WHITE PAPER ON GEOENVIRONMENTAL ENGINEERING

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Geoenvironmental Research Experience:

Recent research projects include:

- Field and Laboratory Evaluation of Protective Cover Soils for Minimizing Mechanical Damage to Landfill Liners, Waste Management Inc.
- In-Situ Electrokinetic Remediation of Contaminated Soils: Bench and Pilot Scale Testing, Gas Research Institute/ Institute of Gas Technology.
- System Effects on Remediation of VOC-Contaminated Saturated Soils and Groundwater Using In-Situ Air Sparging, National Science Foundation.
- Beneficial Use of Scrap Tires in Waste Containment Systems, Illinois Department of Commerce & Community Affairs, Used Tire Recovery Program.
- Development of Integrated Electrokinetic Remediation Technology for Cleanup of Contaminated Sites, STAT Analysis Corporation.
- Geotechnical Evaluation of Biosolids, MWRDGC/Great Lakes Soil & Environmental Consultants, Inc.
- Electrokinetic Remediation of Low Permeability and Heterogeneous Soils Contaminated by Hydrophobic Organic Compounds, National Science Foundation.
- Compatibility of Barrier Wall Materials with Dense Nonaqueous Phase Liquids (DNAPLs), H-Tek Environmental Inc.
- Monitoring Database of Waste Containment Systems, Great Lakes Soil and Environmental Consultants, Inc.

Geoenvironmental Teaching Experience:

Developed and taught the following courses:

- Environmental Geotechnology (undergraduate/graduate)
- Groundwater Flow and Contaminant Transport (undergraduate/graduate)
- Environmental Remediation Engineering (undergraduate/graduate)
- Design of Landfills and Impoundments (graduate)

Geoenvironmental Consulting Experience:

Prior to joining the University of Illinois, worked in a civil and environmental engineering consulting company for over 3 years. In addition to classical geotechnical projects, involved in numerous geoenvironmental projects dealing with:

- Landfills: site characterization, landfill design, groundwater impact assessment, groundwater monitoring system design, regulatory compliance, and public hearings.
- Contaminated Sites: site investigations, risk assessment, and remedial action at leaking underground storage tanks sites, industrial sites, and abandoned landfills.

- Coal Mines: site investigations, groundwater flow and contaminant transport modeling to define groundwater management zones and to select remedial actions, and regulatory compliance.

Appraisal of Geoenvironmental Research, Education and Practice:

Geoenvironmental research and practice has made a significant impact on protecting public health and the environment. The geoenvironmental engineers are playing a crucial role in the selection of suitable sites for new waste containment facilities (landfills and impoundments) as well as in the design and construction of these facilities for effective containment of waste constituents. All these containment facilities are designed with liner systems that perform both as hydraulic and chemical barriers. The mechanical stability of both liner and cover systems are ensured. Besides the waste containment systems, the role of geoenvironmental engineers in the remediation of contaminated sites, especially dealing with in-situ barriers and treatment of contaminated soils and groundwater, has been growing. The knowledge of soil composition, soil stratigraphy, groundwater hydraulics, and geochemistry is being applied to assess, develop, and implement effective remedial methods. In particular, geoenvironmental engineers are leading the subsurface investigations and the design of in-situ remedial strategies. Geoenvironmental engineers are also involved in evaluating the feasibility of using the waste and recycled materials as soil substitutes in various large-scale civil engineering applications including roadways, embankments, and retaining structures. In addition, large-scale environmental engineering use of recycled and waste materials, such as soil substitute in the design of waste containment systems and reactive media substitute in soil and groundwater remediation systems, is rapidly growing. These applications involve evaluation of not only their mechanical properties and behavior, but also environmental aspects including chemical compatibility and durability.

Geoenvironmental engineering requires knowledge of several disciplines, particularly geotechnical engineering, hydrogeology, geochemistry, and microbiology, in order to comprehend the physico-chemico-biological aspects of geoenvironment. In addition, knowledge of environmental laws and regulations is critical. Recent offering of geoenvironmental courses at both undergraduate and graduate levels at many universities is preparing students to acquire such relevant interdisciplinary background and preparing them to address complex geoenvironmental problems.

Overall, geoenvironmental engineering is continuing to evolve. Environmental laws and regulations that have a significant impact on geoenvironmental engineering are constantly changing. Environmental problems are numerous in all industrial and developing countries and will continue to grow with increased chemical waste generation and handling. For these reasons, the geoenvironmental engineers will play a vital role in the pollution control strategies, particularly in the development of effective and economical waste minimization, containment, and remediation technologies.

Perspective on Emerging Geoenvironmental Issues and Technologies:

Over the last decade, there has been rapid growth in geoenvironmental research, education and practice. Geoenvironmental professionals have been heavily involved in characterization of contaminated sites, design of in-situ barriers and landfills, and characterization and beneficial use of waste materials. However, they are now becoming more and more involved in conducting risk assessments, remediating complex contaminated sites, designing and monitoring barrier systems for difficult contaminants such as non-aqueous phase liquids, as well as developing large-scale projects for the reuse of waste and recycled materials. Such an expanded scope for geoenvironmental engineers requires them to have a broader multi-disciplinary knowledge, particularly in fields such as hydrogeology, geochemistry, and microbiology as well as environmental laws, economics and public policy. Another challenge for geoenvironmental engineers is to explore the opportunities to utilize rapidly advancing technologies, such as sensor technologies, nanotechnologies, and information technologies.

