test or leaching behavior test.
- Compliance test
- On-site Verification test

The Characterization test provides basic information about the waste, and how it behaves under different conditions, as a function of time. The first step in this test is to describe the utilization scenario, e.g., co-disposal, monofill , followed by waste characterization, and determination of the stresses or influences that effect that waste in that utilization scenario. The next step is to do the leach testing, followed by modeling the leaching behavior. The Characterization test may take a few days to several weeks to complete, and will tell you the key issues that need to be focused on, or whether more information is needed. Dr. van der Sloot presented examples of characterization testing that has been conducted in the European Community, showing a wide range of materials. He made the point that there are a limited number of parameters that control leachability, and that you frequently see common behaviors that are related to common characteristics, such as the role of organic matter in soil and compost matrices. He pointed out that for predominantly inorganic materials, you need to evaluate the entire leaching curve (concentration vs. pH) to evaluate the chemistry of the system. In addition, it is important to determine the “pH domain”, the most common pH range for that waste.

The Compliance test does not necessarily have to be a leaching test, but does need to provide data that can be compared to the Characterization test data. This test should take no more that 2-3 days to complete, and is used to determine if a waste is behaving as predicted by the Characterization test. Dr. van der Sloot presented examples of compliance testing that has been conducted in the European Community, again showing a wide range of materials. Refer to Dr. van der Sloot's presentation materials to view these leaching graphs.

The On-site Verification test should be able to be completed within an hour, and is used in the field to verify or refute that the waste is behaving as predicted from the Characterization and Compliance testing.

Standard TC 292 includes specific methodology for determining the leaching behavior of waste (ENV 12920). As a result of the work that has been conducted under this effort, characterization data from static pH leaching tests, column leaching tests, and tank leaching tests are available for an extensive list of materials. The list is provided in Dr. van der Sloot's presentation materials.

Dr. van der Sloot stressed that waste management, treatment and stabilization decisions should be based on long-term leaching behavior. Critical elements from a regulatory point of view can be identified by the pH static leach test in relation to the pH domain over the long term. The short test used in conjunction with preliminary characterization or compliance test data provides a sound decision basis and a cost effective means of quality control.

Dr. van der Sloot concluded that the static pH test is useful for:

- comparing the results of different leaching tests within one class of materials
- obtaining the data needed to model the behavior of geochemical controlling phases, and
- evaluating the long term behavior and impact of external stresses on materials.

Modeling forms the basis for long-term predictions. The characterization tests presented provide the input parameters for such geochemical and transport modeling. Scenario-specific and site-specific parameters can be introduced to account for different applications of the same materials and regional differences. Based on an understanding of leaching behavior, integrated concise testing protocols can be drafted for quality control and regulatory purposes.

Additional information on work being conducted by the European Community can be obtained from the Internet (www.leaching.net). The final report on the technical work that has been done for the harmonization effort should be available by the end of 1999, and will be posted on this website. Future workshops are being planned, including several upcoming events covering municipal solid waste management issues:

- REWAS September 6-9, 1999, San Sebastian, Spain.
- Landfill Symposium, October 4-8, 1999, Sardinia, Italy.
- WASCON 2000, May 31-June 2, 2000.

Dr. van der Sloot addressed comments and questions from the participants. Greg Helms, OSW, inquired about the cost of performing the suite of tests required by TC 292. Dr. van der Sloot estimated that it would cost $1500.00 to run the tests at one pH. He advises that the test should be run in multiple configurations, including column testing, requiring about $10,000 to complete the Characterization testing phase. On-going compliance and verification testing would cost significantly less.

Greg Helms also asked about the transferability of Characterization testing data between related waste types, such as bottom ash and fly ash. Dr. van der Sloot said that he had data showing that, in some instances, there was comparability, but that it was not always the case.

A participant asked if one should account for influences of other, co-disposed wastes, when the characterization testing is done on the waste alone. Dr. van der Sloot responded that the characteristics of the material change when co-disposed with other materials, so the characterization of the material alone was inappropriate.

Organic Leaching Science

William Rixey, Associate Professor, Department of Civil and Environmental, Engineering, University of Houston, Houston, TX, presented a discussion of the state of organic leaching science, developed for the American Petroleum Institute (API). A copy of his presentation materials (in pdf format) is available through the following link: rixey.pdf.

Dr. Rixey described the key issues that need to be addressed in the field of leaching, including the role of batch tests for describing leaching for organic compounds and incorporating factors such as presence of residual non-aqueous phase liquids (NAPL), kinetics, and various loss processes.

He described the issues raised by the EPA Science Advisory Board (SAB) with respect to the current leaching tests, including:

- Liquid/solid ratio
- Kinetics
- pH
- Colloid/emulsion formation/oily phase
- Particle size reduction
- Volatile losses
- Interactions with other wastes

and noted that his presentation addressed the liquid/solid ratio, kinetics, and the presence of an oily phase. (For more information on the EPA SAB report on leaching see the presentation by Murarka. [murarka1.pdf])

Dr. Rixey compared the use of batch leaching and fixed-bed leaching on oily wastes. He noted that batch tests can be used to obtain appropriate leaching parameters such as C_{Lo}, the leachate concentration at a leachate/waste ratio extrapolated to zero, and K_w, the partition coefficient. One approach requires either a batch leaching test and an analysis of the waste ("totals" analysis) or multiple batch leaching tests. An alternative is to estimate K_w and C_{Lo} from the oil content of the waste or results for total petroleum hydrocarbons (TPH) and the application of Raoult's Law. Dr. Rixey described these options in detail, and described the derivation of a theoretical description of fixed-bed leaching under equilibrium conditions.

Dr. Rixey concluded that a simple batch test can be used to describe more realistic leaching if one takes into consideration that batch tests work when equilibrium leaching conditions apply, and in the absence of other loss processes, e.g., volatilization and degradation.

The second portion of Dr. Rixey's presentation addressed the effect of non-aqueous phase liquids (NAPL) on partitioning. He noted that in equilibrium partitioning among air, water, and soil, the effect of NAPL is accounted for in the measured values of K_w, resulting is increased equilibrium partitioning. Dr. Rixey presented data for the observed and theoretical K_w values for benzene, toluene, ethyl benzene, *m*-xylene, *p*-xylene, and naphthalene in tank bottom sludge, hydro-refining catalyst, and soil. He concluded that residual NAPL in oily wastes significantly increases K_w compared with K_d for sorption only. Based on a comparison of theoretical partition coefficients and those measured in 48-hour batch experiments, Raoult's law is a useful measure of equilibrium behavior and can be used to indicate the presence or colloids/emulsions, and sequestration (kinetics).

