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A novel approach in calculating site-specific aftercare completion criteria for landfills in The Netherlands: Policy developments

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ABSTRACT

As part of a more circular economy, current attention on waste is shifting from landfilling towards the prevention, re-use and recycling of waste materials. Although the need for landfills is decreasing, there are many landfills around the world that are still operational or at the point of starting the aftercare period. With traditional aftercare management, these landfills require perpetual aftercare at considerable cost due to monitoring and regular maintenance of liners. In an attempt to lower these aftercare costs, and to prevent that future generations become responsible for finding a sustainable solution of present day waste, the Dutch government takes action to explore the possibilities of sustainable landfill management. A project was started to investigate whether the use of source-oriented treatment techniques (so-called active treatment) of landfills can result in a sustainable emission reduction to soil and groundwater. During the next decade, sustainable landfill management is tested at three selected pilot landfills in the Netherlands. To enable this pilot testing and to determine its success after the experimental treatment period, a new methodology and conceptual framework was developed. The aim of this paper is to describe the development of the new methodology, and in particular the policy decisions, needed to determine whether the pilot experiments will be successful. The pilot projects are considered successful when the concentrations in the leachate of the pilot landfills have sufficiently been reduced and for longer periods of time and comply with the derived site-specific Environmental Protection Criteria (EPC). In that case, aftercare can be reduced, and it can be determined whether sustainable landfill management is economically feasible for further implementation.

1. Introduction

The development of a circular economy is nowadays the focus of attention in many legislative frameworks in Europe. In these legislative frameworks, waste is increasingly less considered as an end of pipe product that needs to be discarded of at a certain time. By stimulating innovation to limit the production of waste by e.g., more efficient technologies, re-use or recycling of waste, the need for landfilling is declining. Although developments towards a circular economy are to be preferred above landfilling, the need for landfills including their maintenance remains.

The fabrication of products will generate waste materials that at some point can no longer be re-used, for example due to loss of quality, or high recovery costs of the secondary material. Furthermore, currently operational landfills require proper management and future aftercare, as do landfills that are already in the process of aftercare. The management of current and future landfills should preferably be in line with the concept of environmental sustainability, and the environmental impact of a landfill on soil and groundwater should be minimized as much as possible. In the traditional aftercare of landfills, it is mandatory to seal the landfill completely with bottom, top and side liners to prevent any water from entering the landfill. This approach is generally adequate with regard to environmental protection, but is not considered sustainable. Under these conditions, the composition of the waste inside the landfill remains largely unchanged over time, as natural degradation processes are minimized. Furthermore, this containment is very costly due to everlasting monitoring and liner maintenance (i.e. the replacement of the liners at regular intervals because of their limited lifespan). Landfills that are completely sealed, present a continuing threat to the environment if not properly managed. The traditional way of landfill management thus transfers the responsibility of present day waste to future generations at high costs.

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In order to overcome the afore mentioned problems a project entitled 'Introduction of Sustainable Landfill management' (ISL) was launched in The Netherlands in 2010. This project has recently lead to a so called 'Green Deal', a unique cooperation between the National government, competent authorities, research institutes and the landfill operators. In October 2015 the 'Green Deal' was signed by the Ministry of Infrastructure and Environment of the Dutch national government, the Dutch Sustainable Landfill Foundation and landfill operators. The aim of this deal is to test at three selected existing landfills (hereafter 'pilot landfills') whether the use of source-oriented treatment techniques (so-called active treatment) can result in a sustainable emission reduction to soil and groundwater. National policy frameworks were not considered adequate to enable the rather "unconventional" pilot experiments, therefore current national legislation was extended. The aim of this manuscript is to describe the development of a new methodology, and in particular the policy decisions, needed to determine whether the pilot experiments will be successful after the period of active treatment has ended.

In the methodology that is developed and explained in this manuscript, the pilot projects are considered successful when the concentrations in the leachate of the pilot landfills have sufficiently been reduced to protect (ground) water quality. In that case, the use of protective top liners and their costly replacement may no longer be necessary, while monitoring can be reduced. When successful, the landfill operators determine whether sustainable landfill management is economically feasible for further implementation. The active treatment at the three pilot landfills will start from 2016 onwards, and is expected to take 10–12 years.

In short, the purpose of active treatment is to stimulate natural attenuation processes in the pilot landfills by controlled aeration, irrigation and the recirculation of water through the waste package, in order to wash out soluble substances (e.g. chloride and ammonium), degrade organic substances (e.g. PAH's and VOX) and immobilize metal contaminants. This treatment is contrary to conventional landfills that are completely sealed, where anaerobic processes dominate and attenuation processes proceed much slower. Research on active treatment has been performed previously by Reinhart (1996), Ritzkowski et al. (2006), Rich et al. (2008).