In spite of significant advancements, there are several technical issues to resolve and several opportunities to develop new and improved technologies in geoenvironmental engineering. This makes the geoenvironmental engineering to be a challenging and exciting field to work in. Research opportunities exist in all areas of geoenvironmental engineering, including site characterization and monitoring, contaminant fate and transport, waste containment systems, site remediation, and beneficial use of waste and recycled materials. These opportunities may range from the assessment of transport of toxic leachate constituents (both heavy metals and organics) through liner system components, to the selection of materials for barrier walls to effectively contain difficult contaminants such as free phase DNAPLs, to the potential instability of bioreactor landfills due to increased pore water pressures, to the cost-effective in-situ remediation of brownfields, and even to the durability and long-term environmental impacts of waste material reuse. However, I will focus here some of the research challenges and opportunities in dealing with the remediation of contaminated sites:

- Many in-situ remediation technologies have yielded incomplete remediation mainly as a result of difficulty in removing contaminants from low permeability clayey soil zones in heterogeneous subsurface environments that exist at these sites. New and improved methods to remediate heterogeneous and low permeabiltiy soils are required. Technologies such as hydraulic/pneumatic fracturing and electrokinetics are being explored to facilitate efficient delivery of reactive media and enhance remedial efficiency under the heterogeneous subsurface conditions.

- Toxic heavy metals and organic compounds coexist at numerous contaminated sites, and the technologies to remediate such sites are very limited and they are ineffective and/or inefficient. Development of new and robust technologies to remediate mixed waste sites (including radionuclides at some sites) is needed. Integrated technologies that combine different standard technologies may be required to address mixed waste contamination.

- Recent advances in nanotechnology allowed synthesis of innovative superfine nanostructured materials that have great potential to be utilized as reactive media for the remediation of soils and groundwater contaminated with a wide range of inorganic and organic contaminants. Nanoscale bimetallic particles have the potential to significantly impact the generation of new remediation technologies that could provide cost-effective remedial solutions to some of the most difficult sites. Nanoparticles feature large surface areas and extremely high surface reactivity. Equally important, they provide enormous flexibility for in situ remedial applications when the site contains both organic and inorganic contaminants and when low-permeability and heterogeneous soils are present. An increased knowledge of the dynamics of remediation processes specific to nanoscale materials in natural systems can improve understanding and lead to development of innovative remedial approaches for contaminated soils and groundwater.

- Fenton's reagent is an advanced oxidation process that has been studied by numerous researchers for the treatment of organic contaminants in aqueous streams, soils, and groundwater. However, implementation of such in-situ chemical oxidation in an innovative manner utilizing H_2O_2 in the presence of native iron in soil has potential to rapidly degrade a variety of organic compounds to the non-toxic end product under different soil compositional environments. Compared to currently used technologies, the process offers advantages related to simplicity, cost, and range of effectiveness. However, applying Fenton's chemistry in the field to treat soil and groundwater contamination has challenges because of varying site geochemistry and delivery issues.

- Soil flushing with emerging environmentally benign chemical agents to promote contaminant solubilization and removal has great potential to treat source zone contamination. The chemical agents may include nonionic and ionic surfactants, cosolvents, cyclodextrins, organic acids, etc and their effectiveness is significantly affected by the soil compositional environment.

- Some of the following nontraditional emerging technologies have great potential, but they have not been explored adequately:
    - Remediation of groundwater using waves: This technology is based on wave propagation due to abrupt pressure changes. The unique significance of introducing pressure waves into aquifer is the inexpensive cleanup of groundwater at localized site; mobilize trapped contaminants; and guide the motion of a contaminant plume by controlling the intensity and direction of the applied pressure.
    - High-energy electron beam irradiation technology: This low-temperature method can destroy complex mixtures of hazardous organic chemicals in contaminated soils and groundwater. Use of X-rays for the decontamination of soils is also considered as it can penetrate up to 20 cm within the soil and can be an emerging tool for the treatment of soil.
    - Solar photocatalytic oxidation: Although the potential of solar radiation for disinfection and environmental migration has been known for years, only recently has this technology been scientifically recognized to treat groundwater.
    - Ultrasound technology: Ultrasound is periodic sound waves that are produced at frequencies greater than 20 kHz. When generated in a solution, the sound waves produce cavitation bubbles or gas bubbles that form in the water and collapse. During this process, a great deal of heat is generated, which can assist in remediating contaminated soils and groundwater.

Comprehensive approaches involving physical model tests, mathematical modeling and field demonstrations are required to develop these technologies. Innovative real-time and noninvasive monitoring and information management systems are valuable in understanding the fundamental aspects of these technologies. Attention should also be paid on cost effectiveness as well as regulatory and public policy considerations. A life cycle approach may also be used to select a comprehensive remedial strategy. Recently, regulations have been made flexible to encourage innovation so that innovative technologies could be developed and implemented.