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Del. I1.3.2 Site specific report on the potential of extracting raw materials

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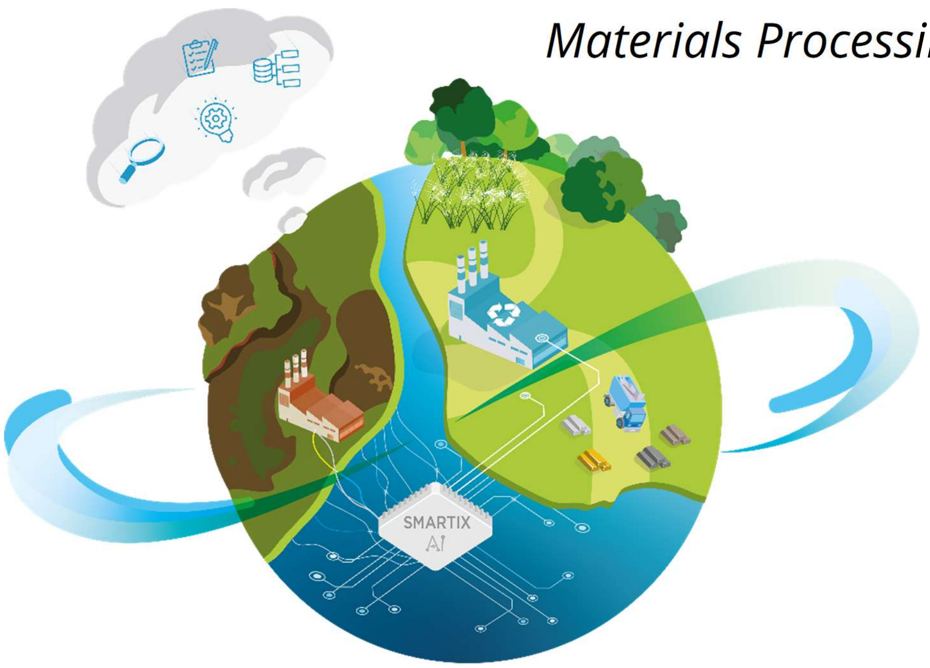

SUMMARY

The Materials Processing Institute together with its project partners has the objective of achieving a systematic, long-term beneficial outcome from recovery and regeneration of Past Metallurgical Sites and Deposits (PMSD) in the INTERREG region of Europe under an EU funded REGENERATIS project. Its aims are the innovative circularity to recover raw materials while regenerating the polluted sites.

This report is submitted in fulfilment of the requirements of work package I1.3.2

1 INTRODUCTION

The NWE-REGENERATIS project (Interreg North-West Europe) aims to recover (metals, minerals, and land) from PMSDs using urban mining methods and valorise the site. Three pilot sites were selected one of which was the former integrated steelworks at Teesside.

As an integrated steelworks which processed from raw materials to finished product there was a number of known areas used for the storage of waste products dating back as far as the 1900s.The South Tees Development Corporation (STDC) site is a vast expanse covering 1500 hectares and has a remarkable history of industrial activity spanning 160 years, dating back to the mid-19th century. During its peak, the site boasted 91 active blast furnaces and was engaged in iron and steel production, as well as the processing of finished products. Over the years, the site has been divided into several areas of past industrial activity, each with its unique characteristics.

These areas include:

- Redcar works complex: A significant portion of the STDC site, covering approximately 670 hectares, where industrial activities such as iron and steel production were concentrated.
- Lackenby steelmaking complex: Encompassing an area of around 160 hectares, this complex was primarily dedicated to steelmaking processes.
- Grangetown Prairie: A smaller zone, spanning about 70 hectares, which contributed to the site's industrial legacy.
- "Landfill and Waste Management facilities" comprising the SLEMS waste management facility, the High Tip Landfill and a metals recovery area zone: One of the most significant zones in terms of potential secondary raw materials. This vast area, estimated at 1000 - 1070 hectares, holds considerable quantities of waste products that have the potential to be valorized.
- South Bank zone: Covering approximately 270 hectares, this area also played a role in past industrial activities.

