Approaches to Bauxite Residue Legacy Issues in Jamaica

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Abstract

Whilst only a small island developing state, Jamaica has been producing alumina for over 60 years. Within this history, several manifestations of legacy issues for the bauxite and alumina industry have developed – each location with its own attendant administrative and regulatory frameworks. The variation in the bauxite residue (or red mud) disposal practices and site-specific geology/hydrology and environmental conditions as well as historic practices, results in varied potentials for environmental impacts, primarily on water and air quality. The proximity of communities to the operations adds another dimension to the long term impacts of exposure to a degraded environment. The development of closure plans with the specific objective of minimizing environmental risks is not straightforward – and must include engineering considerations, geotechnical factors and achievable objectives of environmental management. The development of closure objectives in Jamaica has capitalized on ecological indicators that point to geochemical characteristics and biodiversity.

Keywords: bauxite residue (red mud) disposal, remediation, ground water impacts, land issues, ecological indicators.

1. Background

Jamaica is the third largest island in the Caribbean, bauxite is a key natural resource and it has been mined and processed for over 60 years. The bauxite industry in Jamaica spans several parishes, relocating ore to a number of refineries for processing. The existence of bauxite in Jamaica had been known for many years and studies by British Government geologists, J. G. Sawkins and C. B. Brown, reported in the 1860s on the presence of large quantities of red earth, terra rossa, rich in alumina and iron from St Ann and St Elizabeth [1].

The bauxite bearing lands occur in the central parishes of the island – St. Ann, Trelawny, Manchester, St. Elizabeth, Clarendon and St. Catherine, and present as valley and plateau deposits (see Figure 1 below). The ore, which is typically developed in karst depressions, can be easily mined from these depressions as they are surface deposits accessed after the removal of 30 to 40 cm of topsoil.

Jamaican bauxite composition is typically a mineral assemblage of oxides of aluminium, iron, titanium and silicon. It is mainly gibbsitic but some amount of boehmite is also present. The Jamaican bauxites tend to be very fine grained unconsolidated material with high free moisture, and a total alumina content typically <45% [2]. Present information reported to the JBI puts total alumina averages at 41%. Another constraint on the bauxite ore quality is the percentage of reactive silica – for the Jamaican refineries, less than 2% is desired as this would otherwise drive up the quantities of caustic soda required.