Dr. Rixey's conclusions regarding residual NAPL are that it can have a significant impact on the relationship between the concentration in the leachate (C_L) and the total concentration in the waste (C_T). He found that Raoult’s Law can be used to assess whether equilibrium conditions exist in batch tests, and it is useful especially for oily wastes which tend to have high K_w and that Raoult’s Law can also be useful for estimating leaching in the absence of leach tests.

In order to determine when rate limitations exist, Dr. Rixey recommended comparing actual leaching results with predicted leaching, using batch tests at a fixed L/S ratio, as an initial assessment. The alternative is to use more definitive rate of release (ROR) tests. He found that kinetics can be accounted for using rate of release (ROR) tests, such as modified batch, fixed-bed and other rate of release approaches and that rate constants can then be compared with those for other loss processes using an appropriate modeling framework.

Dr. Rixey pointed to aqueous modified batch methods and aqueous fixed-bed methods as examples of current ROR methods. He noted that several alterative ROR methods are being developed, including:

- Supercritical Fluid Extraction (SFE)
- Accelerated Solvent Extraction (ASE)
- Thermal Desorption Mass Spectrometry (TDMS)

Dr. Rixey presented an example of slow release that involved the fixed-bed desorption of benzene from an aged silty loam soil. He presented data for k_2, the slow rate constant, and F, the available fraction of NAPL in the soil, that were derived from a laboratory-spiked silty loam soil, using both a one-site equilibrium model and a two-site rate-limited model conducted over a 60-day period. He indicated that slow release is important relative to leaching and also relative to biodegradation or volatilization under two sets of conditions that can be described in terms of k_2 and F.

Based on his work, Dr. Rixey concluded that:

- Simple batch tests are useful for describing leaching for organic compounds from oily wastes, especially if equilibrium conditions occur.
- Separate test methods should be used to determine kinetics when needed.
- Estimation methods/separate tests should be used to account for other loss processes, e.g., volatilization and degradation.
- Appropriate tests should reflect a tiered approach to waste assessment.

Among the other issues that must be considered are:

- NAPL migration, volatilization, degradation.
- Lab-to-field translation.
- Field-scale heterogeneities:
  - soil type
  - contaminant distribution
  - paths for various transport processes, e.g., leaching, volatilization, etc.
- Sampling considerations.
- Modeling considerations.
- Other specific test-related issues.

During the question and answer period, David Friedman (EPA) asked how one could use the available information with the current regulations. Dr. Rixey replied that researchers need to work together to develop better descriptions of leaching and need some flexibility.

Overview of California EPA Approach

Bart Simmons of the Hazardous Material Laboratory, Department of Toxic Substances Control, California Environmental Protection Agency (Cal/EPA), presented an overview of the approach that Cal/EPA is currently using to classify wastes. A copy of Mr. Simmons' presentation materials is available through the following link: simmons.pdf. During his presentation, he discussed the development process used by Cal/EPA in developing their criteria for toxicity testing, basing their requirements on both the TCLP regulatory limits and the Waste Extraction Test (WET) soluble threshold limit concentrations (STLCs). Cal/EPA also considered calculated values for oral, dermal, and inhalation toxicity of the target analytes, as well as reports of fish toxicity at concentrations under 500 mg/L, and reported carcinogenicity at concentrations greater than 100 ppm.

Mr. Simmons contrasted the conditions of the TCLP vs. the WET, noting differences in leachant (acetate buffer vs. citrate buffer), duration of leaching (18 hrs vs. 48 hrs), and ratio of liquid (leachant) to solid (waste) (20:1 vs. 10:1).

Cal/EPA designed extraction studies to decide which extraction test (WET, TCLP, or SPLP) best simulates extraction with municipal solid waste leachate. The study determined the concentrations of metals extracted over 48-84 days, with 10% replacement of the leachant, from the following wastes:

- mine tailings (As, Pb)
- composite of burnt or catalyst wastes (Ag, Co, Sb, Zn)
- composite of water-precipitated wastes (Be, Cd, Cr, Mo, Ni, V)
- composite of metallic wastes (Be, Co, Cr, Mo, Ni, V)
- composite of miscellaneous wastes (Ag, As, Ba, Be, Cd, Cr, Cu, Mo, Ni, Se, Tl, V)

using the following leachants:

- citrate (WET protocol)
- acetate (TCLP protocol)
- Synthetic Precipitation Leaching Procedure (SPLP) solution
- Ukiah landfill leachate

From this study, Cal/EPA concluded that the TCLP was better than WET or SPLP at simulating leachate extraction for beryllium, cadmium, chromium (Cr III), cobalt, copper, lead, nickel, and zinc. Cal/EPA further concluded that none of the tests evaluated consistently predicted leachate extraction for antimony, arsenic, molybdenum, selenium, and vanadium, but WET was better than TCLP or SPLP.

The National Academy of Science (NAS) published a report on this study in April, 1999, entitled "Risk-Based Waste Classification in California" that considered the results of the Cal/EPA extraction study as well as other factors. The report presented three recommendations:

- Work with stakeholders and EPA to address shortcomings of TCLP and WET.
- Use extraction study data in probabilistic modeling.
- Incorporate groundwater pathway into multimedia model.

At the close of the presentation, Paul Abernathy, Association of Lighting & Mercury Recyclers, asked where mercury fell in the two categories identified in the study conclusions. Mr. Simmons indicated that the TCLP was more aggressive than the WET, with respect to mercury.

Marty Huppert, SAIC, asked at what stage of its life cycle (e.g., young, or old) was the landfill that supplied the waste samples. Mr Simmons replied that they did not find any leachates at pH = 5, even in relatively young cells. They also did not characterize the organic content of the leachate.

Overview of Research Supported by EPA

Dr. David Kosson, of Rutgers University, presented an overview of the leaching research that EPA has supported in recent years in his laboratory. He described the current applications of leaching tests, including: waste classification (hazardous vs. non-hazardous), evaluation of treatment process effectiveness, waste management options, and alternative disposal options.

Dr. Kosson stressed the need for a consistent approach for evaluating wastes to determine appropriate waste management practices. Such an approach must reflect the maximum potential release of contaminants from the waste. It must consider the cumulative release over a defined time frame. He noted that the initial leachate composition can be very important, and that it tends to reflect the pore water composition.