Given the site's potential as a source of secondary raw materials, it has been selected as one of the three pilot sites for the NWE-REGENERATIS project. The project aims to explore the possibility of valorizing waste products within the STDC site, with a particular focus on the "Landfill and Waste Management facilities" zone, as well as the smaller site, CLE31.

Historical studies and previous investigations have estimated that around 62 million tonnes ($25Mm^3$) of residual slag are spread across the site, with an average thickness of 2.5 meters. The dispersal area of this slag is estimated to be about 1000 -1070 hectares, encompassing the various zones, including Redcar, South Bank, Grangetown, and Lackenby.

This site-specific report builds upon the work of previous geophysical, historical, and analytical investigations that have been carried out on the STDC site. The report's primary objectives are to provide a comprehensive site description and relevant methods and equipment that would be most suitable for excavation of the materials. This will help in understanding the site's unique characteristics and challenges to plan the valorization process effectively. By considering the available information and leveraging insights from past investigations, this report seeks to pave the way for a successful valorization project at the South Tees Development Corporation site. The potential to transform waste materials into valuable resources holds great promise, not only for the site's development but also for contributing to the larger goals of sustainable industrial practices and resource utilization.

2 GENERAL DESCRIPTION OF THE AREA

A number of waste management facilities were identified for consideration within the PMSD-I1 Teesworks area, as shown in Figure 1.

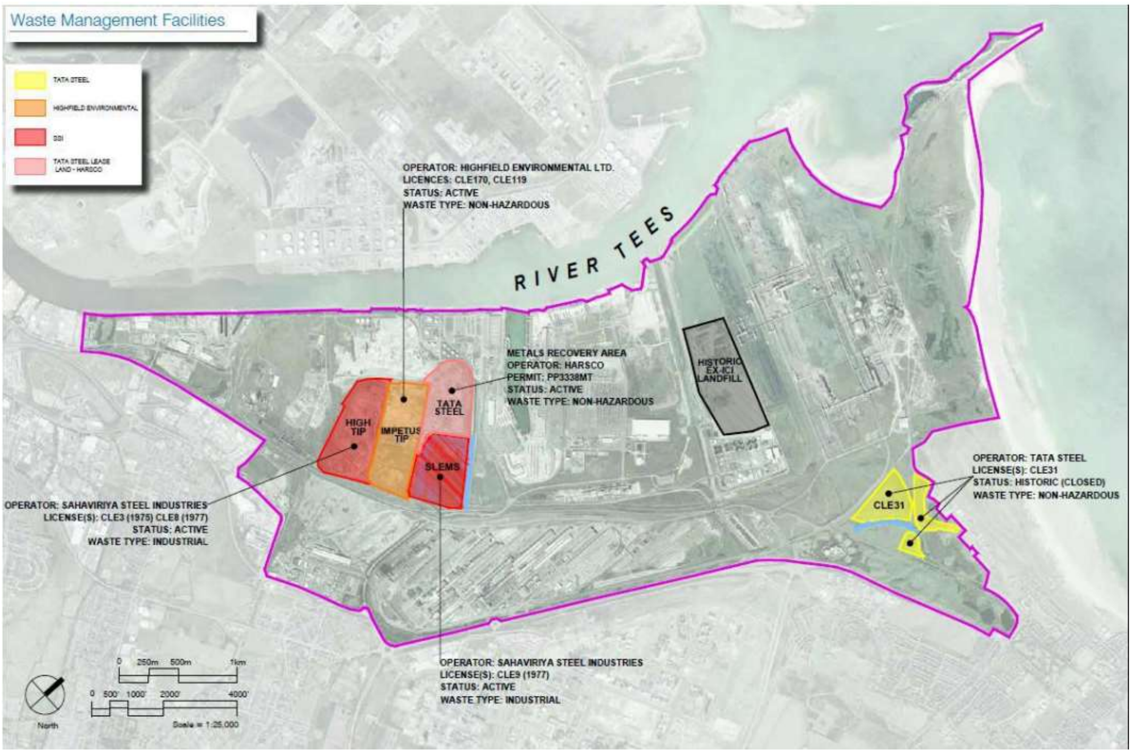

Figure 1: Waste management facilities within PMSD-I1 Teesworks.

