Proper management and disposal of MSW remains an unresolved global problem. The amount of MSW generated and disposed of in the past decades is staggering, while the generation rate of MSW is expected to keep increasing due to steady increase of population and prosperity worldwide. One solution to handle the existing and future MSW is to move away from modern “dry tomb” landfills emphasizing containment to bioreactor landfills to promote degradation of MSW and enhance methane (CH$_4$) generation and its collection as alternative energy. The technology is still immature and based largely on empiricism, but my and others research indicate that it has the ability to transform waste to innocuous state, generate sustainable energy, reduce greenhouse gas emission, and gradually eliminate the unsustainable “legacy” of “dry tomb” landfills. Landfilled MSW is notorious for its heterogeneity and spatial and temporal variability. Solid, liquid (leachate) and gas (biogas) phases coexist in different proportions across a landfill, and evolve with time due to concurring physical, biochemical, mechanical and hydraulics processes. A fundamental understanding of the concurring processes is needed to design, monitor and operate bioreactor landfills effectively and efficiently.

In this study, seven laboratory large-size landfill simulators (30 cm diameter and 60 cm height) have been developed to degrade real-size heterogeneous and spatially variable MSW as in a mega-scale landfill. The simulators have been operated and monitored continually for 5 years to assess coupled physical-biochemical-mechanical-hydraulic processes of municipal solid waste undergoing degradation. These include (1) evolution of the physical, mechanical and hydraulics properties of MSW during active degradation, such as long-term settlement, compression ratio, moisture content, porosity, unit weight, and hydraulic conductivity; (2) evolution of the biochemical characteristics of leachate and biogas generated during MSW degradation, mainly the cumulative volume and rate of CH$_4$ generation; and (3) population dynamics of waste-degrading microorganisms using molecular microbiological tools and high-throughput DNA sequencing.

Besides the comprehensive investigation using laboratory simulators, testing of the MSW in fresh and fully degraded state was performed to assess their compressibility, shear strength, cyclic behavior, $V_s$ and pore pressure generation using a unique 30 cm diameter cyclic simple shear apparatus developed at the University of Michigan. Consequently, relationships between the physical and mechanical properties of waste and the degradation process have been established.

The laboratory studies have been compared with field conditions, and specifically data of CH$_4$ generation from multiple mega-scale landfills containing degrading MSW. The data from in situ measurements and laboratory experimental results, reinforced by an extensive database synthesized from the literature, have been analyzed to identify influencing factors on various behaviors of MSW during degradation and to highlight potential improvements in the design, monitoring and operation of landfills.