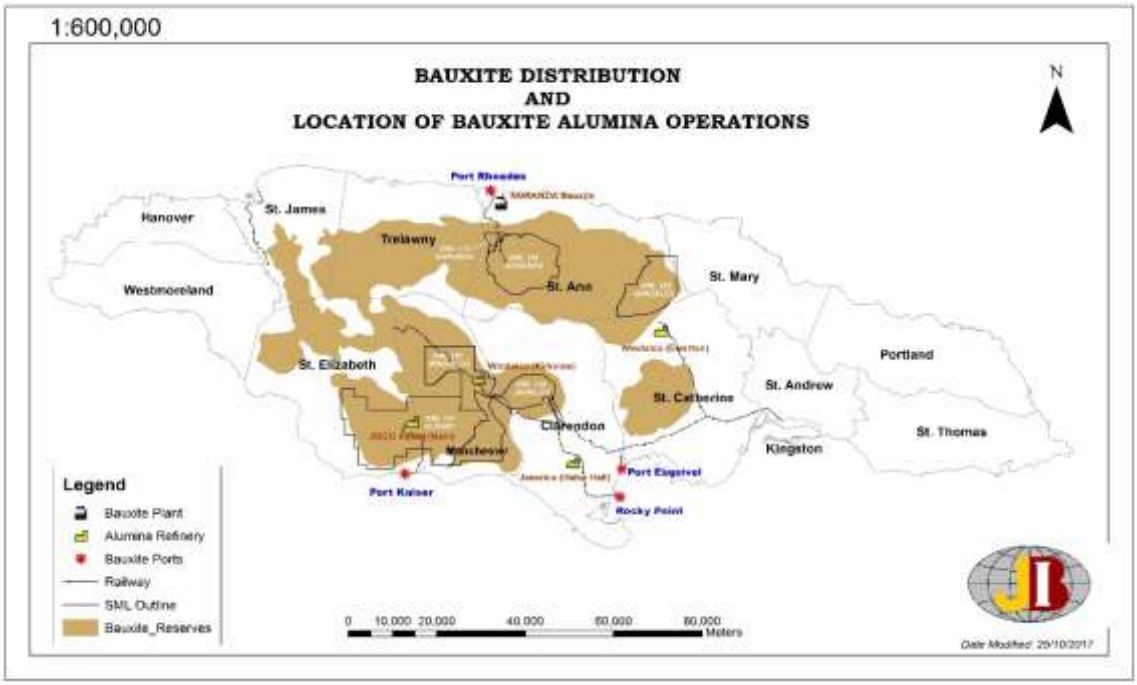

Figure 1. Map of Jamaica showing generalized bauxite reserves areas and associated infrastructure – Processing Plants, Ports in the middle parishes of the island. Source: The JBI Cartography Unit, 2017

The ore is removed from the bauxite deposits and brought to the processing plants for refining to alumina. The large volumes of ore in turn produce similar volumes of bauxite residue (or red mud) waste. The first alumina processing plant was constructed by Alcan in 1952 at Kirkvine, Manchester. Alcan constructed a second plant at Ewarton in 1959 (due to changes in ownership in 2001, these locations are indicated as Windalco (Kirkvine) and Windalco (Ewarton) in Figure 1, above). Additional Bayer plants were added – one at Nain, St. Elizabeth in 1969, a high temperature plant that operated under the name of Alpart, with original owners Kaiser, Reynolds and Anaconda and present owners of JISCO, and, the youngest low-temperature facility at Halse Hall, Clarendon, originally owned by Alcoa, and partially by the Jamaican government since 1976 (through a holding company – Clarendon Alumina Production (CAP)) known as Jamalco and presently owned by Noble; CAP begun operating in 1973. A fifth site existed at Maggoty in St. Elizabeth, but little detail has been found as that location was abandoned in 1975, due to challenges associated with processing the ore at the high temperature plant owned by Revere.

The processing of bauxite through the Bayer process generates red mud (bauxite residue) as the principal waste material. At the outset, red mud was discharged to the closest mined out pits at Kirkvine and subsequently to the unsealed Battersea mud lake, a major landmark seen from the Winston Jones Highway *en route* to Mandeville, the capital of the parish of Manchester. At Ewarton, in St. Catherine, the main storage area was the Mt. Rosser mud lake until 1991, when dry stacking at the Charlemont Mud Drying and Stacking Facility was fully operational. The other major red mud disposal site in Jamaica are the South and West Lakes at Alpart and the residue storage area (RSA) comprised of five sealed cells at Jamalco.

The Jamaica Bauxite Institute (JBI) was formed in 1976 [1], a company of the government with statutory functions. The JBI would come to regulate the industry and be a critical player in the national development of environmental standards and regulations.

The companies that have operated in Jamaica have typically been foreign owned or owned by multinationals, (some would also later be joint ventures with the government of Jamaica), and as international environmental awareness increased, all companies established environmental management teams – to address design aspects, monitoring and control of emissions, land management (including community interactions and restoration after mining) and general public education campaigns [3].

Over time, the companies have generally embraced the principles outlined in the best practice management document published by the IAI in 2013 [4], however each location here has been idiosyncratic with variations in geology, mud disposal technology, depths to groundwater or characteristics of the host watershed. This creates an interesting regulatory challenge for a country with very old environmental legislation, such as the Wildlife Protection Act of 1945 and newly developed regulations that now require environmental permits [5].

Generally, for the purposes of this paper, the legacy issues of the industry are considered all longstanding and outstanding, or unresolved environmental impacts at the time of closure of the facility or location. These legacy issues include all legal obligations as well as identified potential sources of long term contamination that may be abandoned or derelict. In Jamaica, these are identified as abandoned mining areas, waste disposal sites, including several large bauxite residue disposal areas (including operational areas that will need to be closed in the future), and as a consequence of these sites, existing contaminated environments or the potential to contaminate. Both the present and future scenarios are intertwined, particularly where ground contamination due to prior disposal practices are already identified, modelled and monitored. The longstanding issues arise as a consequence of the environmental context – historical attitudes that led to bauxite residue being initially deposited on unlined (unprotected) land.

