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Life-Cycle Inventory and Impact Evaluation of Mining Municipal Solid Waste Landfills

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Supporting Information

ABSTRACT: Recent research and policy directives have emerged with a focus on sustainable management of waste materials, and the mining of old landfills represents an opportunity to meet sustainability goals by reducing the release of liquid- and gas-phase contaminants into the environment, recovering land for more productive use, and recovering energy from the landfilled materials. The emissions associated with the landfill mining process (waste excavation, screening, and on-site transportation) were inventoried on the basis of diesel fuel consumption data from two full-scale mining projects (1.3−1.5 L/in-place m^3 of landfill space mined) and unit emissions (mass per liter of diesel consumption) from heavy equipment typically deployed for mining landfills. An analytical framework was developed and used in an assessment of the life-cycle environmental impacts of a few end-use management options for materials deposited and mined from an unlined landfill. The results showed that substantial greenhouse gas emission reductions can be realized in both the waste relocation and materials and energy recovery scenarios compared to a "do nothing" case. The recovery of metal components from landfilled waste was found to have the greatest benefit across nearly all impact categories evaluated, while emissions associated with heavy equipment to mine the waste itself were found to be negligible compared to the benefits that mining provided.

■ INTRODUCTION

There are hundreds of thousands of active, closed, and abandoned landfills worldwide, with estimates of nearly 100 000 in the U.S. and more than 150 000 in Europe.[1,2] Investigators have examined the concept of landfill mining or mining (also referred to as landfill reclamation) at closed sites because of various potential benefits, including reducing environmental impacts from uncontrolled gas-phase and/or aqueous-phase contaminant migration, recovering the land for other uses, and using the extracted material for a variety of purposes, including recycling, combustion with energy recovery, or other beneficial uses, such as land application of reclaimed soil.[3−7]

Previous investigators reported that historically conducted municipal solid waste (MSW) landfill mining projects have been executed to reclaim previously filled space and reduce environmental impacts by relocating waste from unlined cells to landfill cells with engineered protective components, such as low-permeability liners, liquid collection systems, and active biogas collection systems.[7,8] Generally, the recycling of recovered components has been found to be a secondary goal, owing largely to the poor quality of mined materials, which may make them unsuitable in typical remanufacturing processes for traditional recyclables. Oversized materials with high calorific values that do not readily degrade in an anaerobic landfill environment (e.g., plastic, paper with a high lignin content, textiles, and certain vegetative wastes) have been beneficially used through combustion with energy recovery.[4]

Although mining an old unlined cell with no active landfill gas (LFG) control system and recycling and/or proper containment of the recovered waste potentially would result in the reduction of uncontrolled migration of LFG and leachate, the process itself (using heavy equipment that consume fuel) results in environmental emissions. While the environmental benefits of mining old landfill cells are often qualitatively recognized, the primary driver in the decision-making process for landfill mining projects has been economics typically associated with reducing groundwater impacts by removing the contamination source, more efficiently using

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