Sustainability Assessment of Niobium-based Batteries

Biodiversity Analysis and Life Cycle Assessment of Niobium-based Batteries

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1. Abstract

Batteries are a key driver in the transition towards more a more sustainable future by supporting renewable energy integration. The increasing demand for batteries has put pressure on critical raw materials such as lithium, cobalt, and nickel. As a result, alternative chemistries are being explored where niobium has been identified to play a key role in the development of the next generation of batteries.

This study aims to quantify the environmental impacts associated with niobium-based batteries focussing on the upstream stages of production and specifically homing in on the mining aspects. This has been achieved through:

- A biodiversity analysis of the Geographic Information System (GIS) data of a niobium mine. The results show that the location of the mine can be considered a biodiversity hotspot.
- A cradle-to-gate life cycle assessment (LCA) of the production of high-purity niobium oxide for use in batteries. The results show that the processing procedure to achieve high-purity has the largest environmental impact.

2. Study Area

Niobium is mostly sourced from pyrochlore ore. The Araxá Mine in Brazil, operated by Companhia Brasileira de Metalurgia e Mineração (CBMM), was purposely selected as the study area because it has been proven to have the largest niobium reserve in the world with an estimated pyrochlore reserve of 450 Mt [1] and is responsible for ~80% of global niobium production [2]. The location of the mine is illustrated in Figure 1.

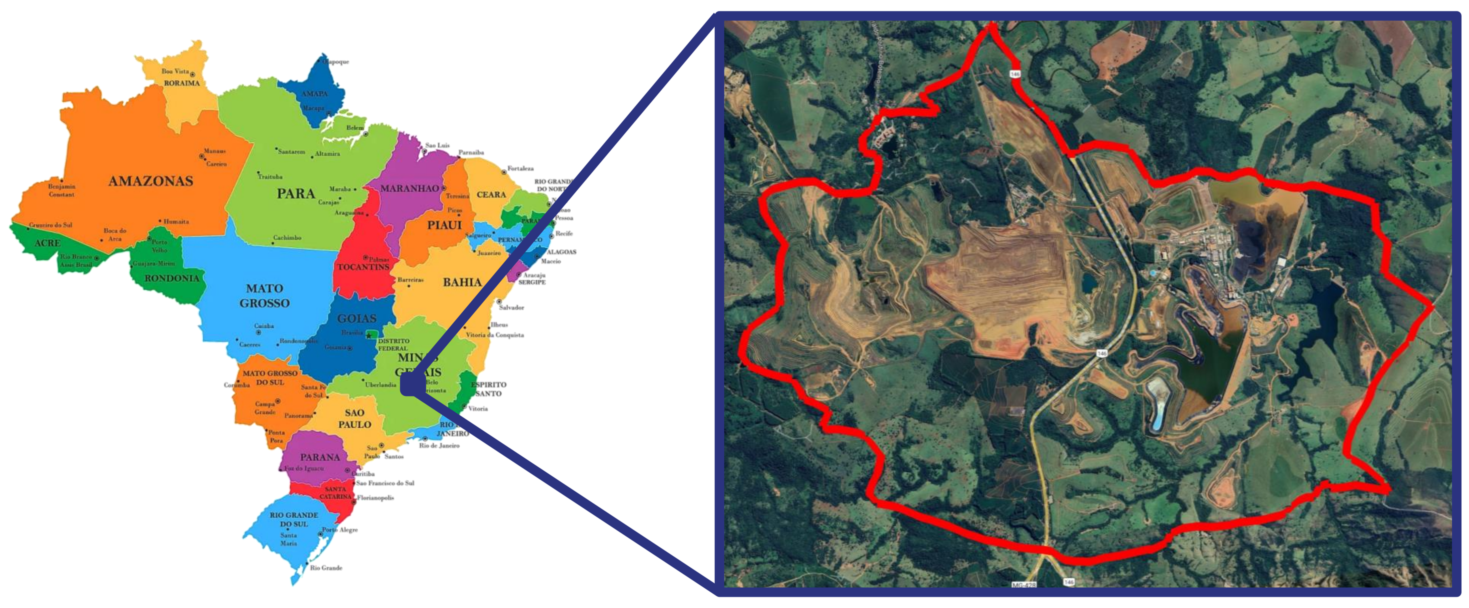

Figure 1:The location of the Araxá Mine.

