Chapter 1: Background Information on Kinetic Tests

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Introduction

The ADTI-WP2 Leaching Column Method development project described in this report is intended to provide a standardized kinetic test method for coal mine drainage prediction, which essentially fulfills a technological need that has existed for many years, and was developed under the auspices of the Acid Drainage Technology Initiative (ADTI). The project was jointly funded by the Office of Surface Mining Reclamation and Enforcement (OSM) of the U.S. Department of the Interior and the U.S. Environmental Protection Agency (EPA); with significant technical input, cooperation and guidance provided by scientists from both of these federal agencies. Additional financial and/or technical assistance was provided by numerous other project cooperators including the Pennsylvania Department of Environmental Protection, the U.S. Geological Survey, the Materials Research Institute of the Pennsylvania State University, the National Mine Land Reclamation Center at the West Virginia University and the Interstate Mining Compact Commission (IMCC). Also, eight laboratories participated in the various phases of weathering tests conducted during the method development process and assisted in the operational refinements of the test method. They will be acknowledged individually in a later section of this report, but they collectively possess a great diversity of experience and interests including four commercial labs, two university research labs, a mining industry research lab, and a Federal government agency research lab.

This introductory chapter provides some background information on kinetic tests and their relationship to static tests for mine drainage prediction; briefly describes the goals and milestones of this ADTI-WP2 Leaching Column Method development process (and the related ADTI-WP1 Humidity Cell Method); briefly outlines the contents of the other chapters of this final report; and provides some information on the applications of this standardized kinetic test method for the various members of the user community.

This report describes results of the 2006 interlaboratory study for validation of the ADTI-WP2 Leaching Column Method, involving eight participating laboratories simultaneously conducting weathering tests on five different lithologic units using an array of nine leaching columns. The report also describes results of weathering studies conducted in 2002 and 2003 as part of the method development. This interlaboratory study satisfies key requirements in the EPA method development process, however, there is a dual purpose to the report as reflected in the structure and contents of the following chapters. OSM is not in the business of developing standard test methods; they rely upon EPA to perform this essential function. However, OSM is closely involved with state and federal mining regulatory personnel and other users of mine drainage prediction and monitoring test methods, and OSM has a very active technology transfer program to disseminate information on new technological developments including geochemical interpretive information on mine drainage prediction tools. Hence, this report is designed to: (1) document the EPA method development process, including the analytical data from the participating laboratories, and (2) present geochemical interpretations of the practical and theoretical aspects of the leaching behavior of the various overburden rock types evaluated during the weathering studies.

The long-term technological need referred to above arose from some inherent limitations of static tests, and two major problems encountered in the use of kinetic tests for mine drainage quality prediction. Both static and kinetic tests produce site-specific geochemical evaluations of potential acidity or alkalinity, and other parameters of predicted water quality. The major difference between static and kinetic tests is that static tests provide measurements of the amount of selected chemical constituents in the rock sample (e.g. total sulfur, neutralization potential), while kinetic tests provide measurements of the amount of selected chemical constituents that come out of the rock samples in leachate (e.g. acidity and iron concentrations) under specified conditions. Static tests for coal mine drainage prediction have been in use for about 30 years (e.g. Smith et al., 1974 and Sobek et al., 1978), and kinetic tests have been used in coal mine drainage research for more than 50 years (e.g. Braley, 1949).

The static test most commonly used to predict mine drainage quality in the eastern United States is acid-base accounting (ABA). This method involves a comparison of the maximum potential acidity (MPA), typically calculated from the total sulfur in the sample, to the neutralization potential (NP). Although other static tests have been developed and used in coal mine drainage prediction, ABA is the most routinely used method for coal mine drainage prediction. The three main limitations of static tests, such as acid-base accounting are: (1) the total sulfur content and neutralization potential (NP) are surrogate measurements of the potential acidity and alkalinity of a rock sample, respectively, and they may not be accurate indicators of the actual concentrations of acidity or alkalinity that can be produced, (2) there is an area of uncertainty, often referred to as the "gray zone" (see Geidel, et al., 2000) where the magnitude of the sulfur and NP values make it very difficult, if not impossible, to accurately predict whether a rock sample will produce substantial acidity or alkalinity, and (3) it is generally not possible to predict metals concentrations from static tests. Despite these limitations, static tests including acid-base accounting have been very useful in many evaluations of mine drainage permit applications.

