22 June 2023

Del. I1.4.3 Report on lessons learnt on site - Teesworks

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Version 1.0

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 I1.4.3

1 INTRODUCTION

The NWE-REGENERATIS project (Interreg North-West Europe) aims to recover (metals, minerals, and land) from Past Metallurgical Sites and Deposits (PMSD)s 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 significant areas of previous industrial activity are those of the Redcar works complex (comprising the blast furnace, coke ovens, sinter plant and materials handling areas), the Lackenby steelmaking complex (comprising the basic oxygen steel and continuous casting plants), the Grangetown Prairie (site of the Cleveland Iron Works), the zone designated as Landfill and Waste Management Facilities (comprising the SLEMS waste management facility, the High Tip Landfill and a metals recovery area) and the South Bank zone (site of the Clay Lane furnaces and the South Bank Coke Ovens).

This report highlights the lessons learnt during the project especially the benefits of geophysical investigation which can provide useful information regarding the nature of deposits within landfill which can provide information for the potential for valorisation.

2 HISTORICAL DATA

The Teesworks site has a significant amount of historical data available. This is invaluable when looking at a PMSD. There were a number of reports detailing the specific use of each landfill area. These reports can be used to gauge the potential for recovery of value from the deposits and guide future development work.

Good historical data can be used to target site geophysics.

Two sites were used during the project. Initially the SLEMS and subsequently CLE31. From historical data it can be seen that these are very different deposits. The SLEMS consists mainly of an Iron oxide dust which was collected from the off-gas system of the Basic Oxygen steelmaking plant. This has a very high iron content which was well documented in the historical data. The CLE31 site had less historical data but it was still possible to predict the site make up from data. The area was mainly steelmaking and some blast furnace slags.

3 GEOPHYSICAL INVESTIGATIONS

The Geophysical investigations carried out on the CLE31 landfill site.

A number of different techniques were applied to the site.

- Topography measurement
- Geomagnetic surveys
  - Measurements of the geomagnetic field amplitude (with a magnetometer)
  - Measurements of surficial magnetic susceptibility (with a kappa-meter)
- ElectroMagnetic Induction (EMI) survey
- Electrical Resistivity and Induced Polarization (IP) tomography profiles

The topography of the heap has been calculated using two different techniques: Differential GPS measurements during geophysical survey and Photogrammetry with UAV view. The map of the difference of elevation between the 2 techniques indicate small differences (less than 25 cm).

The geophysical survey carried out on CLE31 shows that the material filling the heap has variable and heterogeneous geophysical properties.

Magnetic and electromagnetic maps show randomly distributed parameters. The magnetic and electromagnetic surveys are affected by the local variations of magnetic susceptibility which is high and highly variable on these kind of wastes from iron metallurgy. Thus, magnetic and electromagnetic surveys are difficult to interpret in such context and these techniques are not recommended for mapping wastes from iron metallurgy. However, they highlighted the heterogeneous nature of the wastes that are likely to have been deposited randomly.

The electrical resistivity and IP tomography techniques are not affected by highly magnetically susceptible materials. These techniques allow to distinguish one layer and several anomalies with homogeneous electrical properties within the heap. The slag heap was likely built from waste of very different origins.

As electrical resistivity and IP tomography techniques are not sensitive to magnetic susceptibility, it is possible to classify the slag and other metallurgical wastes on Teesside site (CLE31) based on their resistivity and IP signatures. At least, 3 different types of slags have been identified. Using results from the 5 Electrical Resistivity Tomography (ERT) profiles carried out on the slag heap, the geometry and the volume of these different kind of wastes can be calculated.

However, it was not possible to develop a quantitative estimation of the targeted volumes because deeper sampling on site was not achieved during the time of the project. Because of the heterogeneous nature of the deposits observed by the geophysical tools, a quantitative interpretation will only be possible after targeted samples have been analyzed at the laboratory scale, both for geochemical concentration estimations of chemical elements and geophysical properties.

The most useful geophysical methods at the Teesside site are the ERT and IP methods. They allow giving volume estimations of the materials to revalorize. They allowed the detection of the various interfaces and layers within the deposits. In particular, the IP data allowed to identify tilted layers with the highest potential for metal recovery. However, due to the heterogeneous nature of the slags observed in the electrical results, a volume estimation of the parts of the deposit to revalorize will only be possible once samples will be collected and analyzed in the lab over the entire depths of the slag heap.

Full details of the geophysical investigations are presented in reports:

- D. I1.2.1 Site specific report on geophysical survey on Teesside site (UK)
- D. I1.2.2. Site specific report on traditional pre-sampling and post-sampling investigations
- D. I1.2.3. Correlation report of characterization studies based on information from geophysical investigations and traditional investigations
- D. I1.2.4. Site specific dataset for geophysical characterisation method on Teesside site (UK)

4 MINERAL SEPARATION

Mineral separation work was carried out on samples taken from the SLEMS site. Magnetic separation and electrostatic separation tests were carried out by CTP in Belgium and by Bunting Magnetics in the UK. The purpose of this work was to attempt to enrich the iron content of the material to increase the potentials for extraction.

Magnetic and electrostatic separation techniques did not seem efficient for SLEMS BOS oxide material. This test work clearly indicated that the magnetic fraction (iron oxide) was fully distributed through the material and in every size fraction. There was little or no enrichment of the materials by either electrostatic or magnetic separation.