The selected area for initial consideration was the South Lackenby Effluent Management System (SLEMS) landfill site, as depicted in Figure 2. SLEMS primarily serves to treat and manage industrial wastewater or effluent to ensure compliance with environmental regulations. The facility collects effluent from various businesses, undergoes treatment involving filtering, chemical reactions, and biological processes to remove impurities and pollutants, and then carefully monitors it before release. Covering an area of 22 hectares, SLEMS is specifically designed for handling and treating Basic Oxygen Steelmaking (BOS) oxide waste. The site includes a series of settling ponds in its southern section where an aqueous suspension of BOS oxide and blast-furnace waste is processed. Settled material was dredged from the ponds and deposited in adjacent drying bays before being placed at a final deposition point within the landfill.

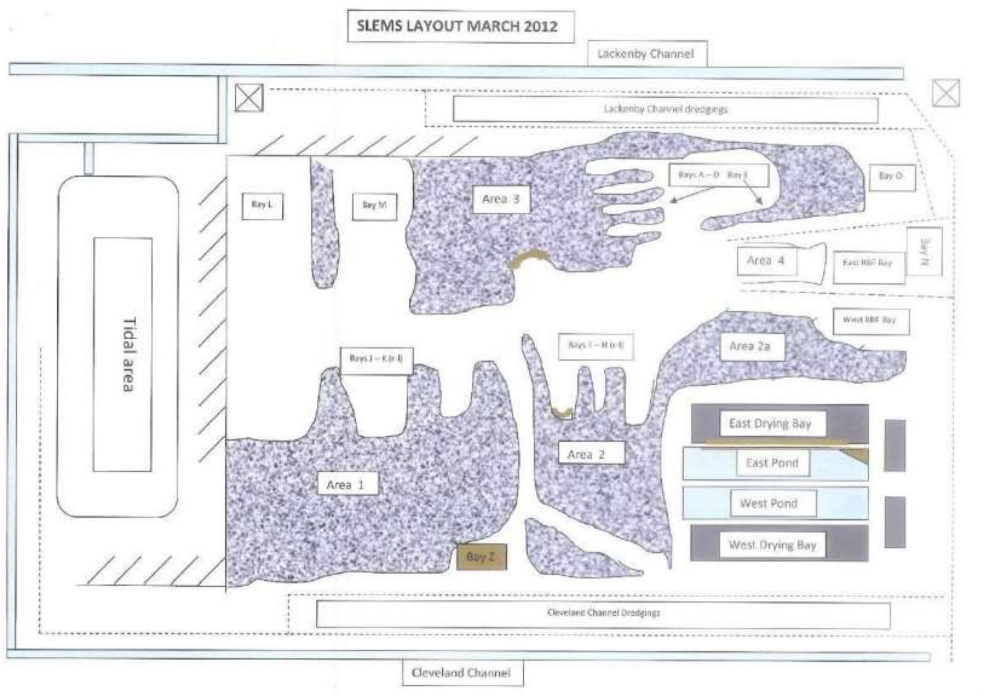

Figure 2: SLEMS site plan

After conducting laboratory work and preparing for geophysical examination, the SLEMS landfill was repurposed for land development activities at Teesworks due to time constraints. Consequently, an alternative area for geophysical study was sought within Teesworks, leading to the selection of the CLE31 landfill site, shown in **Error! Reference source not found.**.

