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TMS Partners in Progress

Closing Material Loops: The Enhanced Landfill Mining Concept

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TMS has forged cooperative agreements with several carefully selected organizations that actively work to benefit the materials science community. In this occasional series, JOM *will provide an update on the activities of these organizations. This installment, by the Center for Resource Recovery & Recycling (CR^3), focuses on Enhanced Landfill Mining. The Center for Resource Recovery & Recycling is a research center established by Worcester Polytechnic Institute, Colorado School of Mines, and K.U. Leuven.*

In a circular economy material loops need to be closed by direct recycling of pre-consumer manufacturing scrap/residues, urban mining of post-consumer End-of-Life products, and landfill mining of historic (and future) urban waste streams. The third approach, which transforms landfills from a major cost to society into a resource recovery opportunity, has received surprisingly little attention. Krook[1] defined landfill mining as "a process for extracting materials or other solid natural resources from waste materials that previously have been disposed of by burying them in the ground." Landfill mining had its genuine start only in the 1990s, in most cases limited to extraction of methane, partial recovery of valuable metals and/or land reclamation.[1–3] Landfill mining strategies are now being further developed with a clear view on resource recovery. These can be subdivided in two main categories. First, in-situ landfill mining refers to resource recovery activities (e.g., methane extraction, which occur on the landfill site without excavating the stored waste streams. Second, ex-situ landfill mining involves resource recovery by partially or fully excavating the waste materials for further treatment. The relevant strategy depends on intrinsic parameters, such as the size, location, age, type, composition and available documentation level of the targeted landfill, as well as extrinsic parameters such as availability of suitable technologies and societal and economic boundary conditions. For instance, landfills containing large fractions of industrial waste (including metals, slags, etc.) tend to be more interesting for an ex-situ approach while municipal solid waste landfills are better suited for the bioreactor concept. Mixed landfills can be simultaneously or consecutively addressed by in-situ and ex-situ landfill mining approaches.

In Figure 1 the various steps in the landfill mining operation are depicted. Essential for business planning is a detailed knowledge of the content. Most landfills lack detailed registration, requiring exploration of the content.[4] Prior to resource recovery from landfills, conditioning of the material is necessary in order to enable cost-efficient mining and reduce risks related to landfill re-use. Conditioning encompasses both pretreatment for immediate mining, such as measures preventing dust and odor problems, and in-situ transformation to a temporary storage. In most landfills, not only are a number of critical compounds present, but also specific situations such as mechanical instability, high leachate level, and areas with reduced permeability have to be addressed.[5] Through in-situ treatment the landfill is effectively transformed into a temporary storage place[6] (double arrow in Figure 1). The first ideas related to the concept of the temporary storage date back to 1999. This concept needs to be developed further to allow implementation in such a way that these resource sites are environmentally and structurally safe, already permitting in-situ recovery of energy, soil, groundwater, land and nature, and allowing future ex-situ resource recovery. If the landfill, or part of it, can be ex-situ mined, then the next step is to develop tailored separation techniques for the excavated materials. Innovative separation flow sheets are required which will deliver (1) materials directly recoverable as new resources for the technosphere, and (2) materials to be further valorized after transformational technologies. The latter include the development of recipes to transform landfill residues (e.g., slags) into high added-value products (e.g., construction materials) and transformational technologies to prepare a solid recovered fuel (SRF) that can be processed in a waste-to-energy installation. The fractions that are not directly recoverable are sent to temporary storage. Concurrently, as shown in Figure 1, the still embryonic temporary storage concept is also relevant for future waste streams from the technosphere. As is the case for currently non-recoverable fractions from the waste-to-material (WtM) plants these new streams (e.g., crushed lamps, asbestos) can also be stored in view of future valorization, whenever technologies are mature and/or economic viability for the resource recovery procedure is ascertained.

