Global Geoenvironmental Engineering Challenges in Managing Environmental Impacts using Sustainable and Cost-Effective Methods

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(1) Current state-of-the-art and the state-of-the-practice of Geoenvironmental Engineering

United States and India represent one of the two largest democratic countries which have been facing some similar Geoenvironmental challenges. The current state-of-the-art in Geoenvironmental engineering can be broken down into these four categories:

(a) **Solid Waste Management**: Landfills are primarily used to dispose off municipal, hazardous, construction, and demolition waste, and fly ash from coal-fired power plants. While the rate of recycling in India for inorganic reusable materials (glass, plastic, and metals) is much greater than the U.S., landfilling is the primary method of waste disposal. Composite hydraulic barriers (liners) are used for liners as well as for covers of the landfills to contain the leachate and landfill gas. Leachate from these landfills is primarily sent off to wastewater treatment plants for treatment and disposal. A small fraction of leachate is recirculated. Leachate recirculation is typically carried out in an ad hoc manner based on site-specific operational and economical constraints. Vertical wells, horizontal trenches, and permeable blankets are used to inject leachate in the landfills. Landfill gas is collected using horizontal trenches and vertical wells and converted into electricity by using gas to energy engines. Recent developments in micro turbines are allowing relatively small gas generation rates of smaller or older landfills to be efficiently converted to electrical energy.

(b) **Remediation of Contaminates Sites**: There are thousands of contaminated soil and groundwater site in the U.S. and India that are adversely impacted due to discharge or spills of hazardous chemicals due to industrial or agricultural activities. The remediation methods vary depending upon the chemicals. For example, chlorinated solvents have been successfully remediated using permeable reactive barriers containing zero valent iron, or bioremediation. Similarly, volatile organic compounds such as benzene and toluene have been successfully remediated using soil vapor extraction system or pump and treat systems. Electrochemical techniques are still in lab-scale research phases and not commonly used commercially. Use of chemicals to generate redox reactions is commonly used to cleanup PCB contaminates soils.

(c) **Contaminated Dredged Sediments**: Both U.S. and India use extensive shoreline (inland as well as marine) to transport goods via ships. In order to keep the navigation paths clear, dredging of sediments is a routine operational activity. Due to industrial and agricultural
discharges. Often the near shore sediments are impacted with organics as well as heavy-metals. Hence, various Geoenvironmental methods are used for cleanup, disposal, and storage of contaminated sediments. While the cleanup of contaminated sediments in the U.S. is less often due to cost constraints, the disposal or temporary storage is often using confined disposal facilities where the sediments are dewatered for future treatment or reuse.

(d) **Sustainable Infrastructure**: Sustainable infrastructure in Geoenvironmental engineering has various applications. Some of these applications include:

a. Green roofs;
b. Green remediation technologies; and
c. Re-use of closed landfill sites.

Green roof is an emerging area in the U.S. while it is relatively well developed in some European countries like Germany and Sweden. Green roofs can reduce the peak storm water runoff from urban watersheds, can reduce energy usage of the building for HVAC, and can sequester carbon from the atmosphere in the plant mass that it can sustain. While there are technologies to build green roofs, long-term data on its sustainable parameters and costs is lacking.

Green remediation technologies is an emerging area where biological or chemical agents are derived from renewal resources. Re-use of landfills is not common due to location, cost, and environmental challenges. However, subsurface stabilization techniques are available to build structures on landfills.

(2) Your expertise and your organization’s facilities to pursue Geoenvironmental research

My key expertise lies in the Geotechnical and Geoenvironmental area. I have worked full-time as a Geoenvironmental consultant in the U.S. and New Zealand for almost seven years. My consulting expertise has been associated with landfill design and operation, investigation and remediation of contaminated sites, and state-of-the-art field-scale and lab-scale testing of geo systems using instrumentation.