The CLE31 landfill site is a closed waste disposal location situated in the northeastern part of Teesworks, centred on National Grid Reference NZ 57673 24707. The site was originally built on slag byproducts, possibly with a layer of clay at the base, although this hasn't been confirmed. Between 1977 and 2002, waste disposal operations took place, with an estimated one million cubic meters of waste deposited at the site. The landfill primarily consists of steelmaking slag, with small quantities of paper and "canteen waste."

Figure 3: CLE31 landfill site

3 Potential of extracting raw materials

An excavation study was done in the past at the initially planned SLEMS site where the total deposited volume was estimated to be 738,425 m^3[1]. Although the mound consists of a variety of materials, approximately 60% was considered to be made of BOS oxide, which comes around 440,000 m^3. However, the site was not accessible during the latter years of REGENERATIS project, the investigation site was shifted to CLE31. Based on theoretical calculations, it was assumed that the total deposit volume of CLE31 should be 461446.5 m^3[2]. The characteristics of the site and deposit allow the use of conventional excavation machines such as excavators, dump trucks, dumpers, and bulldozers for the extraction of waste materials from CLE31. However, there are several visual variations in the appearance of the slag on the site, which can significantly influence the excavation process. The slag exhibits different characteristics and levels of alteration. This could mean that some portions of the slag might be harder or softer than others, requiring adjustments in the excavation process to handle these variations. Some areas of the slag may contain air pockets that are concealed by hardened layers of slag. This presents a potential safety concern during excavation, as the machines may encounter unexpected voids or unstable areas. Certain slag samples may have high porosity, making them more susceptible to crumbling or fragmentation during excavation. The presence of ribbed slag indicates uneven and irregular surfaces, which can make excavation more challenging. Some slag samples show signs of cracking, which might require careful handling during excavation to avoid further damage. Given the variations in slag appearance and characteristics, the approach of selective excavation is deemed inappropriate. However, to deal with the visual variations and potential challenges posed by the slag, there will be a strong emphasis on post-excavation sorting and preprocessing. This means that after the bulk excavation, the slag will be sorted and processed to handle any variations encountered during the excavation process effectively[2].

3.1 Extraction techniques

The excavation of valuable materials (both minerals and metals) from a past metallurgical landfill is a complex task that demands careful planning and execution to ensure efficiency and safety while minimizing environmental impacts. Several excavation techniques can be employed such as Mechanical Excavation, selective excavation, screening and sorting. Mechanical excavation involves the use of heavy equipment like excavators, front-end loaders, bulldozers, and dump trucks. These machines have strong hydraulic systems and attachments that can manage a lot of steel waste. Long-arm excavators can reach far into the waste, and bulldozers can level the ground to make access simpler. The excavated material is transported to approved disposal or processing sites by dump trucks and loaders. However, in some landfills valuable steel waste might be combined with other non-hazardous waste or potentially recyclable materials. CLE31 is one such site, where slag waste is mixed with general canteen waste. Selective excavation needs to be employed in such cases which involves identifying and carefully removing the slag waste while leaving non-hazardous materials in place. This method requires skilled operators and may involve manual sorting to ensure accurate separation. Screening equipment can be used to separate finer particles or debris from the main slag material. This process increases the efficiency of excavation by reducing the volume of waste that needs further processing. Manual sorting may also be employed to remove any large or hazardous items that could interfere with excavation or recycling processes.

Excavation of industrial steel waste can generate dust, especially if the material is dry and fine. Dust control measures, such as water spraying or dust suppression systems, should be employed to protect workers' health and prevent environmental contamination. It is essential to follow all applicable environmental regulations and obtain any necessary permits for the excavation and disposal of waste and water. This ensures that the process is carried out in an environmentally responsible manner. Extra safety must be undertaken during the excavation process. PPE like hard helmets, gloves, and highly visible vests are a must for all the workers. There must be safeguards in place to deal with potential risks like the existence of hidden air pockets or unstable areas. To safeguard the workers and avoid accidents, regular safety briefings and iterative hazard assessments are crucial. The excavated steel waste must be transported for further processing for valuable material recovery by loading onto dump trucks or other appropriate vehicles.