It is estimated that up to the mid-2010's, approximately 350 million tonnes of bauxite residue would have been produced in Jamaica from the said five locations distributed as indicated in Table 1, below. This figure is derived from total bauxite equivalent of alumina produced using a factor of 1:1.1, that is, 1.1 tonnes of red mud is produced for each tonne of ore processed.

Though it is quite easy to find information and data on historic milestones in production, there is little documented to outline the bauxite residue (red mud) disposal practices from the Bayer process from the 1950's to the 1980's in Jamaica.

The principal regulation for the exploitation of the bauxite ore is the Mining Act (1947), and it included the reclamation of mined out pits. The practice for 'mined out pits' was rehabilitation - returning the landscape to the state of pre-mining, which for typical bauxite pits in Jamaica, tended to be broad grasslands surrounded by dry limestone forest. A similar approach was used for the few mined out pits filled with bauxite residue close to the alumina refineries.

Table 1. Estimated red mud volumes from Jamaican processing operations.*

		Parish	Area (ha)	Volume (Millions Mt)
Kirkvine Works	Kirkvine Ponds and Battersea	Manchester	100 (+ small ponds cumulative area)	130
Ewarton Works	Mt Rosser	St. Ann/St. Catherine	35	
	Charlemont Mud Stack	St. Catherine	100	
Alpart	South/West Lake	St. Elizabeth	220	99
	North Lake	St. Elizabeth	40	
Jamalco	RSA 1-5	Clarendon	330	100
Revere		St. Elizabeth		2
Total			**625**	**320-330**

**in the absence of discharge figures (volume of mud discharged) the figure here is estimated from the bauxite equivalent alumina produced and exported, as the accepted ratio of Jamaican waste; Mud volumes rounded to nearest hundred thousand Mt (Source: JBI Economics Division, 2014)*

In addition to those certified, a number of these red-mud filled old pits were granted exemptions from rehabilitation, or closed. This would be the legacy that would have had to be addressed at the future point of sale of Alcan's assets in Jamaica in 2001.

With the absence of early regulation of mud disposal, Jamaica initially had wet mud storage with slurry concentrations of 20 – 22%. Environmental concerns of groundwater contamination were a key factor driving the development of the Alcan dry stacking process at Ewarton Works developed by Chandler [7]. As efficiency of the plants became more of a focus, thickened mud disposals were also embraced to improve recovery of caustic soda and reduce capacity needs and footprints of the disposal sites.

In this dynamic, the JBI had to assume a role for monitoring the environment. In the absence of national standards, international limits were adopted and interim standards devised with the Underground Water Authority (which would later become the Water Resources Authority). Official delegations for this function came from the Minister of Mining in the 1990's and through a Memorandum of Understanding (MOU) with the Natural Resources Conservation Authority (NRCA) in 1994 [8]. With the on-the-job experience, the JBI would then participate in (and occasionally lead) many of the standards development committees for air and water quality, and, for waste management.

In Jamaica, where people live close to most operations of this industry, the environmental impact is visible, especially where rivers are close by and hydrogeological modelling confirm impacts from disposal practices [9]. In the case of the closure of the 37 hectare mud pond at Mount Rosser, impacts were noted to the North, where water analytical results indicated very high levels of sodium, which only logically could be attributed to the caustic nature of the red mud. Once operation of the mud pond was stopped, and dry stacking and the reuse of the liquid fraction was implemented at Charlemont, closer to the plant, marked gradual reduction in sodium levels was observed (see Figure 2).

