Bauxite Residue Deposit Reclamation – a Pathway to Reintegration

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Abstract

The remediation of areas impacted by industrial operations has been challenging for the bauxite processing industry, particularly regarding the residue storage facility areas. Understanding the social and environmental impacts are some of the most relevant stages for closure planning. Hydro Alunorte, the Norsk Hydro refinery plant in the north of Brazil, has operated since the '90s with Solid Residue Deposits 1 (DRS1). The deposit is a dry stacking bauxite residue storage facility, constructed with multi-staged expansions, with a total area of approximately 270 ha, operated for over 20 years based on drum filter disposal. In line with Hydro's ambition, Alunorte set the goal to progressively close the oldest deposit and promote the disposal area rehabilitation. The uncertainties regarding the success of all facets of a cover system associated with the lack of natural resources are undoubtedly some of the challenges to closure designs of bauxite residue deposits. This paper presents the different concepts tested on experimental areas focusing on the DRS1 closure design in terms of elimination of contact run-off, control of fugitive dust, improved visual aspect, and reintegration with native and adjacent bush areas. The tests assessed geotechnical, physic-chemical, and biological progress regarding soil regeneration, surface and subsurface drainage water quality, vegetation growth and mortality, displacements, constructive pore water pressure, and micro and mesofauna restoration. The monitoring data collected from experimental areas provided the layout with more excellent results based on the key performance indicators and determined the design of the progressively closed stripes. Furthermore, the paper will discuss the large-scale progressive closure performance. The author intends to provide guidelines and general practices for the reclamation of bauxite residue facilities.

Keywords: Filtered bauxite residue deposit, Bauxite residue disposal area reclamation.

1. Introduction

The closure and rehabilitation of a tailings facility is of great importance for mining companies. Implementing a successful disposal area reclamation depends on aspects such as the local environment, climate conditions, chemical nature of the tailings, and the post-closure land use and its integration with local communities.

DRS1, the bauxite residue disposal area of Hydro Alunorte, started its operation in 1995 and comprehends an area of approximately 270 ha in its current configuration. The refinery generates annually over 4.2 Mt of bauxite residue, deposited in the two bauxite residue areas, DRS1 and DRS2. The press filter plant, in operation since 2016, and the progressive deposit rehabilitation, which started in 2018, are some of the practices Hydro Alunorte has implemented to ensure safer and more sustainable operation. Hydro Alunorte intends to reduce operational impacts by

controlling fugitive dust, eliminating wastewater generation, improving the visual impact on the local community, and reintegrating the disposal area with adjacent vegetated areas.

The progressive rehabilitation is expected to be implemented within 15 years and will be done in stripes. It includes constructing and monitoring an experimental area to evaluate the most suitable options for cover layering and capping of the residue, considering the local constraints. The deposit area requires encapsulation on closure as it is designed to store a highly alkaline and saline, low plasticity silt without neutralization. The rehabilitation process generally involves reshaping the residue surface to establish a geometrically shaped configuration, lined and covered with a store-and-release vegetative cover required for plant growth. The underlying bauxite residue is isolated from receiving net percolation to reduce underflow generation. Typically, the liner consists of high-density polypropylene (HDPE) and densified soil. The impermeabilization is also fundamental to isolating the capillarity, avoiding the contamination with rising salts with high alkalinity from the residue, and possibly affecting the root zone [1]. On the other hand, capping the bauxite residue surface avoids the contamination of store-and-release cover, maintaining the subsurface water and soil quality to plant growth.

Despite the absence of a methodology considered definitive for remediation of deposits of this nature, capping systems are considered the safest and fastest method for vegetation cover and environmental impact mitigation [2].

The typical approaches employed to residue management are “cap and store” or “*in-situ* remediation” [2]. Generally, *in-situ* remediation consists of adding amendments (organic or inorganic) to bauxite residue to change the critical physical and chemical properties. Nonetheless, the feasibility of this method usually regards the availability of amendments at reasonable costs [1]. The objective of this solution is to provide natural conditions where the substrate is capable of sustaining vegetation growth. Strategies to decrease pH, salinity, decreasing bulk density and enhancing aggregation have been studied, especially involving the application of gypsum combined with organic amendments [3]. The application of microbial as a bioremediation strategy has also been studied [4]. On the other hand, the “cap and store” solutions isolate the residue with mechanisms to significantly reduce the net percolation through the cover system. So, a low permeability layer of high-density polyethylene liner or compacted clay is applied, followed by a composite system with soil and drainage elements to collect and transport infiltration to the cover. This solution avoids the infiltration owing to rainfall reaching the bauxite residue, reducing the contact wastewater generation at lower rates and the risk of contamination of surrounding areas. The result of a successful “cap and store” solution is residue isolation, so it is expected that the water quality is adequate to return to the environment under legal requirements. Furthermore, the cost of implementing the rehabilitation is crucial since applying liners associated with a multi-layered cover system in a “capping and store” solution must be compared to the costs of *in-situ* remediations, where the amendments availability may significantly impact the implementation costs [2]. The estimate of closure costs forms part of the Global Industry Standard on Tailings Management, which states that the cost for closure, reclamation and post-closure of the tailings facility shall be reviewed and publicly disclosed periodically to confirm adequate financial capacity.

Addressing the high alkalinity and salinity of dust and leached bauxite residue are some of the major challenges in reducing environmental risks in closure projects. The success of different reclamation alternatives, such as capping and *in-situ* remediation of bauxite residue, was assessed in tests involving the experimental area within the Hydro Alunorte bauxite residue disposal area [2]. The author monitored the experimental areas with eight sites of 1 500 m², constructed in April 2019 inside the deposit area, and provided valuable natural regeneration monitoring, plant mortality, and wastewater quality parameters of run-off and subsurface drainage water.

Figure 10. General View – DRS1 Reclamation, Hydro Alunorte.

5. Final Considerations

This paper described the rehabilitation method employed by Hydro Alunorte on DRS1 closure. Up to date, over 30 ha were rehabilitated, with approximately 26 000 seedlings planted, 79 immigrant plants, and 23 fauna species reintegrated into the rehabilitation area.

Based on water analysis, dissolved iron and aluminium reached peak values in October 2021, possibly due to external interferences. Nonetheless, the subsurface water showed consistently higher values of dissolved aluminium when compared to surface water, which might be related to soil origin. The pH results demonstrate compliance with the CONAMA 430 limit value of pH < 9 for the 12 months of monitoring for all samples from surface run-off and subsurface. The CONAMA 430 legislation was also complied with dissolved iron during the 12 months monitoring.

Hydro Alunorte shall monitor the reclamation progress to confirm the excellent rehabilitation performance while progressing the closure of the bauxite residue disposal area DRS1. The results collected to date clearly show the potential of DRS1 reintegration into the local area.

6. References

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