Geoenvironmental Engineering at the Onset of 21st Century

Nazli Yesiller
Director
Global Waste Research Institute
California Polytechnic State University
1 Grand Avenue
San Luis Obispo, CA 93407
USA

Current State-of-the-Art and State-of-the-Practice of Geoenvironmental Engineering

Initial development of geoenvironmental engineering was reactionary and occurred largely in response to enactment of significant environmental regulations and associated actions of regulatory agencies over the last three decades of the previous century. Discovery of large-scale pollution and contamination supported by public concerns resulted in the relatively fast early developments in pollution characterization, containment, and remediation areas. Methods to detect the presence of and measure the level of contaminants in air, water, and soil have been developed. Standardized procedures are available for characterization of single and mixed chemicals in various phases.

For containment applications, basic types and characteristics of materials; laboratory and field tests for determination of material properties; and procedures for design and construction have been established. Significant advancements have occurred in development of specialty standardized testing procedures and guidelines are available for containment. Basic template designs for engineered containment of wastes and collection of byproducts such as leachate and gas have been developed. The basic designs generally are prescriptive due to the influence of regulatory developments. A reasonable degree of confidence is present for the designs, in particular for short-term performance. For remediation applications, varied technologies have been developed. While fundamental theoretical investigations have been conducted and theoretical background established for several remedial technologies, various existing and new technologies are experimental with requirements for trial and error practices.

Advancements were made in development of specialized test procedures and standardized test methods for characterization of contaminants and contamination, for evaluation of containment materials, and for remediation applications. Committees have been established within ASTM specifically to develop test methods, practices, guides, specifications, and classifications for evaluation of a wide variety of materials and processes associated with geoenvironmental engineering applications. Test methods and analysis and monitoring procedures and protocols also have been developed by agencies such as the USEPA. Progress has been made in sampling and testing of waste materials. However, these advancements are not as significant as the processes that are available for contaminants, containment materials, or remediation applications.

Modeling approaches are available for various geoenvironmental systems and applications. Significant advancements have been made in contaminant transport analyses. A good degree of confidence is present for fundamental transport analysis including single phases and uniform material properties. Approaches are also available for modeling simultaneous transport of multi phases in porous media and transport through heterogeneous media.

Beneficial reuse of byproducts and recycled materials has increased significantly in the last few decades in response to waste minimization efforts and sustainability trends. Inclusion of byproducts and recycled materials is required by regulations in some applications (e.g., roadway construction). Some theoretical background and fundamental analyses are available for these materials, yet standardized practices and designs generally are not present for the wide variety of byproducts and recycled materials and the potential reuse applications. A subcommittee has been established within ASTM D18 recently on Geotechnics of Sustainable Construction for coordinating standardization efforts for a variety of wastes and byproducts and waste and byproduct amended natural construction materials.

The Pollution Prevention Act of 1990 provided significant impetus to Pollution Prevention (P2) field for shifting from reliance on end-of-pipe treatment to source reduction in management of industrial wastes. P2 is a holistic approach with consideration given to entire lifecycle of products or processes from extraction of raw materials and use of energy, water, and other resources to final disposal. Progress has been made in development of materials and processes for reducing and/or eliminating generation of wastes and contamination at the source as well as increasing recycling and reclamation, reducing use of energy and other resources, and reducing final disposal to simultaneously reduce environmental impacts and reduce manufacturing costs. In similarity to P2 and in line with increasing sustainability trends and greening pressures, businesses employ different types of environmental programs for waste reduction in terms of not only materials but also energy and resources. Some of these programs are highly effective, while some are not adapted fully in practice.

Recycling and waste diversion have increased significantly in the last decades with programs at state and local levels with ambitious targets such as zero waste. Recycling infrastructure has expanded due to the increased recycling levels, yet the operations are tied closely to economic conditions, which indirectly affect recycling programs and infrastructure.

Research activity in the geoenvironmental engineering area, in particular in containment related investigations, is at a reduced level in comparison to the previous decades. This decline resulted from the notion that the containment area has matured with limited critical research priorities and the associated decrease in federal funding. The funding sources for remediation and byproducts and reuse applications generally are more varied than funding sources for containment investigations. Thus, research activity in these areas is more robust than containment. Pollution prevention and recycling areas are not necessarily supported by the typical funding sources of the geoenvironmental engineering discipline and thus research activity in these areas is limited.