Dr. Kosson described an alternative approach to leaching that involves five steps:

- Define the release mode and the fundamental leaching parameters
- Design the test method to measure the fundamental parameters
- Test the waste
- Calculate the release for a given management scenario
- Evaluate the acceptability of the release based on the project impact.

He discussed fundamental leaching parameters, which include:

- Availability of the contaminants
- Liquid/solid equilibrium (solubility of a constituent may vary as a function of pH or of the L/S ratio)
- Release rates (release rates can be different from monolithic wastes vs. compacted granules)
- Acid/base neutralization capacity

Dr. Kosson discussed the problems of particle size and contact time, noting that consideration must be given to the particle size distribution of the actual waste, the potential for the coupled release of contaminants, and the practicality of the test and any particle size reduction techniques.

His current research involves further methods development work for organic constituents, as well as resolving the issues surrounding particle size, equilibrium time, and sample size. Dr. Kosson discussed the need for further development of leaching models.

Dr. Kosson advocated a tiered evaluation framework and the use of a more robust evaluation framework to better facilitate waste management decisions. Tier 1 would look at the availability of the contaminants in the waste. Tier 2 would evaluate the compliance of the results with the equilibrium concentrations (e.g., does an equilibrium model fit the data?). The Tier 3 evaluation would examine the mass transfer rate.

Dr. Kosson described an example disposal scenario that would employ four sets of parallel extractions that could be used to evaluate the importance of particle size reduction, contact time, and leaching fluid composition. Such an evaluation would consider the natural pH of the disposal environment in choosing a series of pH values at which leaching would be conducted. At least two liquid/solid ratios would be tested as well.

He noted that with a tiered approach, the user can better balance the costs against the type of data that is needed for decision-making, ultimately leading to better decisions, more appropriate use of limited landfill space, and an overall increase in environmental protection.

Dr. Kosson concluded his presentation by noting that the measurement of leaching parameters permits estimation of the constituents released in either default or site-specific scenarios and that the comparison of the default approach with site-specific conditions is an important aspect of leaching research. At the conclusion to his presentation, Dr. Kosson addressed questions and comments from the participants.

One participant reminded the group that changes to the leaching test procedure cannot ignore the fact that the RCRA statutes require that EPA provide a means to characterize wastes and identify those that pose a risk when mismanaged. Dr. Kosson replied that the mismanagement scenarios that he has studied and the allowance for different scenarios in the models are consistent with the RCRA statutes. Dr. Kosson noted that leaching tests are used for many other applications beyond RCRA characteristic testing and that if carefully designed, the uses of leaching tests for these different purposes need not exclude their use under RCRA David Friedman, of EPA, also responded, stating that while the RCRA statutes do require that the characteristics testing be based on a mismanagement scenario, the statutes do not specify *what* mismanagement scenario must be used.

Hans van der Sloot, of NERF, commented that one of the problems with metals such as arsenic is that they are greatly affected by the pH at which they are measured. He noted that in the range around pH=5, there is a steep slope in the arsenic solubility curve. Thus, without very careful control of pH, large differences in arsenic concentration can occur. Dr. Kosson replied that this was a good observation and noted that there are quality control procedures that can be used in modeling leaching behavior that allow the investigator to note the differences in the actual materials that were being leached and take actions to ensure accurate pH control. However, when the tests are applied in a regulatory sense, that ability to be flexible may not exist, leading to differences in the final results.

A participant commented that she felt that the testing procedure violated its inherent assumptions regarding issues such as compacted granular materials versus monolithic wastes. She asked if any validation studies had been conducted with real materials, such as cement block. Dr. Kosson replied that there had been many comparative studies performed and that they have examined a wide range of crushed and compacted materials, etc. He offered to discuss the details of the validation efforts after the session.

Hans van der Sloot presented another comment, in partial response to the validation study question. He stated that stabilized wastes had been extensively tested and the results of the testing were used in a model that was designed to predict the changes that would occur over a 10-year period. The wastes were then placed in a landfill which was examined periodically over a 10-year period. He stated that after 10 years, the predicted leaching of some metals was within a factor of 2 of the observed results after 10 years, and that he considered this to be good agreement. He stated that other metals agreed within a factor 5, while a third group, including lead and zinc, only agreed within a factor of 10. He noted that the concentrations studied were low, on the order of milligrams per cubic meter in soil.

Bill Batchelor asked about the availability tests. Did a 1-point test mean that an extraction was only carried out at one pH, or that only one determinative analysis was conducted on the combined leachate from several pHs? Dr. Kosson replied that the details of the various alternative leaching approaches had resulted in an intense debate about this subject. He noted that workers in the Netherlands had conducted a round-robin validation study that looked at leaching wastes at pH=4 and pH=7, then combining the leachates for a single analysis. Another suggested approach was to use the asymptote of the pH-solubility curve and calculate the mass released at a known liquid/soil ratio. A third approach was for leaching at two pH values, with each leachate analyzed separately. Dr. Kosson indicated that while the issue was still being debated, he expected that the final approach would involve a compromise that allowed for a conservative implementation of an alternative leaching protocol, yet that would allow more rigorous approaches to be employed when needed.

Overview of Current Approaches

Sara Hartwell, Science Applications International Corporation, provided an overview of the leaching tests currently in use. A copy of Ms. Hartwell's presentation materials is available through the following link: hartwell1.pdf. She noted that batteries of leaching tests have been proposed or promulgated not only by the US, but by France, the Netherlands, Germany, Sweden, Denmark, the European Union and Canada. Both the government and private sector have developed and incorporated leaching methods into their programs. These methods go way beyond the single-batch testing protocol of the TCLP, and address additional waste management scenarios, leaching properties and waste types. Tests have been developed to account for variability in the ratio of leaching fluid to solid waste, chemical composition of the leaching fluid, testing of monolithic and granular wastes, as well as stabilized and solidified wastes, and to address radioactive wastes. Within the US, standardized leaching protocols have been published by the American Society for Testing and Materials, the International Atomic Energy Agency, the US Army, ANSI/ANS, and the ISO.

Leaching test methods can be divided into 2 general categories: static extraction tests and dynamic extraction tests. In static extraction protocols, leaching takes place with a single, specified volume of leaching fluid. In dynamic extraction protocols, the leaching fluid is renewed throughout the test. In static extraction protocols, a specific amount of leaching fluid is placed in contact with a specific amount of waste for a specified length of time, with no replacement of, or addition to, the leaching fluid. The leachate from the test is removed at specified times, usually the end of the test, for analysis. Static extraction protocols assume that a steady state condition is achieved by the end of the test. Types of static extraction tests include: agitated and non-agitated extraction tests, sequential chemical extraction tests, and concentration buildup tests.

