Field Measurement of Greenhouse Gas Emissions from Landfills in Tropical Developing Countries

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Problem Definition

The vast majority of biodegradable organic solid waste produced in developing countries of South America and Asia usually ends up in landfills, where organic matter undergoes rapid anaerobic decomposition. Anaerobic biodegradation of solid waste, rich in organic matter, is known to produce large quantities of methane (CH_4) and carbon dioxide (CO_2). The produced gases, if not captured for beneficial purposes, usually escapes into the atmosphere via landfill surface cover. Although both CH_4 and CO_2 are greenhouse gases, atmospheric emissions of CH_4 is more of a concern because of its higher global warming potential (GWP). Methane has 23 times the GWP of CO_2 over a 100-year period. Emissions from sanitary landfills around the world are estimated to account for almost 10% of the worldwide anthropogenic CH_4 emissions into the atmosphere. To date, most of the research on landfill CH_4 emissions has been directed at landfills in North America and Europe. Although more than two-thirds of world population live in Asian and South America, very little is known of landfill CH_4 emissions in countries within these two continents. Usual methane budget estimations for these countries rely upon gross assumptions on rate of waste generation and biodegradation kinetics. Most landfills in Asian and South American countries are not engineered. Controlling gas emissions is one of the factors least considered. Because of the higher ambient temperatures and high organic content in the waste stream, landfill gas generation rates could be considerably high. Considering these facts, it is necessary to undertake field studies in these countries to ascertain the validity of assumptions and to obtain an accurate estimate of gas emissions from landfills in tropical developing counties of Asia and South America.

Gas Emission Characterization Surveys

Three gas emission characterization surveys were conducted at two South American and one Asian landfill. Of the three surveys, the survey at Loma Los Colorados landfill was the most comprehensive and most significant. The Loma Los Colorados, an operating landfill located near Santiago, Chile, receives approximately half of the City of Santiago's municipal solid waste stream, or about 1 million tonnes of waste, annually. The landfill is equipped with state-of-the-art leachate control systems and landfill gas collection systems. The collected leachate is re-circulated to enable operation of the landfill as a bioreactor. The landfill gas extraction and control system consists of a network of interconnected wells (spaced 80 m apart) and a landfill gas incinerator. In

addition to surface emissions, there were several point sources of gas emissions at this landfill. They include the landfill gas incinerator and 20 gas wells that are venting gases directly into the atmosphere. In addition, gases are emitted at four locations where leachate seepage has been observed. The four locations are termed "hot spots" because of the very high gas emissions recorded.

Two other surveys were conducted at non-engineered landfills: the Zambiza landfill in Quito, Ecuador; and Khampaeng Saen landfill in Thailand, about 100 km northeast of Bangkok. Flux chambers were used at all three locations to measure surface emission of methane and carbon dioxide gases.

Survey Results

At Loma Los Colorados landfill in Chile, a total of 230 flux chamber measurements were made over the 140-hectare surface area of the landfill. The average flux of methane and carbon dioxide measured over the landfill surface were 349.2 g $m^{-2}day^{-1}$ and 751.0 g $m^{-2}day^{-1}$, respectively. In addition, four "hot spots" were identified on the landfill surface with average emissions of 10,273 g $m^{-2}day^{-1}$ CH_4 and 20,953 g $m^{-2}day^{-1}$ CO_2. These emissions originated from leachate pools, or wet areas in the landfill. Depth profiles of percentage gas were measured for each of the 20 disconnected gas wells, and an average flow rate was calculated from measurements at 8 gas wells. Based on the surface measurements and data gathered from other sources of emissions, a carbon balance exercise was undertaken. Including all sources, the emissions for this landfill were estimated to be 32,800 tonnes/year CH_4 and 65,000 tonnes/year CO_2. The gas incinerator, which is connected to 13 of the landfill's 33 gas wells, burns approximately 1662 tonnes of CH_4 per year, or only 5% of the gas produced within the landfill. The Scholl-Canyon model (assuming a k value of 0.1385 and site specific L_0 value of 174 tonne/m^3 determined from waste composition data) predicts that the CH_4 generation rate as of July/2000 would be 30,600 tonnes/year (about 85% of the estimated total emissions).

Conclusions

Our results show that in comparison to landfills in North America and Europe, the Chilean, Ecuadorian and Thai landfills generally produce higher gas quantities over shorter time periods. Considering the climatic factors, such as high rainfall, and waste composition factors such as high organic content of the waste, these observations are expected. But, there was a wide variability in the rate of emissions among the three landfills surveyed. The variability in the design and operation practices being adopted at the three landfills has a large influence on the overall landfill gas emission rates. The overall landfill gas emission rates of non-engineered landfills in Ecuador and Thailand were lower than that of the engineered bioreactor landfill in Chile, notwithstanding its gas collection system.