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Review

A review of approaches for the long-term management of municipal solid waste landfills

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ABSTRACT

After closure, municipal solid waste (MSW) landfills must be managed and controlled to avoid adverse effects on human health and the environment (HHE). Aftercare (or post-closure care) can be brought to an end when the authorities consider the landfill to no longer pose a threat to HHE. Different approaches have been suggested for long-term landfill management and evaluation of aftercare completion. In this paper, research on aftercare and its completion is analyzed and regulatory approaches for the completion of landfill aftercare are reviewed. Approaches to aftercare could be categorized as (i) target values, (ii) impact/risk assessment, and (iii) performance based. Comparison of these approaches illustrates that each has limitations and strengths. While target values are typically used as screening indicators to be complemented with site-specific assessments, impact/risk assessment approaches address the core issue about aftercare completion, but face large uncertainties and require a high level of expertise. A performance-based approach allows for the combination of target values and impact/risk assessments in a consistent evaluation framework with the aim of sequentially reducing aftercare intensity and, ultimately, leading to the completion of aftercare. At a regulatory level, simple qualitative criteria are typically used as the primary basis for defining completion of aftercare, most likely due to the complexity of developing rigorous evaluation methodologies. This paper argues that development of transparent and consistent regulatory procedures represents the basis for defining the desired state of a landfill at the end of aftercare and for reducing uncertainty about the intensity and duration of aftercare. In this context, recently presented technical guidelines and the ongoing debate with respect to their regulatory acceptance are a valuable step towards developing strategies for the cost-effective protection of HHE at closed MSW landfills. To assess the practicality of evaluation methodologies for aftercare, well-documented case studies including regulatory review and acceptance are needed.

Contents

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1. Introduction

Municipal solid waste (MSW) landfills represent the dominant option for waste disposal in many parts of the world. In general, the comparatively high costs of treatment and disposal alternatives are a major reason for the reliance on MSW landfills, particularly in developing economies (Brunner and Fellner, 2007). Nevertheless, even some highly industrialized countries such as the US, Australia, the UK, and Finland largely depend on landfilling. For example, in the US, 54% of the 250 Tg (1Tg = 10^6 metric tons) of MSW generated was landfilled in 2008, with recycling and composting accounting for about 33% of MSW management (USEPA, 2009). In Australia, about 70% of MSW has been directed to landfills without pre-treatment in 2002 (Productivity Commission, 2006). In Japan, direct disposal of MSW accounted for less than 30% of MSW generation in 2000 with high incineration rates during the last decades due to the historic scarcity of land (Tanaka et al., 2005). Among the EU member states, Greece, the UK, and Finland are some of the most dependent on direct landfilling. The fraction of MSW landfilled in 2008 was 77% in Greece, 55% in the UK, and 51% in Finland (Eurostat, 2010). In contrast, landfilling accounted for less than 5% of MSW management in 2008 in Germany, the Netherlands, Sweden, Denmark, and Austria (Eurostat, 2010).

While the use of landfills is decreasing in many parts of the world, there are nonetheless thousands of closed landfills and thousands more that are operating but will close over the next 10–30 years. For example, there were about 1800 MSW landfills reported to be operating in the US in 2008, down from 6300 in 1990 (USEPA, 2009). Similarly, the number of operating MSW landfills in Germany has decreased from 560 in 1993 to 182 in 2009 (BMU, 2006; Statistisches Bundesamt, 2011). In the UK, more than 2000 MSW landfills were operating in April 2004, but by December 2009 only 465 remained in operation with a Landfill Directive (EC, 1999) compliant permit (Environment Agency, 2010a).

This state of the practice overview on MSW landfills highlights the significant variation among individual countries in both solid waste management practices and the extent of pre-treatment prior to waste disposal. However, there are at least two areas of commonality. First, the basic design elements of modern engineered landfills are similar (in this context, a modern landfill is one at which operation and maintenance is regulated at the national or sub-national level). Such landfills include a waste containment liner system to separate waste from the subsurface environment, systems for the collection and management of leachate and gas, and placement of a final cover after waste deposition is complete. Second, regardless of current approaches, the legacy of closed MSW landfills in almost all industrialized countries will continue to require aftercare (or post-closure care) until protection of human health and the environment (HHE) is not compromised in the absence of such care.

Aftercare management of closed landfills typically includes monitoring of emissions (e.g. leachate and gas) and receiving systems (e.g. groundwater, surface water, soil, and air) and maintenance of the cover and leachate and gas collection systems. In general, regulations specify a minimum period of aftercare for which funding must be accrued. For example, the European Landfill Directive (EC, 1999) specifies a period of at least 30 years of aftercare as a basis for the build-up of financial provisions. This has been translated by many European member states into national regulations that require at least 30 years aftercare. Subtitle D of the Resource Conservation and Recovery Act (RCRA) (USEPA, 1991) specifies a 30-year post-closure monitoring period unless this period is shortened or extended by the regulatory agency on a site-specific basis. These regulations have led many landfill owners to budget aftercare funds on the assumption that care activities will be discontinued after 30 years. However, although few modern landfill owner/operators have yet completed 30 years of aftercare and/or petitioned to modify the aftercare period, a lack of criteria and procedures for evaluating landfill completion will make it difficult for regulators to make decisions to end, extend, or reduce the aftercare period (cf. Barlaz et al., 2002).

The development of cost-effective strategies for long-term management of landfills is in the interest of both regulatory agencies and landfill owners for several reasons. First, funding accrual mechanisms currently in place do not typically consider the potential for aftercare periods in excess of 30 years. If necessary, reform of the current time-based systems would be most effective if changes were made while landfills are still in active operation and accruing funds. Second, appropriate management of existing aftercare funds is critical to provide proper protection of HHE, the financial health of landfill owners, and to prevent the emergence of landfills with exhausted aftercare funding.

The objective of this paper is to critically review approaches for the long-term management of MSW landfills. In the next section, an overview of management alternatives for closed MSW landfills is provided. Thereafter, specific approaches for the evaluation and potential completion of aftercare at MSW landfills that have been described in the literature are analyzed. This is followed by a presentation of country-specific regulatory procedures and technical guidelines. Finally, findings from the analysis of long-term landfill management approaches and procedures are highlighted and recommendations for future efforts to reduce uncertainty on the duration and extent of landfill aftercare are presented.

While the focus of this review is on the aftercare period following landfill closure, management of a landfill earlier in its life is addressed when relevant to the approach proposed for aftercare. Fig. 1 illustrates that while the post-operational period starts directly after the end of waste disposal, the aftercare period starts after final cover installation.

In some cases, measures for enhanced emission reduction are initiated during or after the end of waste deposition. For example, in Wisconsin, USA, landfill owners are encouraged to either eliminate biodegradable material from landfills or to stabilize it by measures for the enhanced reduction of the emission potential remaining in the landfill (e.g. liquids addition, aeration) within 40 years after closure (Wisconsin Department of Natural Resources, 2007). In Germany, there is discussion of aerating landfills after closure to reduce the emission potential within the landfill before a final cover is installed (Stegmann et al., 2006).