The ELFM concept has been under development since 2008 within the Flemish ELFM Consortium. This transdisciplinary consortium of experts was established in Flanders (in northern Belgium) to integrate landfilling in an integrated, systemic resource recovery practice. Currently, ELFM is defined as "the safe conditioning, excavation and integrated valorization of (historic and/or future) landfilled waste streams as both materials (waste-to-material, WtM) and energy (waste-to-energy, WtE), using innovative transformation technologies and respecting the most stringent social and ecological criteria." The "integrated" aspect refers to a maximum valorization of materials and energy, rather than a cherry picking approach. With respect to the innovative character of the involved technologies, the ELFM consortium is investigating the potential of, in particular, the Gasplasma™ WtE technology.[7] As part of the sustainable approach ELFM incorporates the goal to sequester, use, and/or offset a significant fraction of the CO_2 arising during the energy valorization process. Concurrently, the landfill zone can be reclaimed for new societally beneficial usages.[8]

As the definition highlights, the ELFM concept is relevant for both historic and future landfills. In the latter case, landfills become future mines for materials, which cannot yet be (economically) recycled with existing technologies or show a clear potential to be recycled in a more effective way in the near future. Indeed, for certain waste streams, incineration eliminates the possibility of its reuse as a material. The net results are increased material costs and decreased welfare, with respect to a direct materials recycling process. To ensure more materials find their way to recycling instead of incineration or dumping, the 'temporary storage' concept (instead of a permanent landfill) becomes worthwhile. The landfill owner, the landfill operator, and/or the waste producer will have to take into account that the landfill needs to be mined after a short, intermediate or longer period.

The 'Closing the Circle' project (CtC) is the first case-study for the ELFM Consortium to investigate the opportunities and barriers for ELFM in the REMO landfill site in Houthalen-Helchteren (Belgium). CtC was initiated in 2007, ending its concept phase at the end of 2008. Valorization tests, engineering and more detailed elaboration of the project were performed in the period 2009–2012. From 2013 onwards, the project will enter a pilot-scale phase. Subsequently, the full-scale WtE and WtM plants are to be constructed, allowing the resource recovery to start by 2017. The CtC project requires an investment of ~230 M€ and would employ up to 800 people. The WtM and WtE plants will be operational for 20 years. Over that period the landfill site will be gradually developed into a sustainable nature park. The 'Closing the Circle' project addresses a range of scientific, technological and non-technological issues.[9] First, characterization studies of excavated landfilled waste were performed to verify the quality of the available data (log book) of the materials in the landfill. Second, validation studies of the envisaged material recuperation and the energetic valorization technologies were conducted. Third, nature conservation analyses assessed the environmental impact and the envisaged integration of the site in a nearby nature reserve. Finally, the establishment of the project's carbon footprint within a larger environmental economics study was conducted to demonstrate the advantage of landfill mining compared to a do-nothing scenario. More conceptual, societal and legal background studies have also been conducted. Based on extrapolations clear economic, environmental, and social benefits may be expected from a wide deployment of the ELFM concept.[10]

To conclude, by combining (future) valorization of materials with energy production and land re-use, cost efficient resource recovery of landfills will generate economic, environmental, and social spill-overs. As primary resources become more scarce and external costs of primary resources are internalized, ELFM will become more feasible. Technologically, novel separation and high added value creating WtE/M transformation techniques are the key challenges. Furthermore, strategic policy decisions and tailored support systems for ELFM—underpinned by standardized LCA frameworks—will be indispensible to remove the remaining non-technical barriers. To allow this landfill-for-resources concept to become reality, ELFM will therefore require concerted, interdisciplinary and international research programs.

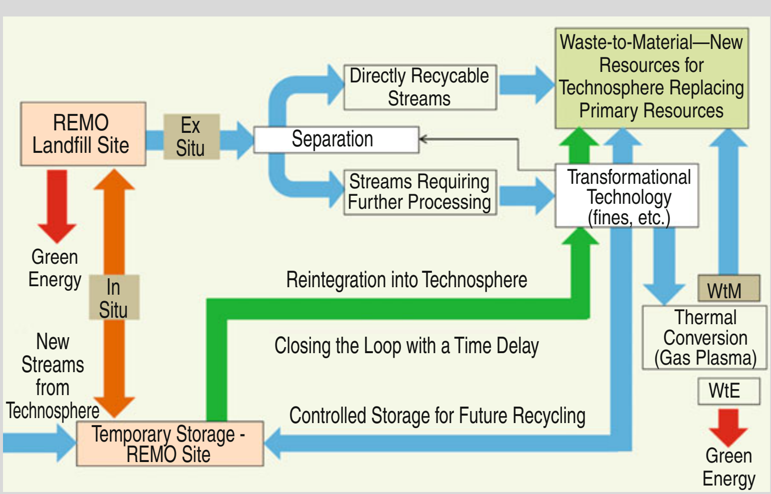

Figure 1. Flow sheet for the REMO Closing the Circle project, which combines in situ with ex situ landfill mining, with a view on maximum resource recovery.

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