For the experiments only those landfills are selected that contain waste that has sufficient potential for stabilization. Landfills with certain types of hazardous waste (as indicated in international and national acceptance criteria for landfilling of waste (Min VROM, 1997; EC, 2003)) were excluded from the selection of pilot landfills. The presence of a bottom liner with a sufficient life span (liners have to be functional for the duration of the experiment), expected limited emissions to the air (landfill gases) and the economic feasibility were further important criteria when selecting suitable landfills for the pilot experiments. The landfills that were selected for the pilot study were: Site 1: Braambergen in Almere, Site 2: Kragge II in Bergen op Zoom, and Site 3: Wieringermeer in Middenmeer. The selected compartments at these landfills contain waste dominated by inorganic materials such as contaminated soil and soil purification residue (Site 1), domestic waste (Site 2), and industrial-, building- and demolition-waste (Site 3), respectively The selected landfills have been operational for 2–3 decades and are now closed for further waste acceptance (Kattenberg and Heimovaara, 2011; Kattenberg et al. 2013; Van Vossen and Heyer, 2009). For site-specific characteristics on the selected pilot landfills is referred to Brand et al. (2014), provided in the supplementary information.

Emissions suh as landfill gas (existing of mostly methane (CH_4) and carbon dioxide (CO_2)) are excluded from the Green Deal (Kattenberg and Heimovaara, 2011) and are not part of the methodology. Also, in the long term, emissions of landfill gas are expected to become insignificant relative to leachate emissions (Laner 2011; Laner et al., 2012a,b), in particular after introduction of active aeration.

2. Establishing reference framework and Environmental Protection Criteria (EPC)

Below will be explained how the methodology was developed to calculate site-specific Environmental Protection Criteria (EPC), with the focus on the necessary policy decisions. The EPC are expressed as maximum concentrations (μg/l) of designated contaminants in the landfill leachate, in such a way that groundwater quality is protected for a certain assessment period (500 years, see Section 2.2.3) after the period of active treatment has ended. Previous studies to determine completion criteria were performed by amongst others Stegmann et al. (2006), Morris and Barlaz (2010), Laner (2011) and Laner et al. (2012a,b). Unique aspects of the methodology described in this paper is that the EPC are site specific (versus generic criteria in existing policies such as the EU Landfill Directive), the role of state-of-the-art geochemical models in the establishment of the site-specific EPC (as further explained in Dijkstra et al., 2016) versus the conventional approach based on generic linear Kd values (Hjelmar et al., 2001), and that it is the first time that aftercare completion criteria are implemented in national policy. Therefore, the methodology and criteria had to be accepted by the National government, politicians, the competent authorities and the general public.

In particular, the "competent authorities" (which are the provinces that have the legal authority to approve or disprove the outcomes, and which carry the costs of the after-care of landfills) had to be convinced that the potential positive results outweigh the potential environmental and financial risks of this experiment, and that sufficient precautionary measures are taken. For this reason, a careful balance was maintained between generic (policy based) criteria and the use of site-specific factors to develop the methodology for derivation of the EPC. The generic criteria mostly apply to the conceptual model of the landfill, and are conservative by nature. These criteria are motivated by current policy and regulatory frameworks, and the general acceptance of these frameworks in practice. The site-specific factors are of a more technical nature and of relevance for modelling and evaluation purposes. Previous studies have stressed the importance of a site-specific approach in the evaluation of the required aftercare of landfills (e.g., Morris and Barlaz 2010; Laner 2011). This paper will address specifically the policy related aspects of the derived methodology and the results, whilst the paper of Dijkstra et al. (2016) will elaborate on the scientific and technical aspects of the geochemical modelling.

2.1. Choices based on policy context

The EU and national regulatory frameworks set the boundary requirements regarding the derivation of EPC, acceptance criteria for waste, as well as the allowed impact on soil and groundwater quality. In Fig. 1, an overview of the relevant European and national frameworks is presented.

2.1.1. Conceptual model to derive EPC

The conceptual model that was adopted to derive the EPC is schematically shown in Fig. 2. This model is based on the framework of the European Groundwater Directive (GWD) (EC, 2006, 2009), European Landfill Directive (ELD) (EC, 1999) and the proposed acceptance criteria for landfilling of the DHI in Denmark (Miljøstyrelsen, 2003). A similar conceptual model was previously developed in the leaching studies of the reuse of building materials