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FLOODING RISKS AT OLD LANDFILL SITES: LINEAR ECONOMY MEETS CLIMATE CHANGE

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Introduction

On the 4th of September 2017, CNN[1] spread the following news: "Toxic waste sites flooded: at least 13 toxic waste sites in Texas were flooded or damaged by Hurricane Harvey, according to the Environmental Protection Agency." This was possibly the first announcement of extreme weather conditions causing large environmental damage at landfill sites, mostly denominated as 3final waste disposal facilities". Suddenly, due to this climatological impact, eternity seems to last only several decades. These eternal storage sites of waste were commonly regarded as sources of methane, which, as such, cause greenhouse gas emissions and, hence, contribute to climate change. This paper gives an overview on the general aspects of flooding of landfills, the risks and the potential contribution of the ELFM-concept as a solution. The development of the specific approach by the governmental agency in Flanders will be shown.

Landfills and flooding risks

Since the 1950s Europe has been disposing vast levels of waste in landfills. Estimates have revealed 350,000 to 500,000 landfills in the EU.[2] The majority of these landfills is no longer operational and/or monitored. According to estimations based on limited mapping results, tens of thousands of historic landfills are situated in coastal and alluvial areas. The content of these historic landfills could pose a significant environmental threat if they are flooded and erode.

Already in 2009, Laner *et al.*[3] investigated the risk of flooding of MSW landfills in Austria. Out of 1,064 landfills, 312 sites or about 30% are located in or next to areas flooded on average once in 200 years. Around 5% of these landfills are equipped with flood protection facilities. Material inventories of 147 landfill sites endangered by flooding are established, and potential emissions during a flood event are estimated by assuming the worst case of complete landfill leaching and erosion.

More recently, Brand[4] performed research on the UK's 21,027 historic landfills and assessed their individual vulnerability to flooding and coastal erosion. Nearly 3,000 of them are located in flood plains and a further 1,264 in low-lying coastal areas, often in the vicinity of the sea. Hence, many waste sites risk being flooded from heavy rain, storm surges and coastal erosion.

The Alaska Department of Environmental Conservation conducted a four-year $1.4 million project to inventory and rank vulnerable sites, and generate detailed action plans for the sites of highest concern. Its Final Report[5] in May 2015 includes the preliminary reports for each community visited, which provides a brief narrative of the community's sites and photos of each site. It also contains the detailed action plans for the 20 sites of highest concern, *i.e.* those that are prone to flooding within the next 50 years.

In order to reduce damage caused by flooding, siting of hazardous facilities is an important element in the decision-making process. According to Sara,[6] the 100-year floodplain is normally an exclusion zone for the disposal of solid waste. As a part of the National Flood Insurance Program, Flood Hazard Boundary Maps (FHBM) have been prepared for virtually all communities that have been identified as “flood prone”. The regulations of Harris County[7] (*cf. supra* CNN) stipulate that construction of critical facilities (*e.g.* waste disposal/storage) shall be, to the extent possible, located outside the limits of the 0.2% floodplain or 500-year floodplain (Shaded Zone X) and any “A” Zone. Despite these restrictions, 13 waste facilities were damaged and flooded during the Harvey hurricane (US EPA[8]).

At the EU-level, the Directive 2007/60/EC[9] on the assessment and management of flood risks entered into force on 26 November 2007. This Directive requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk. Member States should carry out a preliminary assessment by 2011 to identify the river basins and associated coastal areas at risk of flooding. For such zones they would then need to draw up flood risk maps by 2013 and establish flood risk management plans focused on prevention, protection and preparedness by 2015.

Regarding landfills, flood risk maps shall show the potential adverse consequences associated with installations as referred to in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control which might cause accidental pollution in case of flooding and potentially affected protected areas. Best management practices on this specific issue are lacking to date.

Climate change and landfills

Landfills produce landfill gases (methane) and contribute as such to the greenhouse effect and climate change. This concept is not at stake but recent landfilling practices reveal a minor impact due to the fact that organic waste is no longer allowed to be landfilled. This implies a lower impact of landfills on climate change. Moreover, specific initiatives on greening landfills and installing solar energy panels on top, result in a positive effect in view of climate change.