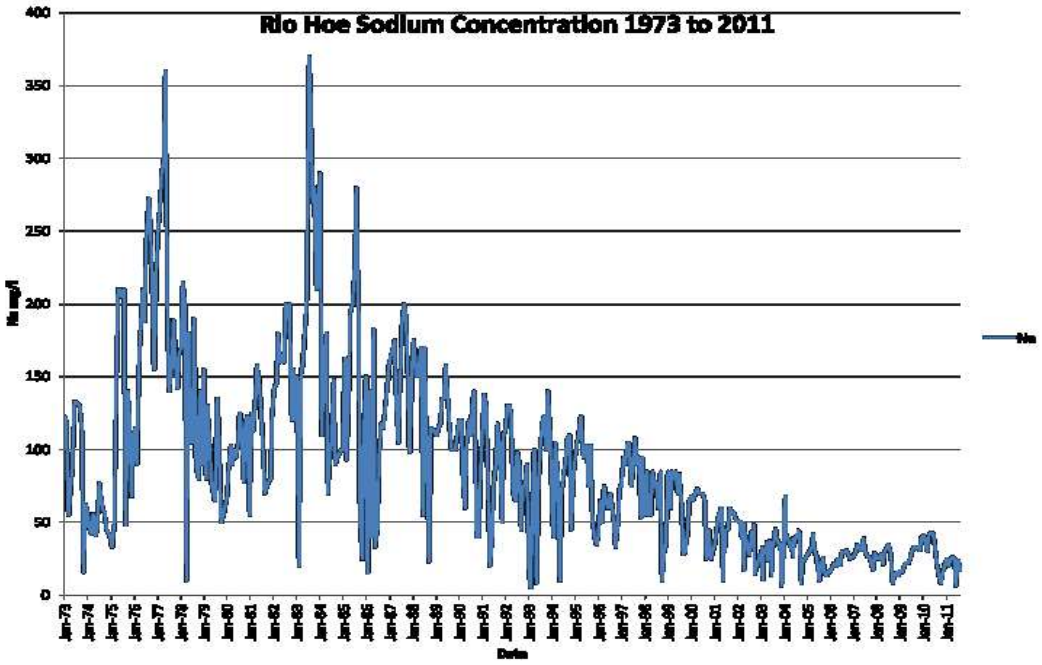

Figure 2. Graph of the Rio Hoe Sodium concentrations indicating the impacts attributed to Mt. Rosser and declining levels of sodium since discontinuation of use. Source (unpublished): Basil Fernandez, Water Resources Authority 2011

2. Closure Planning and the Regulatory Framework: Case of Mount Rosser and Kirkvine Ponds Closure Plan

The year 2001 turned out to be a watershed year in terms of environmental regulation and the industry. Without a closure plan guideline fully developed by the regulators, the sale of Alcan assets created a situation that required closure planning on bauxite residue disposal sites

In 2001, Alcan sold its bauxite mining and alumina plants in Jamaica to the Glencore Group (Glencore Alumina Jamaica Limited – operating locally as Windalco) but retained responsibility for out of use bauxite residue sites at the two locations which were filled or no longer being used - with the intention of safely remediating them and returning ownership to the Government of Jamaica (GoJ). The closure of these sites is being overseen by the JBI, a Government of Jamaica organization, with the specific mandate of overseeing the local bauxite and alumina industry.

The GoJ appointed the JBI to act on its behalf in negotiating the closure agreements with Alcan, the first set of agreements of this type for Jamaica. With respect to closure standards, at the time of the sale agreement in 2001, the NRCA had only developed draft closure plan guidelines [10], so the JBI modified these to assert an industry specific framework for the red mud ponds. It is suggested that these agreements are a good template for all the operating bauxite and alumina companies in Jamaica with the future needs to close bauxite residue storage sites.

Table 1 also illustrates that the closure of the sites belonging to Alcan represent a fraction of the total bauxite residue storage locations in Jamaica that will need eventual closure processes.

Before entering discussions on the rationale for the criteria included in the development of closure plans, it is useful to return to first principles for environmental policy. All policies relating to natural resources in general, and the environment as interactions within an ecosystem, will have foundations in using science to influence how the legal framework is designed and implemented [11].

Alcan already had some ideas on how to approach their ponds at Kirkvine, and agricultural initiatives to vegetate the mud surfaces had started. As some of the original ponds at Kirkvine were in mined out pits, Morgan [12] and O'Callahan [13] and their teams endeavoured to establish some vegetation on the red mud. Of particular relevance was the work done on Pond 6 at Kirkvine, before the Alcan sale to Windalco. Additionally, there was work done at Jamalco in Clarendon in the 1990's by Conrad Douglas and Associates, though a vegetating methodology design was not the output of that research. Internationally, there are few documents that speak to development of these ideas, but Alumar in Brazil also undertook some trials in 1996 [14]. The current method at Kirkvine is a topsoil free one, with the addition of amendments to improve soil-like characteristics and encourage the phytostabilization through planting of high-sodium tolerant species of local origin. Internationally, similar principles have been employed on trial plots by Courtney and Harrington [15] in Ireland.