Expertise and Organizational Facilities

My research interests and expertise are mainly related to containment materials and containment systems. My research studies typically include experimental components both at the laboratory scale and field scale. I am particularly interested in large scale testing. I have conducted studies related to earthen and geosynthetic components of containment systems and related to determination of properties of wastes. A significant long-term research investigation has been related to analysis of coupled heat and gas generation in municipal solid waste landfills and resulting variations of temperatures and gas compositions. I have been conducting studies related to recycling, reclamation, and reuse applications including material testing, system design, and policy aspects. Also, I am interested in nondestructive testing, image analysis, and in particular surface topography analysis. I am highly interested in development of test equipment, methods, procedures, and guidelines. My past and current research interests are directed towards improving the understanding of fundamental properties and response of materials used in geoenvironmental applications and obtaining field-scale data on short- and long-term behavior of geoenvironmental systems. Recently, I have started collaborating with colleagues from other disciplines in studies related to life cycle assessment, pollution prevention, waste minimization, and strategies in the green economy. In addition, research investigations are commencing on investigation of multiple waste to energy applications.

Experimental and computational facilities are available at Cal Poly for conducting research in geoenvironmental engineering studies. In particular, we have constructed large-scale testing infrastructure for determining properties of a wide variety of waste materials and byproducts. In addition, we are in the process of developing test beds at two local landfills for investigating various aspects of the performance of the facilities. Investigation of pilot scale applications of gasification and anaerobic digestion systems also are underway. An optical interferometer will be acquired early next year for advanced surface topography analysis, which has various applications in geoenvironmental engineering.

Challenges and Opportunities

Currently, the major challenge for academia is to retain and expand geoenvironmental specialization both in research and education, in particular under reduced funding conditions. While significant advancements have been made in geoenvironmental engineering, the field is not as well developed and mature as for example geotechnical engineering. All stakeholders in the geoenvironmental field need to be actively involved with promoting the field as well as be cognizant of the current status. Significant scientific research and education are required to advance various aspects of geoenvironmental engineering. Research studies, educational initiatives, and policy development can be undertaken through multi-component multidisciplinary platforms with participation of universities as well as industry and professional organizations. Better integration and collaborations between these groups would contribute to the advancement of the field.

The constraints used in the initial development of the materials, designs, and processes in geoenvironmental engineering infrastructure is not entirely representative of the field conditions and in particular uncertainties exist for long-term performance. Technology transfer to regulation and practice is incomplete. Standardization of materials and test procedures and development of guidelines for construction and operation are required for various applications. Validation of models, in particular for complex field conditions is required for applications in remediation as well as containment. Regulatory agencies as well as industry have significant depositories of data on geoenvironmental facilities that have not been made available in a format that can be used by researchers or fully analyzed for obtaining representative conclusions. Research investigations are required to advance the geoenvironmental field and provide facilities and applications with high level of confidence. Technologies such as incineration, gasification, and anaerobic digestion can provide effective solutions for waste management and waste to energy conversion as an alternative to landfilling or together with landfilling.

Geoenvironmental engineers can provide significant contributions to development and implementation of green technologies as well as development of sustainable infrastructure in the U.S. as well as other parts of the world. Opportunities are present contributing to pollution prevention and life cycle assessment applications in collaboration with multidisciplinary teams. Similarly, opportunities are present for positively contributing to sustainability and greening programs of a wide variety of industrial activities and also institutional and commercial activities. Management of wastes and byproducts is required for new and emerging industries and applications such as biotechnology and alternative energy. In the past, investigation of wastes and byproducts and development of methodologies for the management of these have lagged behind technology and industry developments for manufacture, design, and use. We have an opportunity to prevent potential future pollution and contamination by developing anticipatory solutions for sustainable management of wastes and byproducts in the 21st century.

U.S.-India Collaborations

I am not highly familiar with geoenvironmental research and education or practices and priorities in India. Similarly, I am not fully familiar with joint research studies in the geoenvironmental area or with collaborations in education or practice. This workshop will allow for identifying the expertise and activities of the participants and highlight complementary aspects of the backgrounds of the participants from the two countries for development of future collaborations. Social, economic, and cultural differences between U.S. and India affect waste and byproduct generation and management, sustainability and pollution prevention approaches, and contaminant identification and remediation. Low cost solutions that can be used to manage large volumes of materials and localized as opposed to centralized infrastructure may be more appropriate in geoenvironmental applications in India than the U.S.