detritus Multidisciplinary Journal for Waste Resources & Residues

CISA

Editorial

ENHANCED LANDFILL MINING, THE MISSING LINK TO A CIRCULAR ECONOMY 2.0?

PREFACE TO THE SPECIAL ISSUE ON RESOURCE RECOVERY THROUGH ENHANCED LANDFILL MINING

The transition towards a resource-efficient, climate neutral and circular economy is one of the Grand Societal Challenges of today, as recently endorsed by the European Commission in its European Green Deal (EC 2019). As part of this Green Deal the Commission will also launch a new Circular Economy Action Plan (foreseen in March 2020), which will present a "sustainable products" policy that prioritises reducing and reusing materials before actually recycling them, moving up the Waste Hierarchy. Undoubtedly this is a step in the right direction.

Nevertheless, this shift towards a more pro-active Circular Economy vision does not yet address the question of what Europe and other countries in the world will do with the vast amounts of industrial and consumer waste that have been disposed of in waste dumps and landfills over the past 100 years. In this context Enhanced landfill mining (ELFM) has been proposed as an "out of the box" approach to address the dark side of the Circular Economy vision: i.e. how can we deal with the waste of the past, irrespective of the urgent need to avoid new waste creation and disposal in the future?

As regards Municipal Solid Waste landfills, ELFM has been defined as "the safe conditioning, excavation and integrated valorisation of landfilled waste streams as materials and energy, using innovative transformation technologies and respecting the most stringent social and ecological criteria" (Jones et al. 2013). In this paradigm landfills are considered as resource stocks awaiting future mining in order to recover valuable resources in an integrated way. As has been estimated by the European Enhanced Landfill Mining Consortium (EURELCO), Europe comprises most likely more than 500,000 landfills (Jones 2018) (which is an upgrade of the previous estimation of 150,000 – 500,000 landfills). More importantly, approximately 90% of these landfills are to be considered as "non-sanitary" landfills, predating the EU Landfill Directive of 1999. In order to avoid future environmental and health problems, many of these landfills will at some point require expensive remediation measures. For these landfills, ELFM can be seen as a combined resource recovery and remediation strategy, which can drastically reduce future remediation costs, reclaim valuable land, while at the same time unlocking valuable resources.

Special Issue

The present Detritus special issue "Resource recovery through Enhanced Landfill mining" presents the results of the Horizon 2020 MSCA Innovative Training Network NEW-MINE, a project which aims to develop innovative concepts, technologies and methods for integrated resource recovery and remediation of landfills containing Municipal Solid Waste (MSW). More specifically, the project investigates the full value chain of landfill exploration, excavation, material separation, recovery and upcycling of landfilled materials and energy resources as well as the reclamation of land. In addition, an integrated environmental and economic assessment framework for ELFM is developed and the stakeholders perspectives on ELFM, i.e. the Social License to Operate (SLO), is studied.

NEW-MINE flowsheet

The NEW-MINE project is based on the flowsheet presented in Figure 1, which is the outcome of concerted research performed at the Remo landfill site in Houthalen-Helchteren, Belgium (Jones et al. 2013). This flowsheet, which is to be considered as just one of the possible pathways for performing ELFM, consists of several key operations: waste excavation, mechanical processing to produce recycled materials (e.g. ferrous and non-ferrous metals, aggregates) and to generate a fraction concentrating the components with high calorific value (wood, plastics, textile, etc.). This high calorific fraction is subsequently fed to a thermochemical conversion process, in which a synthetic gas is produced that can be further processed to produce hydrogen, methane or biofuels (Bosmans et al. 2013). As a by-product of the thermochemical conversion, and depending on the applied process, slags or ashes are formed, which subsequently can be upcycled to produce building materials, such as inorganic polymer binders or glass ceramics (Machiels et al. 2017).

Overcoming technological barriers towards ELFM

The ELFM concept is based on treating landfills as anthropogenic deposits (Krook and Leenard 2013). Consequently, the whole value chain known from traditional mining – i.e. exploration, excavation and processing – can be adapted to assess the resource potential of the landfills. Efforts have been made to use geophysical data for the

