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Assessment of the Environmental Impact of Residual and Critical Elements in Steel:Removal, Recovery and Substitution

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Background

Significantly increasing the use of steel scrap in steel production has become a strategic decision for the UK steel industry as part of the move towards decarbonization and the pivot from BOS to EAF steelmaking. The decision is also partly motivated by the current over supply of steel scrap and by projected growth in quantity over the next decade. But there are a number of challenges associated with this approach. Impurities in scrap (residuals) can strongly influence the processing and properties of products. Understanding of the behavior of critical elements in steelmaking operations has increased, but there are still key questions to be answered. There are mechanisms for removal or recovery of these residuals, but the environmental impact of these is uncertain. Strategies for improved scrap efficiency exist but again, quantifying the potential environmental benefits of these strategies is required to assess the overall impact. In addition to these challenges, there exist a number of related issues that involve BOS steelmaking operations too. These involve recovery of expensive elements from steelmaking slag for example, and the environmental impact of strategies for retaining critical elements in the loop, rather than losing them.

Figure 1: Electric Arc Furnace at Liberty Steel [1].

Figure 2: Basic Oxygen Steel furnace at TATA Steel [2].

Research Questions to be Answered

The work planned in this project aims to provide answers to the following research questions

1. What is the material and environmental impact of potential strategies for recovery of critical elements from steelmaking by-products?
2. By changing the way in which we sort and use scrap metal, can we improve the efficiency of the EAF process and at the same time improve the quality of the liquid steel product? Can we use environmental assessment techniques to increase the amount of scrap that we use?
3. What techniques can we use to analyse plant and operational data to calculate the material and resource efficiency of EAF steelmaking operations?

Work Package 1: Assessment of Zinc Recovery Methods

- Seven total methods were assessed: four pyrometallurgical and three hydrometallurgical.
- Criteria of capacity, cost, and effectiveness, with environmental to be assessed using LCA at a later stage.
- Capacity: Hydro methods are generally far below pyro capacity.
- Cost: Hydro methods have significantly lower cost, ESRF and Waelz have additional maintenance costs.
- Effectiveness: Hydro methods involve 80 - 100% leaching, pyro methods usually around 50 - 65%.

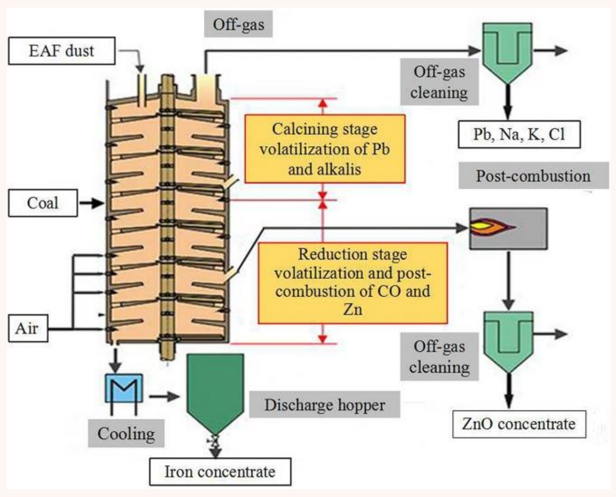

Figure 3: Flow diagram of a PRIMUS process [3].

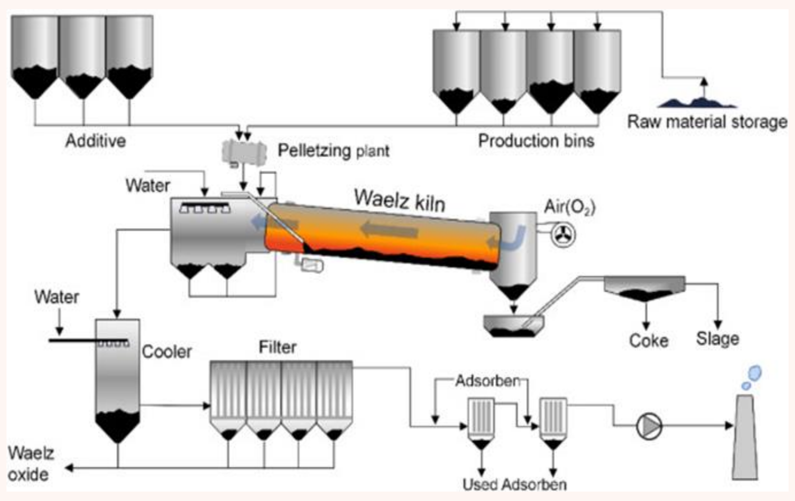

Figure 4: Flow diagram of a Waelz Rotary Kiln process [4].

Table 1: Ranking of assessed removal methods. Methods ranked 1-5 with 5 being the best.

	Method	Capacity	Cost	Effectiveness	Total
Pyrometallurgic	ESRF	4	1	3	8
	PRIMUS	4	2	1	7
	RHF	5	2	1	8
	Waelz	5	1	2	8
Hydrometallurgic	Hydrochloric	1	5	5	11
	Sulphuric	1	4	3	8
	Nitric	1	3	4	8

Conclusion

The hydrometallurgical hydrochloric acid leaching method was given the best score; however, it is severely limited in industrial application by its low capacity. Environmental impact still needs to be considered which will be done using LCA in the near future.

Figure 5: Scrap sorting pile at Liberty Steel [5].

Future Work

- Recovery of Critical Elements: Assess the feasibility of potential processes for recovery from steelmaking by-products of elements that have been identified by the EU as critical (tin, manganese, chromium, vanadium).
- Scrap Optimisation: Assess the environmental impact of the more promising scrap sorting and segregation options, and calculate the potential environmental and economic benefits
- Material and Resource Efficiency: To quantify the material and process efficiency of Liberty Steel electric arc furnace operations by analysing yield and alloy additions over time.

This project was carried out in collaboration with SUSTAIN Steel

[1] https://libertysteelgroup.com/divisions/

[2] https://dat.co.uk/courses/tata-steel-bos-plant-charger-crane/

[3] X. Lin, Z. Peng, J. Yan, et al., "Pyrometallurgical recycling of electric arc furnace dust," Journal of Cleaner Production, vol. 149, pp. 1079–1100, 2017

[4] J. Wang, Y. Zhang, K. Cui, et al., "Pyrometallurgical recovery of zinc and valuable metals from electric arc furnace dust – a review," Journal of Cleaner Production, vol. 298, p. 126 788, 2021.

[5] https://libertysteelgroup.com/uk/greensteel/