In agitated extraction tests, the waste and leachant are co-mingled and agitated, so the test reaches steady-state conditions as quickly as possible. Test protocols frequently incorporate particle size reduction steps to increase the amount of surface area available for contact, thereby reducing the amount of time required to reach a steady state condition. Agitated extraction tests measure the chemical properties of a waste/leachant system rather than the physical, rate-limiting mechanisms. Because of this, this type of test may over-estimate the short-term release of constituents. Examples of agitated extraction tests include the TCLP, EP Tox, California's WET, and the SPLP.

In non-agitated extraction tests, the waste and leachant are co-mingled and not agitated. Non-agitated extraction tests measure the physical, rate-limiting mechanisms, rather than the chemical properties of a waste/leachant system. This type of test is based on the assumption that the physical integrity of the waste matrix affects how much material can be leached out of the matrix. Non-agitated extraction tests take longer to reach steady state conditions than the agitated tests. Example of non-agitated extraction tests include the Strategic Leach test and High Temperature Static Leach test, both from Canada.

A sequential chemical extraction test is a series of agitated extraction tests, using increasingly aggressive leaching fluids. There are two ways to set up a sequential extraction test: you can set up multiple tests, each one with a different leaching fluid - this assumes that each leaching fluid will extract what the less aggressive fluid extracted, plus some additional contaminant or quantity. Alternatively, the same aliquot of waste can be subjected to each successive leachant - this version assumes that each successive leachant will extract something that the previous leachant could not . In either case, the hypothesis is that increasing chemical aggressiveness will result in increasing amounts of extracted contaminants. An example of a sequential chemical extraction test is ASTM's Sequential Batch Extraction of Wastes with Acidic Extraction Fluid. Other sequential extraction tests are being developed.

Protocols for concentration build-up tests call for aliquots of the waste to be contacted repeatedly with the same leachate, at a very low liquid to solid ratio. This type of test models a volume of fluid flowing through a body of waste, with the concentration of extracted contaminants building up in the leachate as it progress through the system. These tests may be a good simulation of the pore-water composition of a waste. An example of a concentration build-up test is Wisconsin's Standard Leach Test, Procedure C.

In dynamic extraction protocols, the leaching fluid is renewed, either continuously or intermittently, to drive the leaching process. Because the physical integrity of the waste is usually maintained during the test, and the information is generated as a function of time, dynamic extraction tests provide information about the kinetics of contaminant mobilization. In general, dynamic extraction tests can be categorized as: serial batch tests, flow-around tests, flow-through tests, and Soxhlet tests.

In a serial batch test, a portion of a crushed, granular sample is mixed with leachant and agitated for a specified time period. At the end of the time period, the leachate is separated, fresh leachant added, and the process repeated until the desired number of leaching periods has been completed. The concentrations of contaminants measured in the serial leachates can provide kinetic information about contaminant dissolution. Examples include the Multiple Extraction Procedure (SW-846 Method 1320); the Availability Test and Serial Batch Test from the Netherlands, and the US Army's Graded Serial Batch test.

Flow-around tests use either monolithic samples, or samples that are somehow contained. The sample is placed in a test vessel, with space around the sample, and leachant is added so that it flows around the sample. The leachant may be renewed continuously, in which case it is sampled periodically, or it may be replaced intermittently. In either case, the liquid to solid ratio is expressed as the ratio of volume of leachant to surface area of sample. Examples of flow-around tests include the ISO Leach Test 6961, ANSI 16-1, the Monolithic Diffusion test from the Netherlands, and ASTM's Static Leaching of Monolithic Waste Forms for disposal of Radioactive Wastes.

Flow-through tests differ from flow-around tests in that the leachant flows through the sample rather than around it. This means that the sample must be porous, rather than monolithic. Beyond that, the tests are conducted very similarly. Flow-through tests are usually constructed as columns or lysimeters, and pose particular experimental challenges such as channeling, flow variations caused by the hydraulic conductivity of the waste, clogging of the system by fine particulates, and biological growth in the system. Notwithstanding, flow-through tests can be set up to mimic site-specific conditions. Examples include Canada's Waste Interface Leach test, NVN 7344 Column Test, and ASTM's Column Test.

A Soxhlet extractor can be used to leach wastes by continuously contacting the waste with leaching fluid. In this test, the leachant is continuously renewed with "recycled" leachant from which previously extracted contaminants have been removed. This test is designed to maximize the amount of extracted contaminants, as quickly as possible. An advantage of the Soxhlet test is that it concentrates contaminants in the leachate, which may help overcome analytical detection issues, however, it is limited to relatively low boiling solvents as leachants, and it is not suitable for use when the contaminants of interest are volatile at or below the boiling point of the leachant. Canada's Soxhlet Test (MCC-5s) is a good example of this type of test.

She closed her presentation noting that each of these wide variety of tests has advantages and disadvantages, and each one is more relevant to some waste disposal scenarios than other.

Session IV - Leaching Policy and Applications

Three panel discussions were held in conjunction with the leaching meeting. The topics for the three panel discussions were: Waste Characterization, Site Characterization, and Treatment Effectiveness. The purpose of the panel discussions was to provide a forum for several of the speakers to amplify portions of their earlier presentations and to solicit comments from the attendees regarding the use of leaching in the context of the three topic areas, and to allow brief focused presentations from other speakers, predominantly those from other parts of EPA and from states and industries.

Each panel discussion included a question and answer session. Some of the questions to the panel were simply requests for the clarification of technical terms and other aspects of the presentations from the main session, while other questions involved new topics and concerns. For the sake of brevity, these minutes only provide those questions that raised new issues or concerns.

Panel I - Test Design and Implications: Waste Characterization

David Friedman, of the EPA Office of Research and Development (ORD), opened this panel discussion session with an overview of the issues he saw as important to EPA's leaching policy decisions. His first point was that the original purpose of waste characterization was to determine if a waste needs to be managed as a hazardous waste and that a major secondary purpose was to allow EPA to evaluate a treated waste to determine if it could be removed from regulation as a hazardous waste.

Mr. Friedman indicated that the assumption that wastes will be co-disposed to municipal (nonhazardous) wastes still applies, and that the wastes to be characterized represent only 5% of the total waste volume in a co-disposal scenario. Thus, the situation is not "waste-limited."

