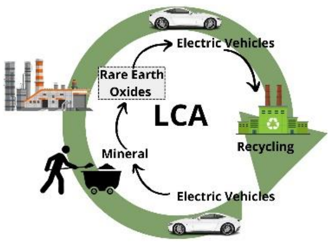
Environmental Impacts of Rare Earth Oxide Production: Considering Energy Consumption and Global Warming Potential	POSTER Ph.D. Student: N Journal: Journal of Environmental Chemical Engineering

L. M. S. Colpini[1,2], *T. Prados*[2], *I. Campos*[3], *S. Cotrim*[3], *F. Lima*[4], *G. Lovón-Canchumani*[1] *(1) Federal University of Parana (UFPR), Campus Avançado Jandaia do Sul, Jandaia do Sul, Brazil, ledasaracol@ufpr.br (2) Federal University of Parana (UFPR), Setor Palotina, Palotina, Brazil (3) State University of Maringa (UEM), Maringá, Brazil (4) Centro de Tecnologia Mineral (CETEM) Rio de Janeiro, Brazil.*



This study evaluates the environmental impacts of rare earth oxide (REO) production, which are crucial for green technologies. The methodology used is Life Cycle Assessment (LCA), focusing on energy consumption and global warming potential, applying IPCC and ReCiPe methods. Among the results obtained, it was shown that the total equivalent CO_2 was 73.8 kilograms, considering a functional unit of 4 kilograms in REO production. It is concluded that a comprehensive understanding of environmental impacts is essential to guide future production practices and sustainability policies.

Introduction

Rare earth elements (REE) comprise 17 chemical [1, 2] elements and are widely used in various applications, particularly green energy technologies such as wind turbines and electric vehicles [3, 4]. REEs act as technology enablers for emission reduction, energy, and performance enhancement, speed, and efficiency improvement [5].

China holds the largest reserves of rare earth minerals [6]. However, the extraction process consumes a lot of energy and produces large amounts of waste [7]. REEs are considered critical materials due to their high demand and the difficulty of their exploitation; a promising alternative is recycling from waste [8]. For a sustainable future, it is essential to implement methods that promote circular economy (CE) and LCA techniques [9]. Additionally, a disadvantage of REE extraction is the radioactive material found in rare earth sources, which can contaminate soil and water sources. In the refining process REE, there is also the generation of greenhouse gases (GHGs), and the chemicals used can cause respiratory problems and cutaneous and occupational poisoning of residents [10, 11]. The production of REOs also results in the emission of exhaust gases, acidic wastewater, and the production of radioactive waste [12].

The objective of this article is to evaluate the environmental impacts of REO production, considering energy consumption and global warming potential. The LCA methodology was used as a tool to assess environmental impacts, to support other LCA studies and CE models.

Material and Methods

LCA is based on ISO 14040 (2006) and ISO 14044 (2006) [13, 14] standards, involving a series of steps for its execution [15]. For the analysis, modeling of the production system in Brazil was performed, and to aid in the calculation of environmental impacts, SimaPro 9.5 software, ecoinvent 3.9.1 database, and method IPCC GWP 100 (Global Warming Potential from the Intergovernmental Panel on Climate Change for 100 years) and ReCiPe Midpoint H ,which is a combination of methods and originates from the Netherlands, was developed in collaboration between RIVM, Radboud University, CML, and Pré-consultants [16, 17], along with data gathered from the literature.

Based on LCA, the extraction of REOs and their production impacts were considered to obtain results on energy consumption and GWP.

Results and Discussion

Scope Definition

To perform the life cycle inventory analysis (LCIA), the inputs and outputs of materials for production were calculated, as well as the energy consumption required for the transformation of REE into REO, allowing for the classification of different categories of environmental impacts resulting from this process. The functional unit defined for the article is 4 kg of REO, comprising neodymium, praseodymium, cerium, and lanthanum oxides, and 2 kg as a byproduct from a medium and heavy fraction. The system boundary, considered "gate to gate" with access to the inventory and base articles, enabled the comparison of information generated with system modeling.

Life Cycle Inventory Analysis (LCIA)

As a result of this article, figures were generated representing the inputs used in the production of REO and the categories that generate the most environmental impacts. In the figures, the y-axis is normalized to 100%, and the x-axis corresponds to impact categories based on the selected methods.

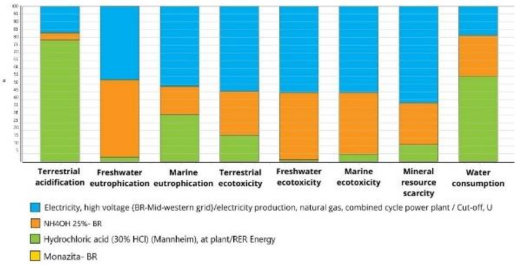


Figure 1. Categories analyzed using the ReCiPe method

According to Figure 1, the predominant colors blue, orange, and green correspond to high energy consumption, ammonium hydroxide (NH_4OH), and hydrochloric acid respectively. The soil acidification impact category is the most affected by high hydrochloric acid consumption at 78.3%, while NH_4OH causes greater damage in the freshwater eutrophication category at 49.8%, and energy consumption, despite generating significant impacts in all categories, is most prominent in mineral resource depletion at 62.3%.