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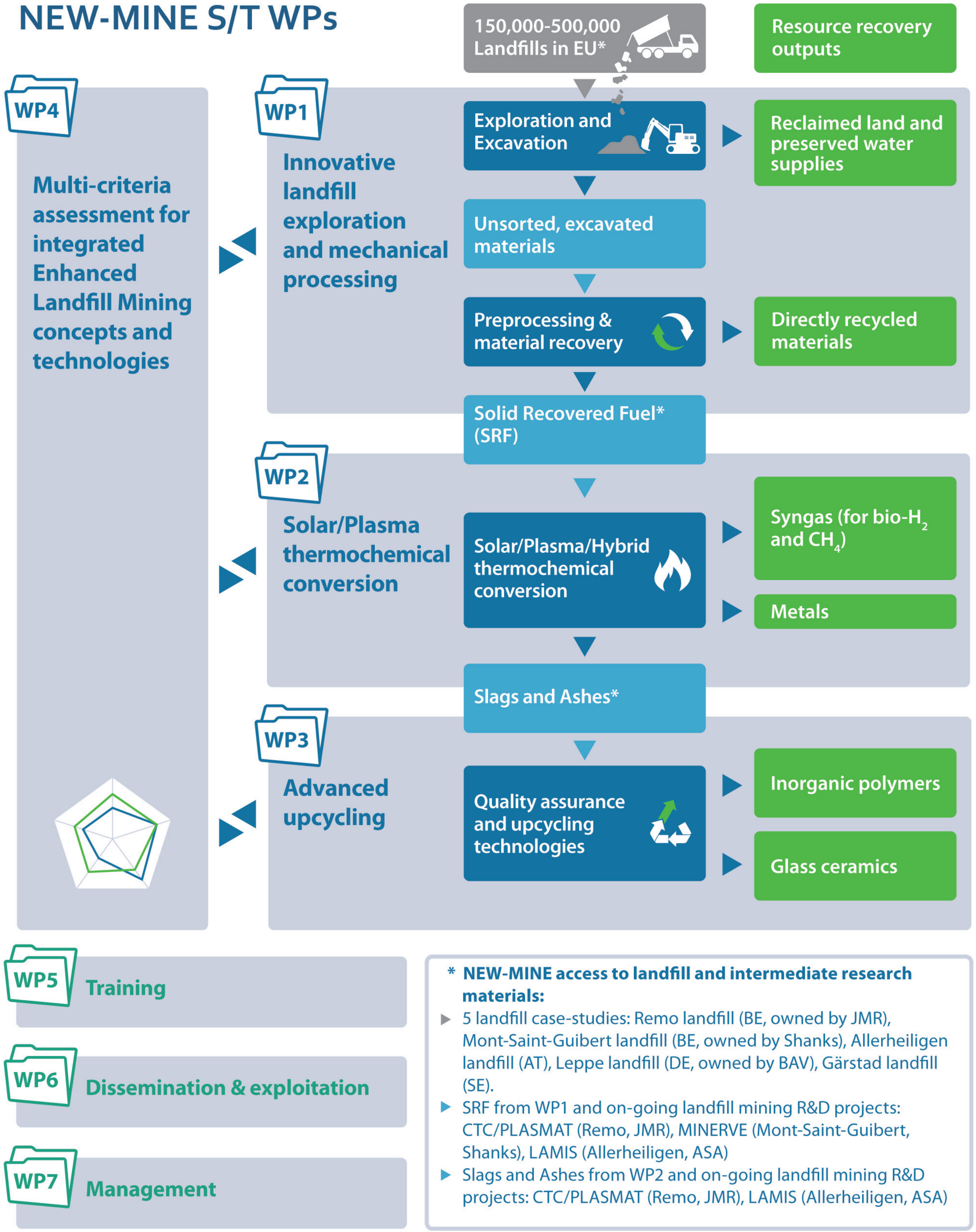
Detritus / Volume 08 - 2019 / pages 1-4
https://doi.org/10.31025/2611-4135/2019.13874



*** NEW-MINE access to landfill and intermediate research materials:**

- 5 landfill case-studies: Remo landfill (BE, owned by JMR), Mont-Saint-Guibert landfill (BE, owned by Shanks), Allerheiligen landfill (AT), Leppe landfill (DE, owned by BAV), Gärstad landfill (SE).
- SRF from WP1 and on-going landfill mining R&D projects: CTC/PLASMAT (Remo, JMR), MINERVE (Mont-Saint-Guibert, Shanks), LAMIS (Allerheiligen, ASA)
- Slags and Ashes from WP2 and on-going landfill mining R&D projects: CTC/PLASMAT (Remo, JMR), LAMIS (Allerheiligen, ASA)

FIGURE 1: Overview of the NEW-MINE work packages and value chain approach

delineation of landfill bodies and to distinguish zones within a landfill containing different waste types (e.g. Municipal Solid Waste versus Industrial Waste). In the NEW-MINE project geophysical data have been correlated with drilling data, from which the different components in the waste can be quantified. A key question is whether geophysical measurements can be used to determine the presence of certain components (e.g. metals), or even better, to quantify their amounts. With respect to this challenge, Vollprecht et al. (this volume) determine whether the metal content of MSW landfills can be estimated through measurement of the magnetic properties.

Once excavated, the waste from the landfills is passed through a series of mechanical separation processes. Within NEW-MINE, state-of-the art processing schemes as well as novel methods have been explored (Figure 2. The key aspect is to understand how excavated, surface-defiled, aged waste from landfills behaves in these processing schemes with respect to fresh MSW. In this Special Issue the results of the tests with both ballistic separators (Garcia Lopez, this volume) and sensor-based sorting (Küppers, this volume) are reported. As non-ferrous metals can form an important part of the revenues of ELFM, the non-ferrous metal output produced in the mechanical separation has been studied in detail (Lucas et al., this volume).