From a practical standpoint, Mr. Friedman argued that leaching test must take less than 24 hours. It must assume that the co-disposal would occur in a young landfill with significant organic contents. One must assume that the stability and physical integrity of the waste will not change, since there is no good way to evaluate its integrity. He pointed out that the cost of the test was a critical factor.

Mr. Friedman went on to raise several questions that he thought that the session ought to address, including:

- Is the co-disposal scenario valid?
- How important is biodegradation, which the TCLP does not address?
- There are trade-offs between time to conduct the test and accuracy of the result. How important are these trade-offs?
- Should waste-specific properties be taken into account?
- How can we related laboratory testing results to the inputs needed for modeling?
- Is there a better existing test than the TCLP?
- Can the problems with waste characterization be fixed with simple modifications or is a new test needed?
- How accurate must the test be?

Greg Helms, of the EPA Office of Solid Waste, presented a brief version of OSW's perspective on the issues to be considered in characterizing wastes. His major points included:

- New/modified test(s) must be reliable across a broad array of waste types.
- The test must be reasonably inexpensive.
- It must produce results in a reasonable time frame.
- It must have a clear, rational relationship to the regulatory and management framework and produce an unambiguous result.
- It must be useful to risk assessment in site-specific setting
- It must be accurate or have a known bias, although increased accuracy will lead to increased cost and complexity.
- It must account for matrix effects and the long-term stability of monolithic wastes.

Harley Hopkins, of the American Petroleum Institute, presented his perspectives on leaching oily wastes, which is a major concern for the oil industry. Mr. Hopkins noted that leaching tests were applied to oily wastes both to characterize hazardous wastes, i.e., Subtitle D vs. Subtitle C management, and in association with corrective actions at contaminated sites. In the case of waste characterization, the groundwater pathway is of concern and relatively specific leaching conditions apply. In contrast, when determining when to begin and when to stop corrective action, other pathways are also important and the various parameters, e.g., infiltration rate, soil type, degradation, volatilization, groundwater velocity, etc., are more site-specific.

Mr. Hopkins indicated that leaching test protocols should be able to handle both cases. The key features a test protocol should have with respect to oily wastes include:

- Tests should be simple - especially a Tier 1 test.
- Tests should generate parameters that can be used in a modeling framework that reflects a good description of the source term.
- Leaching test(s) must account for realistic leaching, especially source depletion over time.
- The protocol should allow a tiered approach to waste assessment.
- Flexibility to consider other loss mechanisms, e.g., volatilization, degradation, etc.
- Flexibility to incorporate site-specific information.

In describing the attributes of new leaching protocols, Mr. Hopkins stated that it would be important to replace the current batch tests with simpler batch tests that are appropriate for oily wastes. The test should be able to address non-aqueous phase liquids (NAPLs) using default values, estimation techniques, or separate specific tests. He felt that the methods should allow the user the flexibility to refine the initial characterization to consider waste properties and the management scenario. Such refinements allow a better characterization at the same level of protectiveness. He advocated a tiered approach, and stated that new tests should account for other loss processes, e.g., volatilization and degradation, with separate estimation techniques/tests using conservative default parameters for lower tier analysis and more specific tests for higher tier analysis.

In terms of refining the characterization of oily wastes, Mr. Hopkins stated that EPA should keep the basic batch leaching test approach, but couple it with totals analysis to obtain leaching parameters for a better assessment of leaching. The refinements should improve the values used for key site-specific parameters, e.g., infiltration rate and degradation rate, that impact risk calculations, account for heterogeneity issues, especially with respect to modeling various transport processes in site specific assessments, and account for kinetic limitations with default values or separate tests, when needed.

In describing the mobility issues surrounding NAPL, Mr. Hopkins noted that because of the land ban restrictions, the mobility of NAPL should be determined separately from leach testing. In many oily wastes, the oil is residually trapped and does not migrate in the environment. Thus, batch tests do not reflect the actual migration behavior. The current batch test protocols report the oily waste as reaching the ground water receptor if a NAPL is generated during the test. However, the presence of a NAPL phase, in fact, generally reduces leachability of organics.

Therefore, a new protocol (an estimation technique or test) may be needed to detect those cases where the oil content exceeds a "residual" level.

Mr. Hopkins commented on the utility of batch tests for oily wastes, noting that simple batch tests are useful for describing realistic leaching for organic compounds from oily wastes, especially if equilibrium conditions occur. Batch tests appear reasonable for lower tier characterization. In some cases, the use of Raoult's Law, which is conservative, may preclude leachate testing. Simple batch tests can be used to develop partition coefficients for simple equations to predict leaching with time. He noted that other specific test issues identified by the SAB should also be considered, if relevant, e.g., colloids/emulsions, particle size effects, etc.

Mr. Hopkins stated that new testing protocols should allow the user to characterize the waste and to determine "how clean is clean?" The tests should also:

- be simple to perform
- be easy to understand
- low cost
- generate data for modeling
- simulate realistic management scenarios
- be flexible in terms of the protocol (for site-specific information)
- be able to account for NAPL mobility
- keep batch approach - add totals analysis
- add site-specific information
- account for heterogeneity
- account for kinetic limits

Mr. Hopkins stated that NAPL mobility should be determined separately from the leaching tests. He noted that the current batch testing produces misleading results when NAPLs are present. He believes that the batch test is useful for oily waste, particularly in terms of lower-tier testing. However, it will be necessary to generate data that can be used for predictive modeling. He reiterated a call to consider the relevance of the issues discussed by the SAB.

Bart Simmons, of the California EPA, delineated three steps that he felt needed to be taken in any revisions to the leaching protocols. These three steps are:

1. Clearly establish policy goals, in quantitative terms

2. Decide what waste management scenarios are consistent with the policy goals

3. Decide what models will be used and what leaching tests are consistent with those models

Mr. Simmons continued his remarks by presenting two additional concerns to the audience and asking them to suggest others.

1. You must account for the uncertainties of the modeling and risk assessment when considering the leach test.

2. You must consider the economics of the test.

The audience offered the following conditions and observations (Given the number of suggestions, no attempt has been made here to identify the person making each suggestion, nor to comment on their relevance).

1. When formulating policy, must consider adding flexibility to account for waste management practices.

2. Must consider similarities in wastes and combined testing (from similar processes) when considering costs of new testing plans or configurations. There are great similarities within waste classes (based on generation process).

3. Safety Kleen has about 80 new generators per day that fall into 120 "Standard Industry Profile" wastes, out of about 300 generators per day. Being able to accept/process wastes under that information would be a big help.