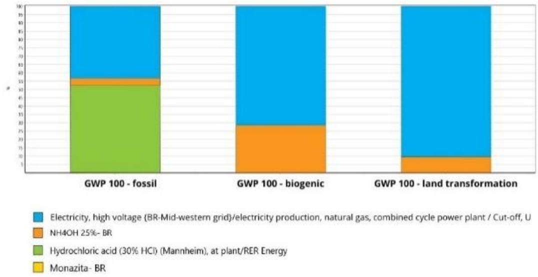


Figure 2. Categories analyzed using the IPCC method

Figure 2 shows the damages caused by CO_2 emissions. It is possible to observe that energy, highlighted in blue, generates the greatest damage in the three considered categories. However, in the land transformation category, it has the highest impact, representing 90.4% of the Global Warming Potential (GWP). Hydrochloric acid stands out as a major pollutant in the fossil category, highlighted in green with 52.4% of the GWP. Meanwhile, NH_4OH, represented by the orange color, although also impacting all three considered categories, is more prominent in the biogenic category with 28.5% of the GWP. Considering the total REO process, it was evidenced that the total equivalent CO_2 was 73.8 kg, considering the functional unit of 4 kg.

Conclusions

The article investigated the environmental effects of rare earth oxides production using an inventory analysis. It underscored the importance of sustainable development and responsible utilization of these resources, given their relevance in green energy technologies and mining. The results show that energy consumption was the input that contributed most to impacts in three categories: fossil, biogenic, and land transformation, considering Global Warming Potential. However, under the ReCiPe methodology, the categories most affected by electricity were mineral resource scarcity, terrestrial ecotoxicity, and freshwater ecotoxicity. Considering these highlighted categories, priority should be given to seeking improvements such as energy consumption that causes fewer environmental impacts. Based on the data from LCA results, implementation of a circular economy is suggested as a model that emphasizes the recycling of rare earth elements. Thus, there is a gap in studies addressing environmental impact assessment methods and energy efficiency indicators, with life cycle assessment suggested for future studies.

Acknowledgments

The authors would like to thank Fundação Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and Ministério da Ciência, Tecnologia e Inovação (MCTI) for its financial support during this study.

References

[1] A. Masmoudi-Soussi, I. Hammas-Nasri, K. Horchani-Naifer, M. Férid, Hydrometallurgy, 191 (2020) 105253.
[2] J. Mentira, J. Liu, Journal Environmental Chemical Engineer, 9 (2021) 106084.
[3] A. Schreiber, J. Marx, P. Zapp, Science of The Total Environment, 791 (2021) 148257.
[4] Z. Liu, J. He, Q. Zhou, Y. Huang, Q. Jiang, Journal of Materials Science & Technology, 98, (2022), 51.
[5] K. T. Rim, K. H. Koo, P. J. Sun, Safety and Health at Work 4 (2013) 12.
[6] M. Ekkert. The International Renewable Energy Agency (IRENA), 2018.
[7] N. M. Ippolito, A. Amato, V. Innocenzi, F. Ferella, S. Zueva, F. Beolchini, F. Vegliò, Journal of Environmental Chemical Engineering 10 (2022) 107064.
[8] M. Gómez, P. Grimes, D. Bin-Jamaludin, G. Fowler, Journal of Environmental Chemical Engineering 11 (2023) 111001.
[9] D. E. A. Momani, Z. Ansari, M. Ouda, M. Abujayyab, M. Kareem, T. Agba, B. Sizirici, Journal of Water Process Engineering 55 (2023) 104223.
[10] W. D. Juiz, G. Azimi, Hydrometallurgy 196 (2020) 105435.
[11] W. Gwenzi, L. Mangori, C. Danha, N. Chaukura, N. Dunjana, E. Sanganyado, Science of The Total Environment 636 (2018) 299.
[12] H. Royen, U. Fortkamp, IVL Svenska Milj¨oinstitutet, 2016.
[13] ISO, 14040, (2006). Environmental Management- Life Cycle Assessment- Principles and Framework.
[14] ISO, 14044,(2006), Environmental management - Life cycle assessment- Requirements and guidelines.
[15] E. VAHIDI, J. Navarro, F. Zhao, Resources, Conservation and Recycling 113 (2016) 1.
[16] N. C. Mendes, C. Bueno, A. R. Ometto, Production, 26 (2015) 160.
[17] M. J. GOEDKOOP, R. HEIJUNGS, M. A. Huijbregts, A. D. Schryver, ReCiPe 2008 (2009).