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**Geoenvironmental Research Experience:**

1. Analysis of properties and condition of geomembranes using ultrasonic and magnetic nondestructive testing and analysis of surface microtexture of textured geomembranes using image analysis.
2. Analysis of cracking properties and small strain dynamic elastic properties of compacted clayey soils.
3. Integrated analysis of landfill byproducts including temperature, gas, and leachate generation and spatial distribution. Includes field investigation of sites located in various climatic regions in North America and numerical analysis of thermal regime of landfills.

**Geoenvironmental Teaching Experience:**

1. Three graduate courses taught that are entirely related to geoenvironmental engineering: Land Disposal of Hazardous Wastes, Design of Waste Containment Facilities, and Remediation Engineering.
2. One graduate course taught that has partial geoenvironmental content: Geosynthetics Engineering.
3. Developed and distributed a 3-module slide series on landfill engineering.

**Geoenvironmental Consulting Experience:**

Conducted engineering property testing for natural and geosynthetic liner materials.

## **Appraisal of Geoenvironmental Research, Education, and Practice**

### **Research:**

Significant theoretical and experimental developments have occurred in the area of natural and synthetic liner systems for containment applications. Well established practices are available for design, construction, and quality assurance procedures for cover and liner systems. For natural liner materials, research has primarily been concentrated on relevant processes of selection and preparation of these materials as well as the transport of liquids and gases in these systems. For synthetic materials, the focus has been on development of suitable materials as well as determination of engineering properties and behavior of these materials in liner systems.

Research has also been conducted related to characterization, engineering properties, and behavior of waste materials and byproducts. Significant research has been conducted on the physicochemical and biological properties and behavior of waste materials. A lesser amount of research has been conducted on the geotechnical behavior of wastes. Various innovative approaches have been applied to re-use waste materials and byproducts in various civil engineering applications.

Various research investigations have also led to the development of standardized test methods that can be used in construction of containment facilities and also for use with applications involving byproducts.

### **Education:**

Most universities have components of geoenvironmental engineering included in their curricula with several universities offering well-developed programs in this area where several courses or series of courses have been developed that are entirely devoted to geoenvironmental engineering. This specialized education typically occurs at the graduate level. While the number of available textbooks in this area is increasing, a need still exists for additional textbooks to effectively cover the various topics included in this area. ASCE GEC is currently preparing a collection of selected papers in the geoenvironmental area that may assist in providing effective teaching materials. The number of undergraduate textbooks with geoenvironmental engineering components is increasing. However, topics in this area are generally not typically covered in the undergraduate curriculum.

Various geoenvironmental teaching aids (namely, slide series) have recently become available to the geotechnical academic community. Additional resources of this sort, as well as training for professors, would be beneficial to the entire geoenvironmental academic community.

### **Practice:**

As mentioned above, theories for design, construction, and field and laboratory testing of containment systems using natural and synthetic materials have been established in the last several decades. Specialized design and construction procedures have been developed for containment systems. However, not all of the critical aspects of the various components are effectively applied in practice. Better dissemination is required to promote more effective and complete technology transfer.

Industry has recently undertaken a number of full-scale applications of novel design methods such as bioreactors. This particular effort has primarily been driven by economics of the waste management industry. The effort has involved the research community to effectively approach analysis and optimization of this type of system.

A significant number of projects has been completed using a variety of industrial byproducts. Progress has been made in characterization of byproducts as well as development of specialized testing and design methods for construction with these materials. This progress has in large part occurred due to effective cooperation between government, industry, and academic partners.

## **Perspective on Emerging Geoenvironmental Issues and Technologies**

Methods and procedures for design, construction, and operation of containment facilities have been developed and used over the last few decades. The effectiveness of these systems and long term performance of these systems still need to be validated (particularly on a field scale).

The formation of a trade association within the geoenvironmental engineering community would provide various benefits. Similar associations in geotechnical and geosynthetics engineering areas facilitate improved networking, dissemination, and collaborations among various constituents of their respective communities. A trade association would also serve well to provide training for practitioners, professors, and regulatory personnel in geoenvironmental engineering topics.

Development of test methods and standardized procedures is still required for waste materials and also for remediation technologies. Methods for containment systems are relatively well developed. However, the methods for characterization of waste materials are not as well established. A need also exists for further development of practices, procedures, and test methods for emerging remediation technologies.

Further investigation and advanced use of hybrid applications and coupled analyses are timely to advance the state of the practice for both containment and remediation applications. Individual components and singular systems have been developed and established for common use in the field. Existing technologies and systems can be effectively combined for optimal performance of various geoenvironmental applications. Similarly, individual and singular analyses have been formulated for design and performance prediction of geoenvironmental systems. These also can be integrated to provide improved analysis and prediction.