The most commonly used kinetic tests for mine drainage prediction are leaching columns and humidity cells. While these kinetic test methods and others have been used in hundreds of mine drainage studies as shown in the chronology contained in Hornberger and Brady (1998) and other references (e.g. Sorini, 1997), they have rarely been used in coal mine permitting by either regulatory agencies or the mining industry. The two major related problems impeding the routine use of these kinetic test methods are : (1) there are a considerable number of variables in the design and operation of these kinetic tests and the variety of test apparatus and procedures in use is so great that it is very difficult to interpret the results and make meaningful comparisons of data from different studies in similar or different lithologic settings, and (2) in the absence of standardized, accepted (e.g. by EPA or ASTM) test methods, mine operators and consultants shy away from kinetic tests because they do not know which apparatus or procedure to use, nor how to interpret the results.

While the ADTI-WP2 Leaching Column method discussed in this report does not preclude the use of other kinetic test methods or solve all of the problems associated with kinetic prediction tests, it does fulfill a technological need by providing a standardized method, and by providing a tool to reduce the effects of the three limitations of static tests.

The role of the ADTI

The Acid Drainage Technology Initiative (ADTI) was initiated in 1995 by federal agencies, the National Mining Association and the Interstate Mining Compact Commission to identify, evaluate, and develop cost-effective and practical acid drainage technologies. In 1999, ADTI was expanded through the addition of the Metal Mining Sector (MMS). ADTI addresses drainage quality issues involving metal mining and related metallurgical operations and acid drainage from coal mines, for abandoned, active and future mines. The guiding principle of ADTI is to build a consensus among industry, federal and state regulatory agencies and academia. With this array of varying interests and expertise in acid mine drainage problems, it was envisioned that a consensus could be developed on reliable, standard static and kinetic test methods and other aspects of mine drainage prediction in the Appalachian Coal Basin.

ADTI includes the Coal Mining Sector (CMS) and the Metal Mining Sector (MMS) under the overall guidance of the ADTI Operations Committee. The Coal Mining Sector has produced two publications on the prediction and prevention of acid drainage (Skousen et al., 1998 and Kleinmann et al., 2000). Three ICARD (International Conference on Acid Rock Drainage) papers presented background information and details of the ADTI (Hornberger, et al., 2000; Williams, 2003 and vanZyl, et al., 2006).

The project to develop standard kinetic test procedures (i.e. ADTI-WP1 Humidity Cell Method and ADTI-WP2 Leaching Column Method) is a good example of cooperation, technology development and consensus building among various ADTI stakeholders. The need for these standardized procedures has been recognized since the inception of ADTI in 1995 as described in Hornberger and Brady (1998) and Geidel, et al., (2000). ADTI members in the MMS and the CMS have extensive experience in kinetic tests and the methods development process, and they provided comments and suggestions in the peer review phase of the project. Kinetic tests have historically been used more by industry and regulatory agencies in metal mining in the western U.S. and Canada (e.g. Lapakko, 1988; Lapakko et al., 1995; White et al., 1994; and Sorini, 1997). This project has been a high priority for the ADTI-CMS.

Background Information on Kinetic Test Methods

A major advantage of kinetic tests for the prediction of mine drainage quality is that, since these types of tests produce an effluent of simulated mine drainage quality, the effluent may be tested for the same water quality parameters as the actual mine drainage that would be monitored during the proposed mining operation. The water quality parameters typically included in the leachate analyses are pH, acidity, alkalinity, sulfates, iron, manganese and aluminum. These are the same water quality parameters typically monitored under the National Pollutant Discharge Elimination System (NPDES) permit requirements for an active mining operation. If the physical, chemical, and biological conditions of the kinetic tests are representative of those found in the mine environment, the concentrations of the water quality parameters in the leachate may be used to predict or estimate the concentrations of these parameters that would be produced by the proposed mining operation.