3.2 Recovery techniques

This section elaborates various separation techniques that can be used to recover valuable elements from steel waste. Magnetic separation is probably the most widely used method to enrich magnetic elements such as iron, which is the most common element in the steel waste. Some large lumps of iron may be recovered as evidenced from the DUFERCO site excavation, however majority of the iron will require more active methods. Froth flotation is another physical separation method which is used especially for recovering zinc and lead from steel slags and other carbonaceous materials. The difficulties in separating more complex chemical compositions of valuable elements must be considered, highlighting the need for additional research and process optimization. Hydrometallurgical techniques such as acid leaching are identified as an effective method for selectively dissolving valuable elements from steel waste, with promising results in recovering zinc, manganese, and chromium. However, the potential environmental impact of using strong alkalis and bases in the leaching process needs to be considered indicating the importance of mitigating such concerns. Alkaline leaching is an alternative approach to extract vanadium and chromium from steel slags. The selective extraction potential of this method is evidenced in literature, but research suggests that further refinement is necessary to improve recovery rates.

Pyrometallurgical techniques such as carbothermal reduction and smelting processes can be employed for obtaining iron and other valuable elements from steel slag. While smelting using a high temperature furnace is an established method, it is noted that energy consumption and emission concerns require careful optimization to ensure its sustainability. Usage of Waelz kiln is highlighted as another method with potential for converting waste into valuable products, particularly for non-ferrous elements like zinc and lead. However, the requirement of at least a minimum quantity of zinc (>15%) for the economic recovery restricts the usage of such equipment. Another available pyrometallurgy technique is the Top Blown Rotary Converter (TBRC) or a Kaldo Converter which can be used to extract low temperature volatiles such as zinc and lead from the waste. Similar to Waelz kiln, TBRC also requires a carbon source for the carbothermal reduction of the material followed by smelting.

The use of microorganisms in extracting metals from steel waste through bioleaching is considered as one of the most environmental friendly techniques. Its potential for recovering zinc, copper, and other valuable elements which are present in trace quantities is considered. However, further research is encouraged to speed up, optimize and scale up this approach for industrial application.

A techno-economic analysis is crucial for determining the practicality of implementing these methods in real-world settings. It needs to be investigated whether a centralized recovery unit or individual recycling unit at each steel plant is the more viable option. Also, the option of a temporary mobile unit could be considered. For the offsite processing, the transport, disposal of residual material and environmental impact during this process needs to be taken in consideration. Another concern is the double landfill tax which might incur during the landfill disposal. The environmental considerations underscore the importance of sustainable practices and the need to minimize the overall impact on the ecosystem.

4 CONCLUSION

The excavation of steel waste from a landfill demands a well-thought-out approach that considers safety, efficiency, environmental protection, and regulatory compliance. Engaging experienced contractors and environmental experts is essential to develop and implement a successful excavation plan. By employing the right techniques and equipment, the valuable steel waste can be efficiently removed from the landfill while minimizing its impact on both workers and the environment.

This report provides a broad overview of the current state of extraction techniques for recovering valuable elements from steel industrial waste. It sheds light on promising avenues for research and application, ultimately contributing to more sustainable and resource-efficient practices in the steel industry. It reiterates the significance of recovering valuable elements from steel waste and highlights the potential of various extraction techniques. Additionally, it emphasizes the importance of further research and development to optimize these methods and address environmental concerns.

5 REFERENCES

[1]. Thurston, N. (2019) Intrusive Investigation Report on The Former SSI Steel Works, Redcar: Former SLEMS Landfill, South Tees Site Company Limited.
[2]. Lommel, L., De Rijdt, R., & Dumont, M. (2023). I1.3.1 Site specific report on excavation activities and civil engineering methods to be applied on Teesside site.