3.1 Biodiversity Analysis Methodology

The *Global Terrestrial Species Richness and Rarity* dataset produced in collaboration with the Half-Earth Project was utilised for the biodiversity analysis [3]. This dataset sections the global map into grid cells of approximately 27.75 km x 27.75 km and assigns each cell a value expressed as a percentile rank values from 1 (low) to 100 (high) for its species richness and rarity, respectively. Species richness is the total number of species in that area and species rarity is based on the number of species found only in that area.

Previous work has shown that direct and indirect mining impacts can additionally extend by 50 km beyond the mine boundary [4]. Therefore, a 2-cell buffer around the location of the mine, roughly covering 19,400 km^2, is a conservative estimate for the analysis.

3.2 Life Cycle Assessment Methodology

Goal definition	Mean
Research goal	Cradle-to-gate life cycle assessment of high-purity niobium oxide for battery application
Scope	From raw material extraction to niobium oxide production
Functional unit	1 kg of high-purity niobium oxide
Database	Ecoinvent 3.6 in openLCA
Impact assessment method	ReCiPe Midpoint (H)

Table 1: A summary of the methods and materials used for the LCA.

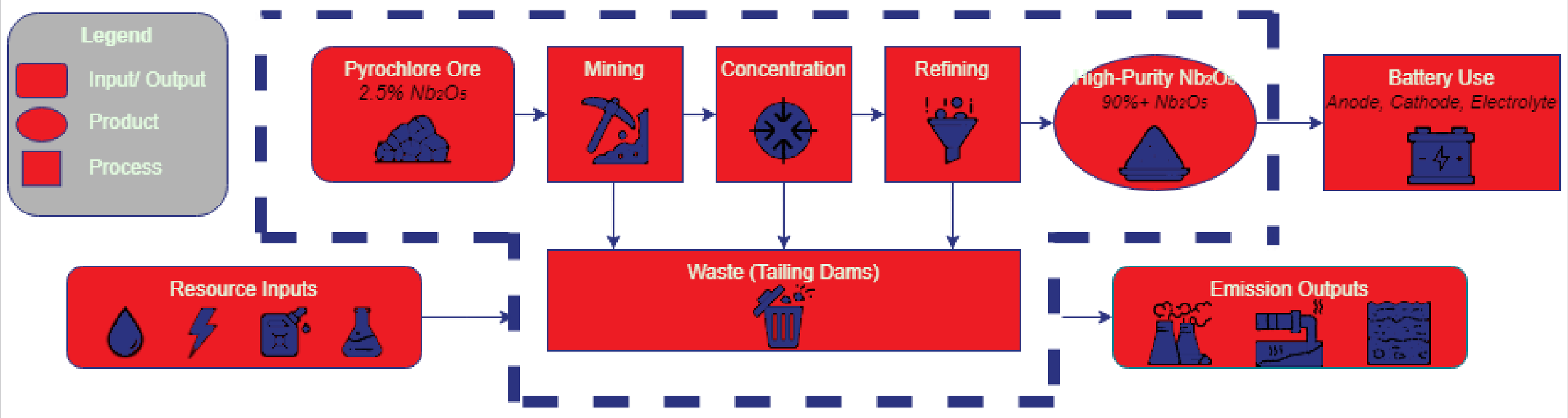

Figure 2: The system boundary for the LCA.

4. Results

The biodiversity dataset was manipulated and visualised using ArcGIS Pro and its results for species richness and rarity are illustrated in Figure 3a and 3b, respectively. A statistical calculation of the values for species richness and rarity for the 25 cells investigated in this study within the surrounding region of the mine is completed and is presented in Table 2. The key takeaways are:

- The combination of both metrics showing relatively high mean values indicate that the mine's location is a biodiversity hotspot.
- The higher mean and lower standard of deviation of species richness indicates that it is the more critical metric for the consideration of biodiversity impact for this specific mining location.