Hornberger and Brady (1998) compiled a comprehensive chapter on kinetic tests for mine drainage prediction that included: (1) a chronology and synopsis of scientific literature on these kinetic tests as they have developed over approximately 50 years, (2) an evaluation of the factors to be considered involving physical, chemical, and biological processes, and (3) general guidelines for test procedures, data interpretations, and recommendations for further research to develop standard methods. That chapter and a related chapter by Geidel, et al., (2000) in the ADTI prediction book formed much of the basis for members of the ADTI prediction working group to commence development of the ADTI-WP1 Humidity Cell and ADTI-WP2 Leaching Column standard test methods described in this report.

The chronology in Hornberger and Brady (1998) documents the historical development of kinetic tests for mine drainage prediction and practical applications of the test results on mine sites in the Appalachian coal fields and elsewhere. In citing more than 275 scientific references it demonstrates that most of the kinetic test methods in use today were substantially developed and applied more than 40 or 50 years ago, including leaching columns (Braley, 1949), humidity cells (Hanna and Brant, 1962) Soxhlet reactors (Pedro, 1961) and field scale tests with actual precipitation (Glover and Kenyon, 1962).

physical, chemical and biological factors: The kinetic tests described in the chronology referred to above, incorporate physical, chemical and biological processes and constraints. Physical factors include: the size, shape and structure of the apparatus used to conduct the tests; the volume, texture and particle size distribution of the sample to be tested; and the volume, pathway and resultant saturation conditions (e.g. saturated zone, capillary fringe or relative humidity of pore spaces) of the fluids introduced into or removed from the apparatus for analysis.

Chemical factors include: the mineralogical composition of the rock sample, the composition (i.e. concentration of cations and anions) of the influent and effluent fluids; the solubility controls on the acidity and alkalinity generating processes, the interrelationships between these processes and other constraints affecting the reaction kinetics, and the composition of gaseous phases (e.g. partial pressures of oxygen and carbon dioxide) in the fluids and void spaces within the kinetic test apparatus.

Biological factors include: the presence and relative abundance of bacteria (e.g. *Thiobacillus*), that catalyze the AMD producing reactions; the availability of nutrients and other life-supporting ingredients; and the interrelationships among controls on the biological system, such as temperature and pH, which determine whether various organisms flourish, barely survive, or die.

It is useful to briefly review the controls and range of acidity, alkalinity, sulfate, and metals concentrations which may be found in nature, particularly mine environments, in order to demonstrate the variations in mine drainage composition associated with the range of geologic settings in Pennsylvania and elsewhere, and to place some expectations on the variations in leachate composition from kinetic tests. Lovell (1983), and Hornberger and Brady, (1998), list ranges of component concentrations in Appalachian acid mine drainage where pH may be as low as 1.4, and maximum concentrations for the following parameters are : acidity of 45,000 mg/L, total iron or ferrous iron of 10,000 mg/L, aluminum of 2,000 mg/L, and sulfate of 25,000 mg/L.

The alkalinity production process has a dramatically different set of controls, and the resultant maximum alkalinity concentrations are typically one or two orders of magnitude less than the maximum acidity concentrations found in mine environments. The carbonate rocks which produce significant alkalinity or bicarbonate concentrations in groundwater, surface-water, and mine drainage samples (i.e. coal surface mines, stone quarries, and coal and noncoal underground mines) are limestones and dolomites and the principal carbonate minerals are typically calcite (calcium carbonate) and dolomite (calcium-magnesium carbonate).

Very thorough discussions of the chemical reactions of carbonate mineral dissolution and precipitation and associated solubility and chemical equilibria controls are found in Stumm and Morgan (1970), Krauskopf (1967), Garrels and Christ (1965), Freeze and Cherry (1979), Plummer et al. (1978), White (1988), and Langmuir (1997). Rose (1997) calculated the range of bicarbonate concentrations for calcite dissolution in pure water from 83 mg/L at PCO_2 of 10^{-3} to 370 mg/L at PCO_2 of 10^{-1} using the methods (i.e. Case 4) described in Garrels and Christ (1965). Figure 1.1 from White (1988) shows solubility curves for calcite as a function of carbon dioxide partial pressure, and Rose and Cravotta (1998) depict bicarbonate and alkalinity concentration for a similar range of PCO_2, based upon Case 2 of Garrels and Christ (1965, p. 81).