During the last eight years since I joined Michigan State University, my key research projects have focused on:

a) Permeable blankets for leachate recirculation and gas extraction for MSW Landfills;
b) Real-time sensing of hydraulic properties of waste using instrumented blankets;
c) Lysimeters to evaluate field-scale performance of earthen caps for landfills;
d) Electrochemical remediation ground water impacted with MTBE and PAHs;
e) Unsaturated hydraulic properties of large-scale waste samples using geotechnical centrifuge;
f) Moisture consumption in landfills during methane production;
g) Field-scale instrumentation of a PVC retaining wall for deformation modeling
At MSU, the lab facilities can be grouped as follows:

(a) **Characterization of Unsaturated Hydraulic Properties**: Tempe Cells (500 kPa), pressure plate extractors (1500 kPa), WP4 Dewpoint Potentiometer (10 to 300 MPa); Buchner funnels (0 to 5 m); 1 m tall Instantaneous Profile Columns with water content and water potential sensors;

(b) **Characterization of Saturated Hydraulic Properties**: Flexible wall permeameters (10 cm to 30 cm diameter and 15 cm to 30 cm tall), sand columns for filtration and water balance testing; Fixed head rigid wall permeameters for coarse-grained soils.

(c) **Field-Scale Testing Instrumentation**: Campbell Scientific dataloggers (CR10X and CR1000), multiplexers, TDR 100 and associate multiplexers, MD485 Interfaces, Vibrating Wire Interfaces, Pressure head and temperature sensors, water content sensors (TDR-based), water potential sensors (humidity based), Relays, DC motors.

(d) **Electrochemical Testing**: Bipolar amplifiers, function generators, digital oscilloscopes, LCR meters, Perkin Elmer HPLC, Dionex Extractor, GC and GC-MS.

(e) **Geotechnical Centrifuge**: 200 g – 200 lb geotechnical centrifuge with 2 ft³ sample storage, 11 ft in diameter, 32 channel electrical slip ring and 100 psi pneumatic slip ring. This centrifuge can be used for soil deformation modeling or for unsaturated hydraulic testing of soils or waste at high effective stress.

(f) **Temperature Chamber**: -10 °C to 200 °C temperature chamber with 4 ft³ of sample capacity to test hydraulic and freeze thaw properties of geomaterials.

Selective photos of the relevant equipment in the MSU laboratories is presented in Figs. 1 to 2.

Fig. 1 Photo of typical saturated hydraulic conductivity setup at MSU
Emerging global geoenvironmental challenges and opportunities can be broadly summarized as follows:

(a) **Landfills**: Long-term GHG emissions and carbon sequestration in landfills, effect of various end use in mitigating GHG emissions, optimizing gas production and increasing the gas extraction efficiency;

(b) **Contaminates Sites**: Cost-effective methods to remediate contaminated sites using renewable physical, chemical, and biological methods;

(c) **Cleanup of Dredged Sediments**: Innovative physical separation methods and use of green technologies;

(d) **Sustainable Infrastructure**: There are opportunities in developing cost-effective green roofs, managing storm water, use of recycled construction materials, and energy efficient methods.

(4) Potential US-India collaborative projects and partnerships

a) US-India partnership could explore projects that will benefit from the socio-economic contrasts offered by two largest democratic countries in the world.

b) Reduce uncontrolled discharge of landfill leachate as well as controlled discharge to waste water treatment plants. This can be achieved by long-term lab-scale and field-scale projects that involve treatment of leachate using wetlands, aerobic ponds, and via leachate recirculation using bioreactor technology.
c) Landfills in India, due to greater recycling of inorganic waste, contain more organic fraction. Hence, leachate from municipal solid waste landfills in India would provide a more severe scenario for testing various leachate treatment methods.

d) While geosynthetic materials are commonly used in the U.S. for constructing the bottom liners and final covers, geosynthetic components are relatively expensive. For developing countries like India, introduction of geosynthetics in landfills is relatively new. While landfills near bigger cities in India could use expensive geosynthetic components, it will be economically not possible for smaller cities and townships. Hence, it will be a significant contribution to develop liners using sustainable materials such as modified clays, organic animal or plant based products.

e) Mutual benefits are possible from biogas technologies to generate biogas from animal waste. Reduction in GHG emissions from landfills by using low-cost compost piles.