4. There is currently a bill pending in California to require more testing for waste classification.

5. Waste management scenarios must also consider storage options and all exposure pathways.

6. HWIR is looking at multi-pathway risk in order to exit the waste regulatory system. Should EPA consider a similar approach for entry?

7. For Tier 1 testing, you must keep the model simple. You cannot write regulations that account for all eventualities, all site-specific conditions, and heterogeneity.

8. EPA's challenge: How do you know when someone is not doing what you intended? If a waste is not managed under certain conditions, how might it be managed? If the intent is give credit for management of non-hazardous waste under certain conditions, how do you control that?

9. It seems inequitable to require the same testing for mismanaged wasted and properly managed/treated wastes.

10. This system would include secondary testing to confirm that waste batches would conform to the "Standard Industry Profile," as well as providing operational data for testing.

11. Prescription vs. process aspects of testing (testing a method-defined parameter vs.the PBMS approach to leach testing)

12. Changing the leaching fluid is an easy fix.

13. Defining the accuracy of a test is resource-intensive (precision is easier). EPA must define how accurate they need (want) the test to be, then make the measurements.

14. The history of the particular waste can influence whether a waste fits into a “Standard Industry Profile.” Foundry sands are a good example.

15. Cost is only important if the test is accurate.

16. People will pay more for good data.

17. What happens when a waste falls outside of the RCRA regulations? In RCRA, there is a tiered system of landfills to which wastes are assigned on the basis of testing. One can also consider waste compatibility, based on landfill design.

18. Multiple pH leachings, where the pH is determined by the waste, have been useful.

19. One test will not accomplish EPA’s wish list. If there was a list of “this procedure for that situation,” then the industry could cope. Because the cost of the leaching is a minor component of the overall analytical costs, running two tests, one for inorganics and one for organics is not a burden.

20. Testing frequency is an issue. The Netherlands specifies testing frequency, on a waste-by- waste basis, for the compliance phase of testing.

21. The variability of the concentration of certain elements, at a given pH, can provide a useful indicator of whether or not a waste fits into the “Standard Industry Profile”.

22. Industry *is* interested in looking to see if ground water is contaminated, and managing the waste accordingly.

23. Our regulatory system is not amendable to the current state of leaching science.

24. Contingent management is a difficult process, in the regulatory sense.

25. Separate the management scenarios from the test procedure. The scenarios tell you how to interpret the results. Within reason, the important information to have is the total amount of material that could leach, and that may require multiple test procedures.

Panel II - Test Design and Implications: Site Characterization

David Friedman, of EPA's Office of Research and Development, opened this panel discussion by posing two questions to the audience.

1. How applicable are the current tools?

2. How do we address site-specific variations?

Robin Anderson, representing EPA Office of Emergency and Remedial Response (OERR) presented information on how the Superfund program utilizes leaching tests. First, she noted that leaching test results may be used in the selection of a remedy at a Superfund site by providing information to identify:

- Applicable or Relevant and Appropriate Requirements (ARARs)
- Remediation levels
- Treatment effectiveness requirements

In general, she has found that the situation under Superfund is much easier than under the RCRA regulations in that, initially, all Superfund sites are held to the same standards. The goal is to determine that ground water contamination has occurred and then to remediate the contamination to a specific level.

TCLP Results may also be used in assessing the remedial action implementation by providing information on:

- ARARs Compliance
- Cleanup Level compliance testing

She explained that Synthetic Precipitation Leaching Procedure (SPLP) results may be used for soil screening level determinations but that TCLP results are generally not used as an indicator of protectiveness or a predictor of future leachate concentrations.

In the context of Superfund sites, the EPA Regions are given latitude to identify one or more leaching tests that are appropriate for their situation (e.g., site-specific decision making).

Ms. Anderson said that Superfund provides soil screening guidance, including a methodology to calculate risk-based, site-specific, soil screening levels (SSLs). These SSLs provide a means for identifying those areas that do not warrant further consideration. She emphasized that SSLs are not national cleanup standards. She stated that generic SSLs are based on default assumptions that are protective when employed for most sites. These generic SSLs can be supplemented by site-specific SSLs that are based on modeling and site-specific assumptions.

The SSL generic ground water model assumptions include:

- Simple linear equilibrium soil/water partition equation
- Simple water-balance equation to calculate a dilution factor from mixing in an aquifer
- Partition equation used to calculate total soil concentration

Alternately, a soil leaching test may be used to calculate soil concentration. Typically the SPLP is used for this purpose. The SPLP is designed to "...model acid rain leaching environment and is generally appropriate for contaminated soil scenario."

Five risk pathways are considered, including:

- Direct ingestion
- Inhalation of volatiles and dust, etc.
- Dermal adsorption
- Ingestion of homegrown produce
- Migration of volatiles into basement

Four migration pathways are considered, including::

- Ground water migration
- Surface water migration
- Volatilization and entrainment
- Direct Contact

Ms. Anderson stressed that in order to support protectiveness and long-term reliability, the leachate test should model the conditions of the site (current and future) and should evaluate the form of the material that is present in the environment. She added that the test should relate directly to the environmental impact of the material and noted that Superfund benefits from a simple scenario because the existing statute limits the evaluations that can be conducted to assessing the extent of contamination and the extent of clean-up, and to compliance monitoring.

Ms. Anderson stated that leaching tests are used in Superfund for the evaluation of treatment effectiveness and for ARAR compliance. The latter use is because the test methods are required by law and are therefore both "required" and "relevant" (e.g., fall under the definition of ARARs). Beyond that, there are only a few instances in which appropriate methods have been defined under the law.

Ms. Anderson noted that once EPA moves beyond the initial stages, there is a great deal of flexibility in the program, including in determining what level of cleanup is needed at a given site and in the ability to monitor contamination based on site-specific conditions. She stated that the overall remediation approach is established using a tiered approach that depends on site-specific conditions. The monitoring requirements are set forth in the Record of Decision (ROD) developed for each site.

Superfund provides soil screening guidance that is based on a conservative (10^{-6}) risk assessment. This risk assessment is augmented by other tests including leaching tests, and includes soil-water partitioning data drawn from leaching tests.

Ms. Anderson indicated that for Superfund, the major question is the threat to human health and the environment that is posed by a given site. They always consider the ground water exposure pathway, and that other pathways and scenarios are assessed. The assessment considers how the leachates will change over time and they use a range of leaching tests to obtain that information. However they are aware that no tests give assessment of long-term behavior. For Superfund, an important question is whether the observed behavior is reversible.