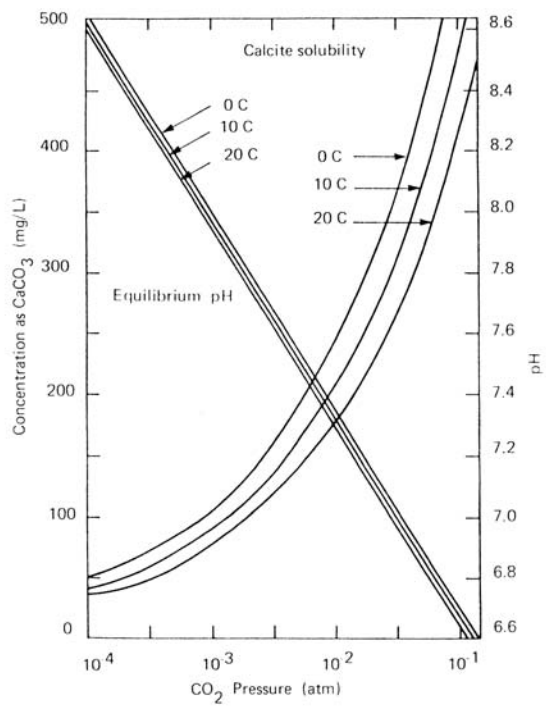

Figure 1.1 Solubility curves for calcite as a function of carbon dioxide partial pressure (from GEOMORPHOLOGY AND HYDROLOGY OF KARST TERRAINS by William B. White. Copyright © 1988 by Oxford Univ. Press, Inc.).

Typical bicarbonate and alkalinity concentrations associated with limestone and dolomites in Pennsylvania are found in Langmuir (1971), Shuster (1970) and Shuster and White (1971). Langmuir (1971) reported bicarbonate concentrations ranging from 81 to 438 mg/L for wells and springs in limestone of central Pennsylvania. Given the ranges and extreme values of pH, acidity, alkalinity, iron, aluminum, and sulfate reported above, it is reasonable to expect that kinetic tests for AMD prediction should be capable of producing leachate with acidity and sulfate concentrations of several thousand to tens of thousands mg/L, and metals concentrations of several hundred mg/L from worst-case AMD producing rock samples, and leachate with alkalinity concentration of several hundred mg/L from best-case carbonate rock samples.

Of all of the physical, chemical and biological factors to be considered in kinetic tests, two of them warrant special attention in the development of the ADTI-WP2 Leaching Column Method, and in kinetic tests in general: (1) the partial pressure of carbon dioxide (PCO_2) used in the gas handling provisions of the test, and (2) the effects of the particle size distribution, and the related surface area to volume ratio of the water handling provisions of the test.

partial pressure of carbon dioxide (PCO_2): The significance of oxygen and carbon dioxide in acidity and alkalinity production in the mine environment and in kinetic tests to predict mine drainage quality has been noted throughout this chapter and elsewhere. Without sufficient oxygen and aeration of the rock samples, pyrite oxidation and weathering will be impeded and AMD production will not reach its full potential. Without sufficient carbon dioxide, the dissolution and maximum solubility concentration of carbonate rocks will be reduced dramatically, and alkalinity production will not reach the full potential of the carbonate rocks.

Concerning the role of gases in laboratory kinetic tests, Hyman et al. (1995, p. 11) state, "Gas phases, such as oxygen and carbon dioxide, that occur in field conditions may not be represented appropriately in the laboratory test conditions." Gas handling provisions in kinetic test design and operation should: (1) account for percentages of oxygen and carbon dioxide within the test apparatus that are representative of field conditions of the mine environment (e.g. pore gas composition of a backfilled surface mine) and (2) include mechanisms to circulate the gas mixture through the apparatus to ensure that chemical reactions (oxidation and dissolution) may take place and promote weathering of the rock samples. From the discussion on pyrite oxidation above, it is presumed that there should be more than enough oxygen available for pyrite oxidation in the normal laboratory setting if the kinetic test apparatus is open to the air and the rock samples are not entirely saturated within the apparatus. However, the amount of carbon dioxide needed to facilitate significant dissolution of carbonate minerals is more than can be achieved under normal atmospheric conditions as described above. Therefore, carbon dioxide generally needs to be added to or concentrated within the kinetic test apparatus to enrich the carbon dioxide concentration within the gas mixture unless interactions of minerals (e.g. pyrite) and fluids will increase the PCO_2. If the partial pressure of carbon dioxide in the gas mixture is $10^{-3.5}$ bars (i.e. atmospheric conditions) within the kinetic test apparatus, the maximum alkalinity/bicarbonate concentrations in the leachate will be less than 100 mg/L, even with pure limestones and dolomites. If there is too much carbon dioxide in the gas mixture (e.g. greater than 10^{-1} bars, PCO_2 typically found in groundwater systems and pore gas of surface mine backfills) the bicarbonate and alkalinity concentrations may be greater than 500 mg/L, for example, as shown on Figure 1.1.

