Evaluation of air injection and extraction tests in a landfill site in Korea: implications for landfill management

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Abstract Air extraction and injection were evaluated for extracting hazardous landfill gas and enhancing degradation of organic materials in a landfill in Korea. From the pilot and full-scale tests, the following results were obtained. The pressure radii of influence varies with direction (anisotropy). A smaller oxygen radius of influence compared with the pressure radius of influence was observed in the landfill where the oxygen consumption rate was relatively high. This was in contrast to a petroleum-contaminated site, where the oxygen radius of influence was estimated to be larger than the pressure radius of influence. The increase in the pressure radius of influence was relatively small compared with the increase in air injection rate. When air was injected at a flow rate of 1 pore volume, the air temperature inside the landfill material increased by up to \(20^\circ C\) because of a calorific reaction. It was also observed that the air-extraction system recovered landfill gas (LFG), and also enhanced aerobic degradation of landfill materials. Methane oxidation occurred during the continuous air injection, which was supported by a decrease in the \(CH_4/CO_2\) ratio. Oxygen consumption rate for the air injection was larger than that for the LFG extraction. Furthermore, the intermittent air injection appeared less effective in landfill stabilization than the continuous injection when they are applied to an active younger landfill with larger oxygen consumption rates, whereas the reverse is the case when applied to an aged landfill.

Keywords Aeration • Korea • Landfill • Methane oxidation • Oxygen consumption

Introduction

Over the last several years, concern has grown regarding the release of potential air pollutants from landfills. Control of gas movement is primarily used to prevent outgas from damaging plants and property, or from causing injury to human health. Methane (\(CH_4\)) generated in landfills kills vegetation and displaces oxygen from the root zone. Furthermore, methane accumulates in buildings and, if its concentration exceeds a lower explosive limit of 5%, there may be a gas explosion (Campbell 1996; Stegmann 1996). Landfill gas (LFG) collection systems remove the landfill gas under a vacuum from the landfill or the surrounding soil formation. These systems use gas-recovery wells and vacuum pumps to provide migration control and/or the recovery of methane for use as an energy source. A pipe network is built to interconnect the wells and the blower equipment. When the primary purpose is migration control, the recovery wells are constructed near the perimeter of the landfill. Depending on site conditions, these wells may be placed in the waste itself, or in the soil immediately adjacent to the landfill. The location of the recovery wells depends on the site characteristics, including type of soil formation and type of waste in the landfill.

Solid waste initially decomposes aerobically. The primary gas product is carbon dioxide (\(CO_2\)). As oxygen is depleted, facultative and anaerobic microorganisms will predominate. These microorganisms continue to produce carbon dioxide, but the process proceeds into anaerobic decomposition, in which methane and carbon dioxide are produced in approximately a 60/40 ratio. In addition, other compounds are produced and additional chemicals are released into the air surrounding the landfill by volatilization.

The main components of LFG after relatively short times after disposal are 55±5% of \(CH_4\) and 45±5% of \(CO_2\).
(Rettenberger and Stegmann 1996). These concentrations remain relatively constant, whereas higher methane concentrations can be observed in an older landfill. A change in LFG composition within the landfill will take place when oxygen enters into the landfill (Stegmann and others 2000). Oxygen may enter the landfill by natural diffusion from the atmosphere, but this is limited to the uppermost part of the landfill. If a substantial vacuum is created within the landfill by extensive gas extraction, and/or forced air injection occurs, air enters the landfill; this accelerates waste decomposition and inhibits methane generation in the influenced area.

Landfills can produce severe environmental impacts via secondary pollution, such as landfill gas and leachate. Even after a landfill has stopped accepting new solid wastes, there will be continuous LFG production, sometimes for an additional 20–30 years (Augenstein and Pacey 1991). The methane gas generated, besides being an environmental threat, represents a potential explosion hazard. Closed landfills should be treated using proper technologies to recover landfill space and environment. The landfill stabilization phases are mainly composed of initial methanogenic and stable methanogenic phases, which are relatively longer periods of degradation (Christensen and Kjeldsen 1989). Reduction of these periods can offer some important advantages in the management of landfills, including enhanced land usage and minimized long-term liabilities.

Some aeration technologies may be applied to minimize the period of the anaerobic degradation, which changes landfill conditions from anaerobic to aerobic. The air-based remedial technologies, such as air injection and LFG extraction, which have been widely used in the remediation of petroleum-contaminated soil, may be applicable to landfills to achieve early stabilization. In this study, the feasibility of aeration processes was evaluated for extraction of hazardous gas and/or enhancement of degradation of organic materials in a landfill in Korea.

Materials and methods

The landfill under study is 5 km west of Seoul, Korea (Fig. 1). The landfill has a surface area of approximately 222,480 m² and a 590,000 m³ volume of waste. The landfill was in operation from February 1990 to December 1992. The average composition of the solid wastes dumped at this site was 60% biowastes, 17% industrial wastes, and 23% construction wastes.

The equipment for the experiments was set up at areas where decomposition was in progress. The equipment included a blower system for injection and extraction. Injection and extraction wells and monitoring wells were constructed. The injection and extraction systems were designed to apply various kinds of injection/extraction methods. Two types of monitoring wells were constructed at different depths (2 and 5 m) and these were equipped to measure gas pressure, landfill gas and oxygen concentrations, and air temperature.

The injection experiment was conducted first, to prevent any problems that may arise during the extraction. A portable infrared meter (GA94, Geotechnical Instruments) was used for the LFG analysis.