Ms. Anderson concluded her remarks by noting that Superfund is also struggling with the issue of how to employ leaching tests that are relevant to site-specific conditions.

David Merrill, of the Gradient Corporation, described his 10 years of experience in applying leaching protocols. He noted that his first experience with the TCLP was directed at establishing action levels. More recently, he has been working to link leach testing with risk assessment methods. He noted that there has always been a problem with what to do with the leaching results outside of the context of waste characterization and concluded that leaching test results must be interpreted in context of risk assessment.

Mr. Merrill stated that, at present, he uses the TCLP to characterize leaching potential, while information on transport potential may be gained by several means, including the EPA CMTP model.

Mr. Merrill noted that site-specific assessments are difficult to model. However, models can be effective in selecting management strategies. Focusing most of his remarks on metals, he noted that modeling metals transport is still very challenging. He noted that although the EPA models have come a long way over time, especially in the area of metals, a narrow range of leachate numbers still result in a wide range (6 orders of magnitude) of retardation factors for different metals. Given the wide range of transport results, the interpretation of the results is difficult, and Mr. Merrill indicated that more emphasis needs to be placed on what to do with the results. Transport uncertainties need to be considered in leach assessment. These variations can result in 1-2 orders of magnitude or more. He noted that the time scale of the transport process may not match the time scale of leaching process.

Mr. Nihar Mohanty, of the Massachusetts Department of Environmental Protection (MA DEP), described his department's work in setting clean-up standards. The MA DEP uses probabilistic risk assessment, employing a slightly different approach then described in the EPA contaminated soil guidance. They employ data collected from many sites within Massachusetts, which exhibit less heterogeneity than from sites nationwide, and do not have leaching-based standards. At present, Massachusetts does not allow TCLP results to be used to establish clean-up levels. Mr. Mohanty hoped that any new EPA leaching methods might complement the tiered approach that is currently used in Massachusetts.

Mr. Mohanty stated that they use risk models to determine the 90^{th} percentile value at the point of exposure. Essentially, they work backwards from the ground water well (the point of exposure) to determine how much of a given contaminant can be in a given waste and still not pose a threat. He noted that there is some uncertainty due to variation in the sampling results.

Mr. Mohanty described their work at a uranium site that had been leaching for over 25 years. The basic questions to be answered can be phrased as:

- How much can we leave in place and not affect groundwater?
- Should we consider reversibility?
- Where do we sample: close or more distant?
- How do we limit costs and the number of samples?

- Do we consider batch or column leaching Adsorption or desorption?

He noted that they must balance the costs against the statistical validity of the sampling approach and the ultimate decision. Mr. Mohanty concluded by discussing five issues that he hoped could be addressed in any new leaching test protocols.

1) Compounding uncertainties: As you know, there are uncertainties due to heterogeneities of geologic media and sampling techniques of a contaminant during site characterizations. If a contaminant exists under reducing conditions at a site (usually this is the case except for radioactive material), analysis under oxidizing conditions (in the presence of iron oxides) would add errors. Others at this meeting have suggested that errors up to three-fold have been observed during TCLP measurements. In light this, a proposed method should be sufficiently robust to reduce the measurement uncertainty that may be compounded due to heterogeneity from a single site. Some guidelines for collecting samples for TCLP would be helpful.

(2) Statistical issues: As an example, three samples are collected from a single site showing three different partitioning coefficients, 1 mL/g, 50 mL/g and 300 mL/g under equilibrium conditions. What number may be used to represent actual conditions at a site? Should averaging be allowed. or should additional samples be collected to reduce uncertainty? It may be impossible to satisfy the minimum requirements of statistics. Mr. Mohanty recommended using a reasonably conservative sampling scenario or safeguards that perhaps over predicts leaching (known bias) to some degree.

(3) Ionizing organics show different leaching behavior under different pH conditions. So, if the test is not run for pHs where a chemical is known to leach the most, there is a potential to under predict leaching. This is most important for a compliance or "bright line" test recommended in the first tier of a tiered approach.

(4) The proposed new methods assume that the pH and the solid-to-liquid ratio are the key parameters. The leaching characteristics of monolithic materials are also given importance, which makes sense. To be consistent, the proposed method should clearly state the acceptable sample preparation methods, in order to represent monolithic behavior in a lab.

5) Determining equilibrium conditions during a test: Mr. Mohanty agreed that grinding a sample would help achieve a quick equilibrium in a test. For example, if a chemical does not achieve equilibrium within the proposed time frame of the test, how does one consistently measure equilibrium conditions? Would it be acceptable to assume equilibrium conditions when a chemical does not desorb/adsorb more than 5% (mass) in 24 hours after the duration of the proposed time frame? If equilibrium is not achieved during the time allowed for the test, the it would be helpful to have a method of predicting equilibrium conditions based on results of the "short time" test. The conservative way is preferable, if not exact. It would be good to have guidelines so that everyone determines equilibrium in the same way.

Ginny Colten-Bradley, of the EPA Office of Solid Waste, Economics, Methods, and Risk Assessment Division, briefly described EPA's composite model with transformation products (CMTP). Ms. Colten-Bradley noted that the CMTP is not designed to be a site-specific tool. It does, however, use equations that are similar to those in site-specific models, but the CMTP is hard-wired to accept national inputs. She noted that changes are underway to allow it to be used in a site-specific fashion. In general, it is a probabilistic tool which does result in a range of values. However, when low infiltration rates are used, the range of results is reduced. She noted that the difficulties lie in the fact that site parameters vary widely, and those parameters can greatly affect the dilution-attenuation factors.

Ms. Colten-Bradley noted, regarding metals, that some issues have been raised regarding fossil fuels and EPA wants to address them. There were questions from the audience about how you select the proper percentile? Is it stable at 95%, 90%? How do you determine the sensitivity to specific parameters? Ms. Colten-Bradley responded that most important parameters had been assessed with sensitivity analyses, though more work is underway. She noted that there is some concern about adsorption.

At the end of the panel discussion on site characterization, a number of issues and questions were raised by members of the audience. Richard Lesser, RMRS, Inc., commented that he believes that the size reduction requirement it is too conservative for debris. He prefers the bulk product approach, such as is used for PCBs, where substitute D is allowed.

Bart Simmons, Cal/EPA, noted that the speciation of metals is important. For Selenium, a simple total analysis and a deionized water leaching provide a good assessment. He asked if EPA can collect or catalog such cases?