In summary, the pore gas composition within the kinetic test apparatus should be similar to that within reclaimed surface mine spoil, particularly to have a partial pressure of carbon dioxide sufficient to facilitate the dissolution of carbonate minerals. To ensure a representative and realistic gas mixture in kinetic tests for mine drainage prediction, it may be necessary to have the kinetic test apparatus fitted with gas ports to enable the constant or intermittent introduction of a controlled gas mixture into the apparatus (i.e. for carbon dioxide enrichment). For example, a mixture of 10% oxygen, 10% carbon dioxide and 80% nitrogen in a compressed gas cylinder would supply adequate and representative amounts of oxygen for pyrite oxidation and carbon dioxide for carbonate mineral dissolution.

particle size distribution and surface area of rock samples: Concerning particle size and surface area effects, the goals of sampling for kinetic testing should be to obtain rock samples that are representative of the physical (i.e. particle size distribution) and chemical (i.e. mineralogic composition) characteristics of the consolidated overburden strata, or backfilled mine spoil, or waste dump to be simulated in the test. Consideration should be given to the percentage of relatively coarse (i.e. gravel sized) particles and relatively fine grained particles in the sample. A greater percentage of fine particles increases the surface area available for reaction, which is a critical parameter in the production of acidity or alkalinity.

Usually, for the purposes of pre-mine prediction of AMD potential, the rock samples will be obtained from exploration drill holes, and the particle size distribution of the rock sample used in the kinetic test will be determined by the type and method of drilling equipment and by any subsequent crushing or other sample preparation equipment and procedures.

Most consolidated rock overburden strata should yield a relatively large percentage of gravel-sized particles in samples obtained from air-rotary drilling. It could be expected that sandstone overburden samples would possess a relatively large percentage of coarse particles and relatively few fines, especially where the sample is indurated, well-cemented sandstone; and that overburden samples from more fine-grained rocks, like shales and underclays, would possess larger percentages of silt and clay-sized particles.

The presence of a relatively large percentage of fine-grained particles in an overburden sample may have positive and negative effects upon the kinetic test results. According to Bradham and Caruccio (1990), the fine-grained nature of the Canadian metal mines tailings that they tested in leaching columns, caused high specific retention of fluid and created air locks within the columns which skewed the results. In addition, the particle size distribution at the conclusion of the kinetic test may be different (i.e. more fine) than the original particle size distribution of the sample, due to particle decomposition during the test.

Notwithstanding the potential operational problems with some fine-grained samples and some types of kinetic test apparatus, variations in the surface area available for reaction may have dramatic effects upon the chemical reactions of acidity and alkalinity production. According to Brady (1974, p. 43) concerning silt and clay-sized particles in soil: “Surface area is the characteristic most affected by the small size and fine subdivision of silt and especially clay. A grain of fine colloidal clay has about 10,000 times as much surface area as the same weight of medium-sized sand.”

According to Rose and Cravotta (1998): "Kinetic studies indicate that the rate of acid generation depends on the surface area of pyrite exposed to solution, and on the crystallinity and chemical properties of the pyrite surface" (e.g. McKibben and Barnes, 1986). The consideration of surface area available for reaction in kinetic tests leads to the evaluation of the ratio of the surface area to the volume of leachate, which may be the most important factor in kinetic test design, performance, and data interpretation.