Full details of the mineral separation work are presented in reports:

- D. T2.1.4. Full Report on lab scale (<25 kg) and pilot scale tests (<5 T) undertaken for mineral processing
- D. I1.2.2. Site specific report on traditional pre-sampling and post-sampling investigations

5 PYROMETALLURGY

This study explored the efficiency of separating the landfill waste from SLEMS area on Teesside site. A carbothermal reduction was employed at high temperature to reduce the iron oxide compositions into metallic Fe in an attempt to valorise these wastes. The SLEMS samples were melted in an induction furnace of 45 kW to recover the constituent metals present in the samples. The samples were mixed with graphite powder, which acts as a reducing agent.

Initial trials showed poor recovery because the material failed to melt completely even at elevated temperatures. The basicity of the materials was investigated and the chemistry of the SLEMS material was adjusted by the addition of silica in the form of initially fly ash and then sand. This addition reduced basicity of the slag reducing the melting temperature. This was intended to maximise the iron recovery while reducing the necessary furnace temperature in order to obtain maximum yield at minimum temperature.

Despite the attempts at modification of the chemistry the only moderately successful attempt was when a high temperature of 1700 °C was used and then only approximately 88% of the iron was recovered.

It is concluded that the SLEMS material which is primarily basic oxygen furnace dust and has very high iron content is of high value. Seven trials were attempted to recover metallic iron by varying temperature and basicity. However, the basicity of the slag was high and the yield of metallic iron was low which makes the pyrometallurgical recovery using these techniques not a feasible option.

The process used was a one-step melting process. It may be possible to separate the reduced iron from the remaining slag using either a secondary melting process or a crushing and magnetic separation. The resulting iron will be low Zinc and could be used as a convention steelmaking feedstock however, the extra processing costs of this would likely be uneconomical for the value of the recovered material.
The material may be recoverable using a more conventional blast furnace route for example, but this is made difficult by the residual Zinc content. It may be that a secondary process may be able to reduce the Zinc to acceptable levels such as hydrometallurgy.

Full details of the pyrometallurgical work are presented in report:

- D. T2.2.1. Report on lab scale test (<25 kg) undertaken for metal extraction on samples from 3 sites

6 Hydrometallurgy

Hydrometallurgy is a process which uses solvents to recover metals from a material by using a solvent to leach elements. Hydrometallurgy tests were carried out at Cranfield University using the Teesside SLEMS BOS dust material. The samples were subjected to batch and column testing using chemical solvents and biological solvents.

6.1 Bioleaching

Bioleaching from BOS dust, in batch samples the highest metal recovery from majority of selected elements, Zn, Pb, Al, Li and Y, was achieved under the condition of 1% solid concentration, 1% energy source concentration, 1% inoculum concentration, and pH 1.5 among nine conditions. Under this condition, 54% Mn, 61% Zn, 13% Pb, 59% Al, 92% Li, 40% Co, 99% Y and 67% Ce were dissolved from BOS dust.

Scaling up to column tests, the highest metal recovery from BOS dust was achieved at 1% solid concentration, 1% energy source concentration, 1% inoculum concentration, and pH 1.5. Solid concentration emerged as the most influential parameter, followed by pH. Regular monitoring and adjustment of pH can effectively prevent the formation of jarosite and enhance the bioleaching yield.

According to statistical analysis the joint optimum condition for recovery of Y, Ce, Nd, Li, Co, Cu, Zn Mn and Al from BOS dust was defined as 1% solid concentration, 1% energy source concentration, 1% inoculum concentration, and pH 1.75.

More study and controlled environment are needed to use percolation method as industrial application. As a scale-up alternative, at this stage, stirred tank reactor can be suggested for an industrial application of bioleaching for BOS dust. More study is needed to recover metals from the leachate.

6.2 Chemical leaching

The study investigated the efficiency of solvents to extract metals, with an emphasis on critical metals; Fe, Cu, Zn, Pb, Li, Al, Cr, Mn, Co, Ni, and Cd, from BOS. Green solvents have been developed to be a more environmentally friendly (biodegradable, recyclable, non-corrosive etc.,) alternative to petrochemical solvents. Two types of “green” solvents were tested – deep eutectic solvents (DES) and Chelating agents (CA).

Ethylenediaminetetraacetic acid (EDTA) was used as a control for conventional hydrometallurgical practices, but these solvents are considered unsustainable and not environmentally friendly.

In the BOS dust batch study the highest total metal extracted using DES was between 47% and 57.7%. The results from this batch study conform to previous studies and suggest that DES will prove to be a more effective solvent for metal extraction whilst being more sustainable than conventional EDTA solvents.

In column tests the highest total metal extraction was; Fe, (89.46%) > Pb (64.07%) > Cu (62.85%) > Cr (60.68%) > Li (49.19%) > Co (46.47%) > Ni (42.43%) > Cd (39.63%) > Zn (38.72%) > Al (18.49%) > Mn (16.39%). It can be noted that Fe, Cu and Li extraction is improved through dynamic rather than static leaching. For Fe this was up to 100% improvement.

Different solvents have been shown to perform differently for different target elements. The results from these static and dynamic studies have been used to develop an initial criterion for green solvent selection. It has been suggested that a sequential approach where different solvents are applied in order needs to be used for the most effective elemental extraction.

Full details of the pyrometallurgical work are presented in reports:

- D. T2.2.1. Report on lab scale test (<25 kg) undertaken for metal extraction on samples from 3 sites
- Del. I1.2.2. Site specific report on traditional pre-sampling and post-sampling investigations