Richard Lesser, of RMRS, Inc., commented that EPA should develop alternative methods to assess adsorption. They should be quick and dirty tests. Pennsylvania has established a three-tiered testing approach involving:

1. total analysis
2. SPLP to compare the results to the drinking water limits
3. full risk assessment

Hans van der Sloot, Netherlands Energy Research Foundation, commented that, with regard to testing costs, the column tests are very expensive but cost can be controlled.

Panel III - Test Design and Implications: Treatment Effectiveness

Gail Hansen, of EPA's Office of Solid Waste, opened the panel discussion by posing several questions:

- How do we determine if the treatment is effective?
- Does the treatment meet the best demonstrated available technology (BDAT)?
- How do we address nontraditional treatments such as vitrification?
- How long do we have to test to determine long-term stability?

Trish Erickson, of the EPA Office of Emergency and Remedial Response (OERR), described how the Superfund program utilizes leaching tests to evaluate treatments of hazardous wastes used for site remediation. She discussed how leaching tests are used to demonstrate both short-term and long-term environmental compatibility. Leaching tests maybe used to demonstrate the effects of treatment. She noted that such uses of leaching tests must be sufficiently supported by theory to identify "trick" treatments and conditions that would cause failure. EPA needs tests that have been validated in the field, not just the laboratory. The tests should be inexpensive, quick, simple procedures, free of interferences, equally effective for the full range of contaminants of concern and a variety of dispositions.

She described how under ideal circumstances, EPA would like a test that works for both short-term and long-term problems. Such tests would be used to determine the effectiveness of waste treatments and the reasons that the treatments are effective. They could be used identify ill-conceived treatments and alert the user to incompatible situations. Tests would be simple and inexpensive and applicable to any disposal environment.

Other concerns that EPA would like to have addressed are the need for tests to be compatible with risk assessment. In addition, reactive wastes are a special concern particularly when managed in a different environment than where they are generated. Ms. Erickson concluded by stating that it is not possible to achieve all of these goals, and there may be a need to compromise some test attributes to achieve the best possible balance.

Bill Ziegler, of ENSCO, presented his perspective on leaching tests. He stated that the TCLP is a good indicator of treatment. However, there are several problems with using TCLP results to assess treatment technologies. He mentioned that pH is an overriding factor. A target pH range would be 8 to 9, but that there was a need to be use a surgical approach to focus work during treatment.

Mr. Ziegler indicated that the original mismanagement/disposal scenario inherent in the TCLP may not be appropriate for all treatment studies. In particular, the actual leachate has a higher pH and the oxyanions may be a problem. As a result, investigators must focus on a pH during treatment ad they my be adding more alkali than needed due to using the TCLP.

Mr. Ziegler advocated several options, resulting in several benefits. He suggested a single test at neutral pH and a test employing two pH ranges, one low and one high. He described several other considerations:

- there must be consistency among EPA Regions and States
- new tests should not be used to challenge prior decisions
- recognition that a "totals analysis" is not appropriate,

and noted that he was not comfortable with the use of multiple test scenarios.

Mike Winka, of the New Jersey Department of Environmental Protection (NJDEP), described his state's treatment technology verification program. He noted that one of their goals was the harmonization (reciprocity)of programs, such as has been done in the Netherlands. He believed that the rules can be revised, and the goal should be clean air and water. He stated that the inertia of the current system must be broken.

Mr. Winka described several technologies that have been evaluated. New Jersey has looked at chrome treatment by concentration. This requires part A/B, but New Jersey has worked around it. Lead in soil issues have been affected by the TCLP, using stabilization with alternate leaching at various pH and total metals analyses. Soil washing and phytoremediation have been evaluated using mass balance, total metals. He stressed the need to match the test to the situation. It is possible to have beneficial use standards using various tests including the TCLP. At present they use total metals. However, as the state moves to alternative tests, Mr Winka indicated that there is a need to develop alternate standards. He said that partnerships with states are preferred over delegated responsibility.

Summary of Meeting Results

Dave Friedman, EPA/ORD, presented a brief summary of the overall results of the meeting. He noted that everyone agrees that the system needs to be fixed to improve waste characterization. He said that there are two ways that wastes are escaping the system: those that are not adequately handled, and those escaping control.

Mr. Friedman said that in order to adequately support risk assessment, EPA must deal with the fact that the models are not as site-specific as they should be and that the tests that are now used were not developed for site-specific risk assessments.

In terms of quality control, Mr. Friedman said that the questions are whether the quality checks are adequately ensuring that waste was treated properly, and is that treatment effective. He said that everyone agreed that a single point pH test would be appropriate. He noted the call for a tiered approach to testing, with a first level screening that is very aggressive, followed by a second level to characterize waste (modify TCLP by adding pH considerations). He indicated the need to look at long term stability, and the chemical and physical nature of the waste. The participants supported the use of models rather than doing everything in the laboratory.

Mr. Friedman wondered what constitutes adequate protection, and pointed to drinking water standards and a multi-media approach (including air exposure), and noted that storage and handling may pose a greater risk now than in the 1970s.

He felt that the meeting pointed out that the current approach to waste characterization is too aggressive in some cases and not aggressive enough in others (false negatives) and that real question was how much might be released.

In describing the potential concerns about the TCLP, he indicated that pH, especially for metals, seems to be the biggest factor, and that bulk waste can absorb organics. Another concern with the current TCLP is that it only counts those wastes that pass through a glass filter, and there is a question of whether this is accurate. There was a clear call for tests that are fast to perform and inexpensive. He noted that the participants generally supported the use of site-characterization risk assessment models and that where many wastes fall into the same characterization, shared information may reduce cost of testing.

He outlined several approaches to solving test problems, including:

- Policy issues, .e.g., the need to determine what we are trying to accomplish, and who or what we are trying to protect,
- Scientific issues,
- Practicality Issues, and\
- Other considerations

Greg Helms, EPA/OSW, outlined the next steps that he saw the Agency taking. First, there is a need for a multiple testing approach, in order to make better decisions and to reflect conditions in the field. EPA must disconnect mismanagement from testing procedures and retain simplicity in the testing approach.

Mr. Helms noted that EPA's research efforts must find ways to integrate the research results into the waste characterization process itself. The policy and project planning needs are to establish the risk goals and to incorporate different management scenarios into the process.

Mr. Helms stated that EPA will work with a small group of experts, while maintaining a public process, to assess problems more quickly, but that EPA needed to do the project planning and budget work to obtain the necessary resources.

Mr. Helms concluded his summary by reiterating EPA's position that the TCLP is not doing a bad job, but that it needs validation, verification, and some characterization adjustment.