One of the shortcomings of previous leaching studies has been not considering the effects of surface area and particle size. This factor was extensively studied in the decade from the mid-1970's through the mid-1980's by scientists who were investigating the stability of materials used for the sequestration of nuclear waste (e.g. Ethridge et al., 1979; Hench et al., 1980; Buckwalter et al., 1982; Oversby, 1982; Pederson et al., 1982). The work of John K. Bates and associates at Argonne National Laboratory on nuclear waste glass also provides relevant information on surface area/leachate volume ratios (Aines et al., 1986; Ebert and Bates, 1992; Feng and Bates, 1993; and Feng et al., 1994).

It was recognized by this group of researchers that the particle size of the leached materials and the volume of fluid that was available for the leaching process had a significant impact on the experimental results. Figure 6.3 in Chapter 6 of this document demonstrates this dependence. Shown is the release of silica from a nuclear waste form as a function of time with specific control of the surface area to volume ratio. What is important in Figure 6.3 is that by specifically including the surface area/volume parameter, leaching rates varying over 3 orders of magnitude can be scaled onto the same plot. Surface area must also be taken into account in coal overburden leaching experiments. Otherwise the cross-laboratory experiments, although individually correct, cannot be compared, and the results cannot be compared with other results in the literature, and cannot be used to extract quantitative rate constants. The observed leach rates would be an accurate result of the individual experiment, but meaningless as a fundamental property of the material itself.

For this study, the surface area of each fraction of sieved starting material was determined by BET (Brunauer et al., 1938; and Yates, 1992) instrumentation using N_2 gas bulk adsorption. This method is a routine analytical approach to measure the accessible surface of the rock to gas molecules. Additional discussion of surface area measurements and their relationships to porosity and reaction kinetics are given by Brantley and Mellott (2002) and Brady et al., (2004).

Goals and Milestones of the ADTI-WP2 Method Development Process

The three major goals of the project are: (1) standardizing kinetic test procedures; (2) improving test methods by (a) maintaining a carbon dioxide-enriched environment to optimize carbonate mineral dissolution and (b) quantifying particle size variables to evaluate reaction kinetics; and (3) providing flexibility in test method implementation consistent with EPA guidelines for Performance-Based Measurement Systems (PBMS). The importance of the carbon dioxide enriched leaching environment and the particle size and surface area factors was explained in the preceding section on background information. The EPA guidelines for PBMS will be explained in Chapter 2.

There have been three phases or episodes of weathering tests in this standard method development process. The original concept was to develop two standard kinetic test methods under the auspices of ADTI: the Weathering Procedure 1: Humidity Cell Method and the Weathering Procedure 2: Leaching Column Method. The first phase of weathering tests occurred in 2002 and is described in greater detail in Chapter 2 and Hornberger, et al., (2003). This initial phase involved the weathering of three lithologic units (Brush Creek Shale, Wadesville Sandstone and Valentine Limestone) by 2 laboratories. A commercial laboratory (Geochemical Testing) constructed 8 humidity cells and 8 leaching columns and tested 4 shale and 4 sandstone splits of the rock samples, using duplicate apparatus set-ups on two different gas handling procedures. A university laboratory (Materials Research Institute of the Pennsylvania State University) (MRI) evaluated different gas handling options and particle size factors on 3 single leaching columns of shale, sandstone and limestone.

The second phase of weathering tests occurred in 2003 and is described in greater detail in Chapter 3 of this report and in Hornberger, et al., (2004) and Brady, et al., (2004). This second phase of kinetic test development involved the weathering of three rock samples (Brush Creek Shale, Vanport Limestone and Lower Kittanning Coal refuse) by 2 commercial laboratories (Geochemical Testing and Mahaffey Laboratories) and a university laboratory (MRI). The 2 commercial laboratories each constructed 12 leaching columns and 12 humidity cells in order to test 4 shale, 4 limestone and 4 refuse representative splits of the rock samples, using duplicate apparatus set-ups on two different revised gas handling procedures. The MRI laboratory evaluated the weathering behavior of shale samples in leaching columns of three different diameters, and performed detailed surface area measurements on all particle size classes, pre- and post-weathering.