Through a consultative process between JBI and Alcan, the guidelines were adapted to reflect the additional areas of concern and subsequently additional government stakeholders integrated in the agreement for the terms of the Closure Plan. These included many government agencies with different mandates and agendas for environmental quality: the NRCA; the Water Resources Authority (WRA); the Mines and Geology Division (MGD); the Commissioner of Lands (CoL); the Commissioner of Mines (CoM); the National Water Commission (NWC), and the Environmental Health Unit of the Ministry of Health (EHU-MOH).

The previously mentioned draft closure plan guidelines of NEPA essentially outlined information required for the environmental context – setting and description, nature of the waste, and proposed works. Tacit in the guidelines is the removal and/or significant reduction of environmental risk of the site, and in the finalized version of 2010 [16], named The NRCA Guideline for the Closure of Industrial Type Projects indicates the purpose as:

"a Closure Plan as *the procedures for decommissioning of a facility and the removal of all the possible contaminants to air, soil and water; equipment decontamination; sampling and laboratory analysis and closure to the satisfaction of the relevant standards and regulations stipulated by the National Environment and Planning Agency*".

It does not detail any end state criteria, other than the removal of infrastructure and contaminants. However, in the case of the bauxite residue sites, and by extension hazardous waste sites generally in Jamaica, where the waste will not be removed, there is a need for environmental criteria that includes ecosystemic considerations and safety from human trespass.

It should also be noted that on these historic waste sites, which are not covered by any legal instrument of the NRCA Act, i.e. by an environmental permit or licence, there would not have been a closure plan requirement as a specific condition for their operation. This is addressed by the 2015 amendment of the Permits and Licence Regulations, which removes the 'grandfathering clause' of the 1996 regulations. That clause had exempted from environmental permitting, existing operations and facilities that were in existence before 1996. However, modifications, upgrades and changes of operations would have been included.

In terms of development on the Alcan's closure plan [16], this was achieved by a series of multi-stakeholder consultations and document circulation to determine key criteria for the closure.
The standard that was agreed on was related to the following environmental aspects:

i. impact on the aquifer
ii. ecological – vegetation cover and biodiversity
iii. security
iv. a period of monitoring post-closure
v. environmental permits required for the discharge and the wastewater treatment plant

JBI became, in this instance, the centre of the regulatory project management undertaken. In this way, the JBI undertook the coordination of documentation, meetings and technical review for the Government of Jamaica. This continued the Institute's precedence of leading the environmental policy as it relates to the industry.

This closure plan, to date sets the precedent for having all the regulators sign off on the closure plan proposal before the implementation of the works. It may be debatable that this was a premature vote of confidence given the somewhat unpredictable nature of how environmental problems evolve in time. By having the stakeholders sign off, each agency has at a minimum agreed that their potential environmental concerns have been considered, been included in the measure to mitigate/address specific aspects related to their mandates and operations.

Before the 2015 Permits and Licence Amendment, the scheme of the developments approval process of the NEPA, this model did not pertain for a number of reasons:

1. Grandfathering clause in the environmental legislature - A closure plan requirement is a feature of the Permits and Licences Regulations (1996); environmental permits were issued starting in 1998. There was exclusion for older existing activities, even though the NRCA Act [17] can demand that an application be made for activities it deems will have significant environmental impact. This has changed with the amendment to the Prohibition of Categories (1996 amended 2015). Early permits did not require closure plans. In fact, some of the very first permits were issued to the bauxite and alumina (BA) industry, though the records cannot account for the first, 01P95, the second 02P95 was issued for the Alpart Mud Lake in St. Elizabeth
2. The closure plan in the scheme of the Permits and Licences process presently executed by NEPA appears as a specific condition of Environmental Permits, and is not required to be submitted to multiple stakeholders or reviewed by them; it is only reviewed by the Pollution Prevention Branch of NEPA, so before the works, directly affected stakeholders may not necessarily be included in the approval/development of the plan.