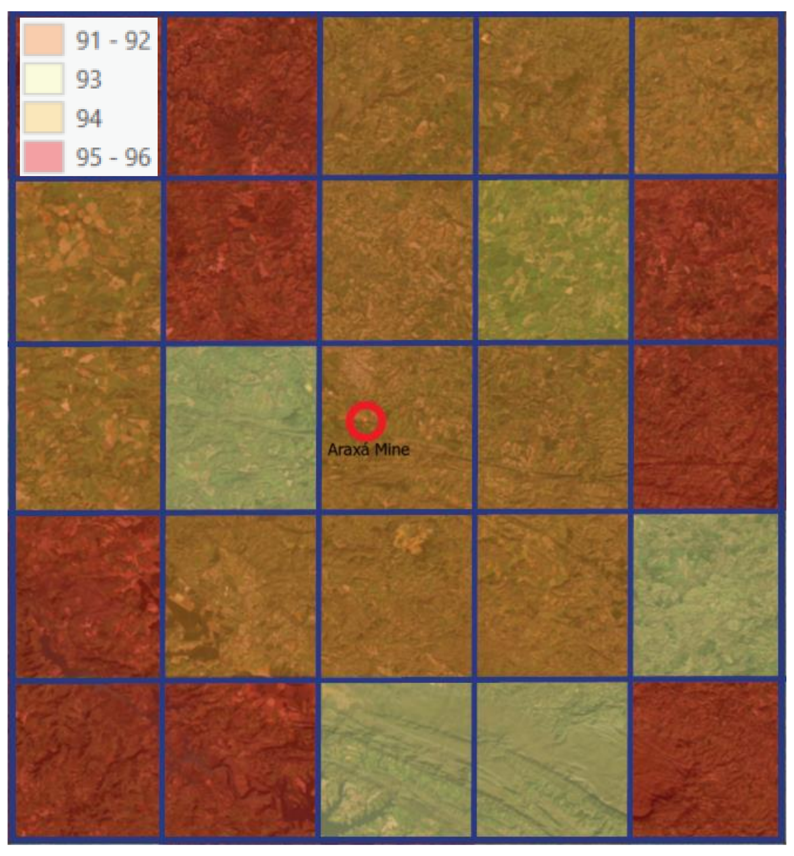

Figure 3a: Species richness values

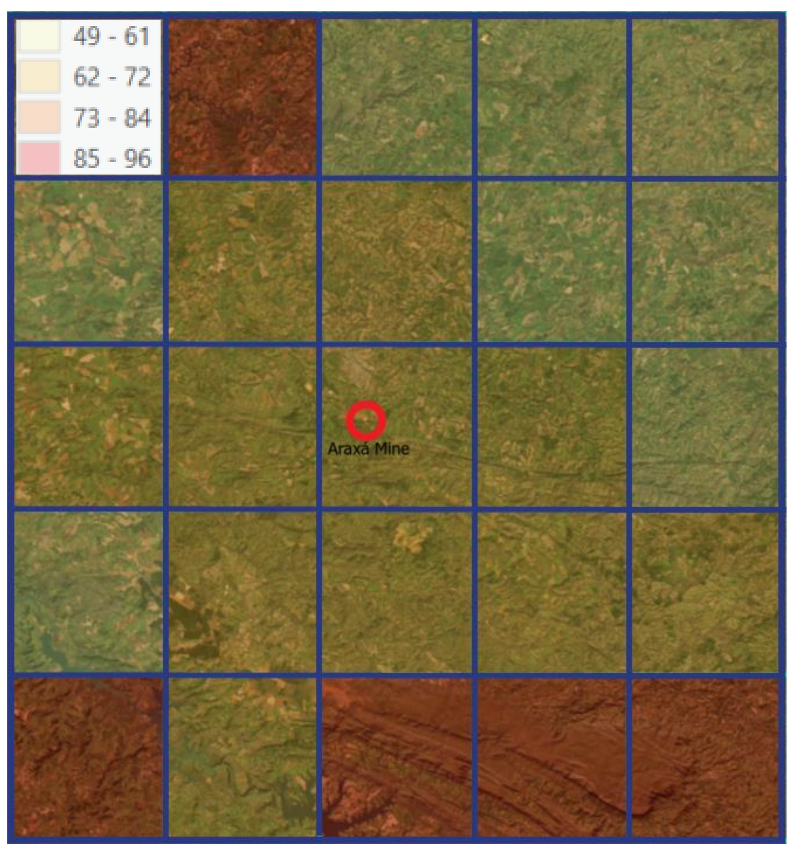

Figure 3b: Species rarity values

Metric	Mean	Standard Deviation
Species richness	93.4	1.7
Species rarity	67.3	13.8

Table 2: The means and standard deviations for species richness and rarity.

The results of the LCA are illustrated in Figure 4. The key results show that for all 4 main environmental metrics, the niobium oxide processing procedure to achieve high-purity has the largest impact, followed by fuel usage.