The third phase of weathering tests, which is the major component of this report, occurred in 2006, and is the full inter-laboratory study for validation of the ADTI-WP2 Leaching Column Method. This final phase of weathering studies in the method development process is described in greater detail in Chapter 4 (the data report and statistical evaluation of inter-laboratory method performance criteria), and related chapters (5 through 10). Chapter 5 provides a detailed mineralogical characterization of the unweathered rock samples, plus characterization of some of the post-weathering rock samples and trace element content in leachate from the leaching columns, conducted by USGS researchers. Chapter 6 is an evaluation of particle size and surface area effects from BET measurements of effective surface areas pre- and post-weathering, conducted by Penn State researchers from the Materials Research Institute, while Chapter 7 is a related evaluation of weathering rates, surface area to volume (SAV) ratios and kinetic data. Chapter 8 is principally an interpretation of the metals data and related water quality parameters from the large database of metals data compiled from the 9 leaching columns at each of the 8 participating laboratories; this chapter is also closely related to the interpretive content of Chapter 7. The strengths and weaknesses of the acid-base accounting data conducted for this project are described in Chapter 9, because these static test data are typically a companion or precursor to the kinetic test data. Finally, Chapter 10 is a guide to the overall interpretation and conclusions of the ADTI-WP2 leaching column results in several levels of sophistication and detail. The revised final draft of the ADTI-WP2 Leaching Column Method is contained in Appendix A of this report.

This third phase of kinetic test development involved the weathering of four shale samples (Brush Creek Shale and Lower Kittanning Shale from PA, Kanawha Black Flint Shale from WV, and Houchin Creek Shale from IN), and a sandstone sample (Middle Kittanning Sandstone from PA) by eight participating laboratories, using an array of nine identical leaching columns (i.e. duplicate columns for each of the four shale samples and a single relatively inert sandstone column to represent a "blank" sample). The eight participating labs comprise a diverse cross-section of four commercial labs from two states, two university labs, a coal industry research lab and a federal agency research lab. This is a sufficient number of laboratories to satisfy conformance with the protocol in ASTM Standard D-2777 on Standard Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D-19 on Water.

In addition to these three phases of weathering tests, a peer review study on the draft ADTI-WP2 Leaching Column Method was conducted in 2004. Results of the peer review are included in Appendix B.

Applications and Users of The ADTI-WP2 Leaching Column Method

The need for standardized kinetic test methods is recognized by OSM and EPA to provide improved predictions of coal mine drainage quality and overburden strata characterizations for use by state and federal regulatory agencies and the mining industry. Such predictions can be used in addressing the Probable Hydrologic Consequences (PHC) and Cumulative Hydrologic Impact Assessment (CHIA) requirements of the SMCRA, associated federal and state regulations, and surface mining permit applications and NPDES permits. OSM is administering this project and EPA is ensuring that the method development process meets their rigorous requirements to become an approved EPA method.

Following the completion and distribution of this final report, the final draft of the ADTI-WP2 Leaching Column Method, (contained in Appendix A of this report) will have to be published in the Federal Register in accordance with 40 CFR Part 136 in order to become an approved EPA method. That publication of the draft method would be in the format of a proposed EPA method, followed by a public comment period, and ultimately publication as a final approved EPA method.

It is anticipated that the user community for the standard ADTI-WP2 Leaching Column Method will consist of three main groups: (1) state and federal agency permit reviewers who evaluate and write SMCRA permits and NPDES permits for mine drainage discharges, (2) mining industry geologists, engineers and chemists who prepare mining permit applications, and who evaluate mine drainage problems during active mining operations and the abatement of any unanticipated post-mining discharges, and (3) laboratory personnel who conduct the weathering tests in their laboratories to produce the leaching data for use in the permit applications or other purposes.

Two major advantages of developing standard kinetic procedures are that almost everyone, especially for mine permitting purposes, would be using the same test procedures (which

facilitates data comparison and data base building) and that scientific and legal controversies between government and industry users of prediction techniques over interpretations of the test results and accuracy of the predictions would be substantially reduced.

It is recognized, however, that kinetic tests alone are not the answer to the prediction of mine drainage quality. These tests should be used in combination with static tests and other predictive techniques including evaluation of background water quality, mine drainage quality produced at nearby mine sites or mines in similar lithologic settings, and detailed stratigraphic analyses. Kinetic tests will usually be more expensive and more time consuming than static tests; therefore the kinetic tests should be used selectively, in cases when the static tests are inconclusive or require augmentation.