The removal of the 'grandfathering clause' in the 2015 amendment of the Permits and Licences Regulations will cover active operations, so derelict sites may be excluded from this change in the regulatory framework.

2.1. Administration of Closure and Nations Approaches

The closure of old bauxite residue disposal sites is not presently common practice the world over and is relatively new to the regulatory needs of countries – a few other examples occur in the United Kingdom, Germany and France. The small ponds that were created in mined out pits at Kirkvine are not representative of the typical scale. The Irish Environmental Protection Agency (EPA), as part of their Integrated Pollution Prevention and Control Licence [18], required trials for the projected closure of the bauxite residue disposal areas at Auginish. At Belgaum, Karnataka, India, Hindalco undertook some vegetation trials on sections of their active bauxite residue disposal area, principally to minimize potential community impact [19].

In 2011, Lyew Ayee et al. [1] discussed the general process of closure in Jamaica with the anticipated challenges to be faced with the closing of the Mount Rosser site.

Historically, with the beginning of mining in Jamaica in the 1950's, the existing environmental management framework would have initially been poorly developed, the mining having started in a pre-independence context. It would take nearly another 40 years for the overarching environmental law – the NRCA Act, to be enacted in 1991.

Generally, the bauxite and alumina industry players locally would have kept abreast of internal and international industry standards including in areas of environmental management. However, at the outset, the disposal of bauxite residue was no more sophisticated than discharging to depressions and dammed valleys. There was no significant effort for other environmental impacts, other than for physical containment. Certainly, globally, the increasing interest for environment was precipitated by concerns for pollution, degraded natural systems and needs of a growing world population.

3. The Conceptual Framework for Closing a Bauxite Residue (Red Mud) Legacy Site

The development of closure objectives in Jamaica has capitalized on ecological indicators that point to geochemical characteristics and biodiversity. But what are the real objectives? A particular question could be framed to direct the policy:

Can the existing governance design described here for closure planning include auditable ecological outputs and government/owner obligations for the closure of bauxite residue disposal areas (BRDA's) in Jamaica?

As is the nature of environmental issues, the approach must be interdisciplinary, including: *policy and government administration*; address environment *duty within the government*: asserting who in the local governance framework is the appropriate responsible agency or entity to administer the closure process; and, *ecologically*: using the rigor of scientific design, experimenting with factors that would produce optimum revegetation of the bauxite residue surface. The process should result in an environmental indicator with potential conclusions for predicting long-term evolution of the site.

This process as well, adds another dimension and will form part of the scientific legacy of the bauxite and alumina industry in Jamaica.

Future contemplated developments and additional analysis will include the review/definition of key aspects related to environmental economics and the utility of an environmental bond.

A conceptual framework diagram has been elaborated in Figure 3. Both streams of investigation, that is the ecological aspects and the governance aspects will elaborate the mechanisms using inputs, processes and outputs, arriving at distinct outcomes that in fact will mutually reinforce the primary objective of supporting regulatory decisions with sound multidisciplinary considerations.

Figure 3. Conceptual framework diagram showing the interdisciplinary approach exploring Ecology and Governance

In conclusion, the Jamaican bauxite and alumina industry has a good technological grasp of the environmental issues related to bauxite residue sites. However, it is important that the environmental management systems used to address the operational environmental impact and legacy issues and the companies align with national objectives and the environmental regulatory framework. Locally, the operating companies have invested in social development and it is hoped that they will continue to be ethical partners. The Government of Jamaica on their part must retain/obtain the technical capacity to contemplate and implement requirements to address environmental impacts, particularly the legacy issues while companies are still operational. For companies that depart our shores, a technical dilemma of addressing a site while no process feeds that site, results in creative governance, including developing trigger alert schemes so that ground water is still protected, even during closure. This has been a success and now translates to other locations in the island through the environmental permitting process.

It is important for Jamaica to balance the concepts of environmental sustainability, taking into account changes (including climate changes), with the use of its natural resources to economically benefit all its people. The establishment of robust environmental protection measures, including best practice rehabilitation strategies, is a key aspect in securing sustainable economic prosperity with minimal adverse effect for Jamaica and its people.

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