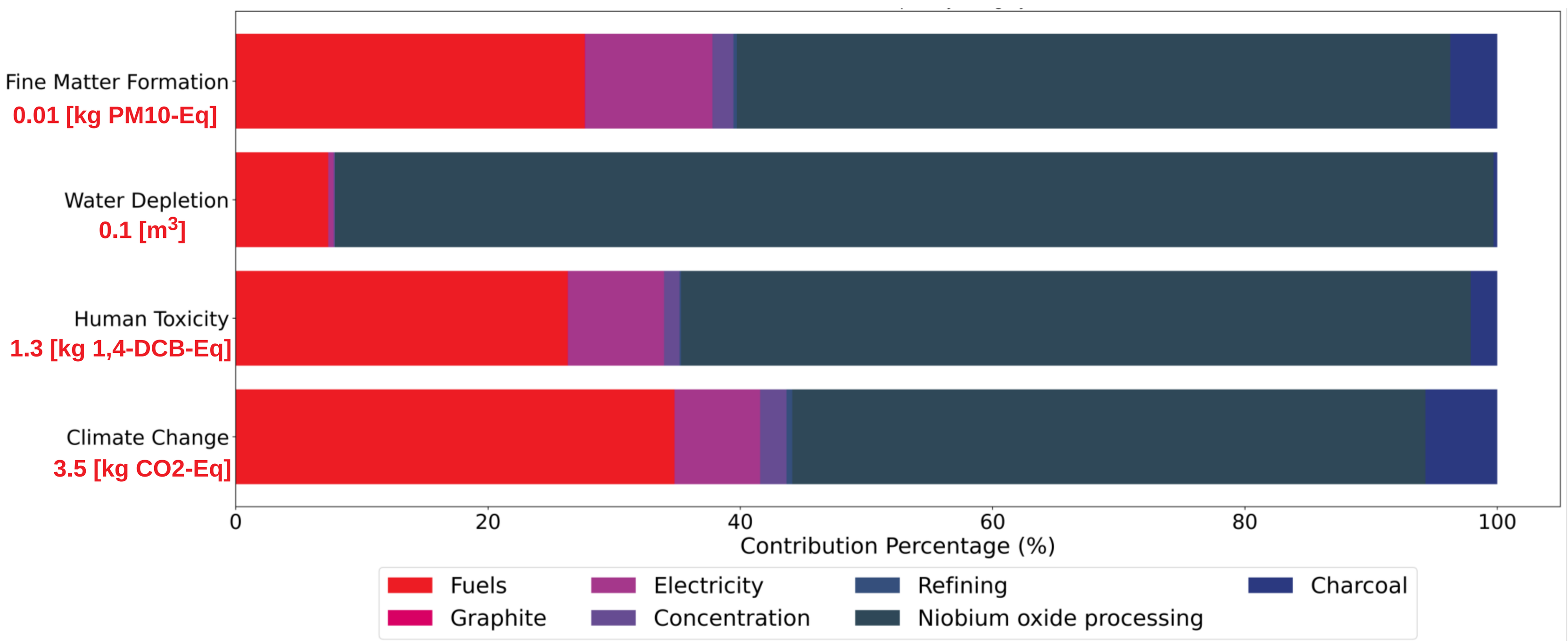

Figure 4: The contribution for each process in the production of high-purity niobium oxide for the 4 main environmental impacts with the total values in red on the left.

5. Next Steps

- Further research to understand the specific species and ecosystems present in the mining area to more comprehensively assess the potential threats.
- Analysis of additional niobium mines which will have varying location and processes and will allow for interesting comparisons.
- Expansion of the system boundary to include the downstream processes to capture a more holistic assessment, e.g., niobium anode production.

References

- [1] U.S. Geological Survey, 2023, Mineral commodity summaries 2023, 210 p., https://doi.org/10.3133/mcs2023.
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- [4] Sonter, L.J., Dade, M.C., Watson, J.E.M. et al. Renewable energy production will exacerbate mining threats to biodiversity. Nat Commun 11, 4174 (2020). https://doi.org/10.1038/s41467-020-17928-5

Intern Bio

Elian is a penultimate year MEng Engineering Design student at the University of Bristol. He is interested in how low carbon energy systems can pave the way to a more sustainable future and has previous experience in the offshore wind and pumped hydro storage industries. Outside of work and studies, he enjoys playing football and cycling.

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