On the other hand, the impact of climate change on landfills is barely investigated. As mentioned above, the main risks come from higher rainfall intensity in short intervals causing erosion and flooding. Especially landfills in lower areas are vulnerable to these changes. The environmental consequences due to higher flooding patterns were seldomly taken into account in the commonly used risk models.

The external impact on landfills might be of larger importance than the internal adverse effects of the landfilled waste. The traditional management concepts aim at a continuation of the static feature, although the boundary conditions of the complex system are substantially changing. If flooding becomes an increasingly important factor, the stand-still principle is far more a *contradictio in terminis* than a sustainable solution.

Situation in Flanders (Belgium)

Since the end of the 18th century general regulations on waste management came into force. The decree of 16-24 August 1790[10] emphasised the rapid evacuation of waste out of the (medieval) city centre. Those cities were often situated along rivers and waste was initially transported to the adjacent lowlands. It can be regarded as a kind of land reclamation. Later on, shipment to larger landfills close to the water network became a common practice. Based on the OVAM inventory of landfills, VITO detected 965 landfill sites vulnerable to flooding on a total of 1,735 sites, *i.e.* 55% (Table 1).

Table 1: Landfills and flooding risks in Flanders

Province	flooding risk		no flooding risk	
	number	ha	number	ha
Antwerp	260	1898.7	283	1368.8
Limburg	124	278.5	145	917.1
Eastern Flanders	132	930.7	75	930.7
Flemish Brabant	193	690.5	81	195.8
Western Flanders	256	1020.3	186	560.1
Total	965	4818.7	770	3972.4

The vast majority of the landfill facilities were closed before 1984 and currently only 28 landfills are operational. Only 7 landfill zones have public access and since the last decade less than 2% of the Municipal Solid Waste is landfilled. Landfill bans on both unsorted waste and on separately collected waste materials since 1998, and a landfill ban on combustible residual wastes since 2000, resulted in a decreasing content of biodegradable waste. The recovery rate of landfill gas is diminishing over the last decade: 13 installations produced 865 TJ in 2004 and 12 installations recovered 415 TJ (VITO[11]). A similar decreasing tendency was pointed out in the Environmental Status Report MIRA-T.[12]

Table 2: Methane emissions in Flanders

Emission methane (kton CO2-eq)					
1990	1995	2000	2005	2006	2007
1 641	1 519	1 193	632	544	479

This positive effect of lower methane production is jeopardised by the increasing risk of flooding. Beside the erosion of waste, intrusion of water in old landfills can initiate renewed biogas production. Recently, OVAM discussed the issue with the responsible agencies on Flooding risk control (Sigma plan[13]). The presence of landfills is now integrated in the planning process in order to avoid supplementary risks.

The possibility of eliminating/mining landfills in alluvial areas is tested in 2 pilots. By introducing the concept of ELFM, the reduction of the landfilled material offers more options to create a safer environment to flooding. The reuse of the recycled material in new infrastructure is considered and was already proven in an earlier project at Zaventem. The surface occupied by the old landfill was reduced to less than 50% and the reclaimed space was reshaped as a buffer basin. The construction and demolition material was processed and partly reused on site. This action resulted in a remediated landfill site and better flood control; no dwellings were flooded since its installation in 1996. Landfills are no longer a threat but can also present an opportunity regarding climate change. Besides the recycling of materials, landfills may contribute to a multi-layer flooding safety management and be part of measures on climate adaptation.[14]

Conclusion

The waste management policies of the EU resulted in a significant decrease of landfilled waste and its biodegradable content. These actions imply an on-going reduction of methane production and the release of this greenhouse gas is also limited due to its energetic valorisation. This positive tendency is under pressure because of increasing flooding risks. A vulnerability index for historic landfill sites is needed to determine where resources and attention might best be focused. The concept of Enhanced Landfill mining could become an appropriate option if (partial) relocation of landfills is required.

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