Particular attention is paid to the "fines" fraction, i.e. the size fraction < 90 mm. This fraction often represents the Achilles heel for an ELFM operation as it typically comprises more than 50% of the waste volume and hardly any valorisation solutions have been identified for it (Quaghebeur et al., 2013). A detailed characterisation of the fines fraction of the Mont-Saint-Guibert landfill in Belgium provides more insight in these materials (Hernández Parrodi, this volume). In a corresponding paper, Hernández Parrodi (this volume) presents a detailed fines processing scheme involving particle size classification, ferrous- and non-ferrous metal extraction, density separation and sensor-based sorting, all with the aim to produce different output fractions that can be valorised, including a soil-like fraction, building aggregates as well as ferrous and non-ferrous fractions.

Another key fraction that needs to be valorised in an ELFM operation is the high calorific fraction, which is one of the outputs from the mechanical processing of the excavated waste. This fraction can be thermochemically converted to produce a synthetic gas, metals and, depending on the conversion technology used, slags or ashes. To improve the profitability of an ELFM project, the outputs of the thermochemical conversion are further upcycled to products with a high added value. Firstly, syngas can be upcycled to produce H_2, CH_4 or liquid fuels. Secondly, slags and ashes can be upcycled to produce binders and low-carbon building materials. Within NEW-MINE, two routes have been studied for valorisation of slags/ashes, i.e. the production of inorganic polymers (Ascensão et al., this volume) and glass ceramics (Rabelo Monich et al., this volume).

Within NEW-MINE, an integrated systems analysis framework has also been developed, in order to specify key economic, environmental, technological, social, market and policy conditions and measures for facilitating the implementation of ELFM projects. Hernández Parrodi et al. (this volume) aim to embed landfill mining as a strategy in current waste management systems, taking into account (i) reduction of the landfill volume, (ii) reduction of risks and impact and (iii) increase in resource recovery and overall profitability. In the work of Esguerra et al. (this volume) the economic assessments performed in the framework of landfill mining are reviewed. Finally, while assessments of ELFM have until now mainly focused on environmental and private economic issues, societal impacts have rarely been analysed. Einhäupl et al. (this volume) therefore developed a method for integrating stakeholder archetypes in the assessment of ELFM projects.

FIGURE 2: Overview of key aspects of the NEW-MINE value chain. Upper part from left to right: Geophysical exploration, excavation and ballistic separation at the Mont-Saint-Guibert landfill in Belgium. Lower part from left to right: sensor based sorting, tapping of slag derived from gasification of the calorific fraction derived from EFFM, pavers produces using an inorganic polymer derived from ELFM SLAG. *Pictures from C. Bobe, C. Garcia Lopez and J.C. Hernàndez Parrodi.*

FIGURE 3: Public acceptance as a key aspect in the implementation of an ELFM project. *Source: https://www.geograph.org.uk/photo/372466*

To mine or not to mine, that's the question

This brings us to the question: what is the status of ELFM in terms of real-world implementation? Despite progress in the technical aspects of ELFM, at this point, the first, full-scale industrial, resource recovery-driven ELFM-project is still to be developed. Multiple barriers seem to persist (see Figure 3), as confirmed also by experiences outside New-MINE, in Italy (Cappa, this volume).

First of all, market barriers for ELFM remain: ELFM-derived (recycled) products need to compete with too cheap primary resources, as external environmental and health costs are typically not internalised in their price. As a result, only when land reclamation can provide substantial additional revenues will the economics of ELFM become positive in the present market context. Furthermore, several industries are still reluctant to absorb ELFM-derived materials.

Secondly, local communities may take some convincing about ELFM projects in their backyard, as experienced in the Remo landfill case. The resistance of only a handful people who (metaphorically) take up arms and initiate time-consuming court cases can be enough to block an ELFM project for years. Obtaining the Social License to Operate for ELFM projects is, therefore, not straightforward, even when multi-actor facilitation processes and "citizen science" concepts are employed.

Finally, legislation for ELFM on the EU level has not yet come to terms with the dynamics of the ELFM concept. The fact that the ELFM Amendment that was agreed by the European Parliament in 2017 was later blocked by the European Council highlights that there is still a long way to go before ELFM is accepted as the new standard by policy makers. This represents a major delay for getting ELFM implemented at the EU-level.

In reality this implies that Europe basically still considers landfills as "end stations" for obsolete waste, rather than as "dynamic resource stocks" that can be re-injected into the economy when the time and the economics are right. The importance of the required paradigm shift with respect to the definition of a "landfill" – from a static (linear) view towards a dynamic (circular) perspective – will need to be put on the agenda again in the coming years so that we can clean up our historic waste legacy. Only then can we truly speak of a Circular Economy 2.0 version in which "climate and resource frontrunners" (EC 2019) are facilitated rather than blocked.

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ACKNOWLEDGEMENTS

The research leading to the results presented in this Special Issue has received funding from the European Union´s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 721185 "NEW-MINE" (EU Training Network for Resource Recovery through Enhanced Landfill Mining).

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