Moving Towards Zero Waste to Landfill in Integrated Aluminium Company

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Abstract

Hindalco Industries Limited, an integrated Aluminium and Copper producer, generates approximately 12 Mt of wastes per year. These are basically categorised as Bulk Wastes, Hazardous Wastes and Other Wastes. Some examples are: Bauxite Residue (also known as Red Mud), fly ash, spent pot lining, aluminium dross, vanadium sludge, used oil, plastic waste, municipal solid waste, electronic waste, spent resins, shot blasting dust, fluoride bags etc. We adopt 5 R +1 S (Reduce, Redesign, Recover, Rehabilitate, Recycle, and Store) principle towards management of wastes. Furthermore, Hindalco has targeted to achieve Zero Waste to Landfill (ZWTL) by 2050. Using both in-house and collaborative research with industry partners, educational institutes, expert organizations, we intend to develop alternate applications for sustainable use of these wastes. Currently, Hindalco's wastes are being used in the cement industry, construction work, road development, backfilling of mines etc. In financial year 2022, Hindalco could achieve 86 % utilization of waste as useful raw material for other applications. Further research work is in progress for developing new and innovative products and applications. With this approach, Hindalco is moving towards the set target of ZWTL.

Keywords: ZWTL - zero waste to landfill, Circular economy, Recycling, Bauxite residue, Fly ash.

1. Introduction

Hindalco Industries Limited is a metals flagship company of the Aditya Birla Group. We are the world's largest aluminium rolling and recycling company and a major copper player. We are also recognised as one of Asia's largest producers of primary aluminium. We maintain a presence throughout the manufacturing value chain from bauxite mining, alumina refining, coal mining, aluminium smelting to downstream rolling, extrusions, and foils. Driven by our purpose of building a greener, stronger, smarter world, we provide innovative solutions for a sustainable and prosperous planet. Our core focus as a company is to provide high-grade, environmentally friendly products across our business portfolio which is achieved through robust and significantly optimised manufacturing practices and capabilities. We focus on our ability to bring the best possible value to all our people and stakeholders.

Being cognisant of the impacts of climate change on businesses and the pressing need to transition to a lower-carbon economy and adapt to climate change, we are continuously evolving our understanding of the challenges around climate change and working on how we can integrate it in our strategic decision-making and business processes.

Our finished products include alumina, speciality alumina and hydrate, primary aluminium in the form of ingots, billets and wire rods, value-added products such as rolled products, extrusions and foils. Metallurgical alumina is used for our own captive needs. Chemical alumina and hydrates

are used in a range of industries including water treatment, fillers in cables and plastics, refractories and ceramics, and glass among others.

Hindalco has always strived for establishing highest level of governance in the organization. It plays a pivotal role in driving the climate change agenda across the organization. We have a robust multi-tier governance with Board Oversight on climate-related issues. The Apex Sustainability team, comprising the Executive committee members of Hindalco under the leadership of the Managing Director, guide and review the company's sustainability efforts on a monthly basis. Hindalco has a well-rounded approach to sustainability – encompassing a variety of areas like sustainable mining practices, energy conservation, recycling, environment-friendly utilization / disposal of industrial wastes, water conservation, safety practices, socio-economic development of the communities around the plant and empowerment of employees. Hindalco's approach is to set clear policy and institutional framework, systematically monitor the performance, encourage continuous improvements and innovative practices, and deepen the dialogue with all stakeholders. The Waste task force with proper Terms of Reference (TOR) is formulated since 2019-20 to drive our actions on the ground.

Hindalco is world's most sustainable aluminium company in the Dow Jones Sustainability Indices 2021 and is the only aluminium company in the prestigious DJSI World Index 2021. This is the 2nd consecutive year that Hindalco is at the top of the DJSI Indices having achieved a score of 73 percentage points against an industry average score of 30 [1].

Our initiatives include:

- Choosing the right technology for our greenfield projects to ensure energy efficiency and environmental protection.
- Enhancing material efficiency, process/equipment productivity backed by pollution prevention practices and adoption of cleaner technologies for brownfield projects.
- Waste Management System for systematic collection of scrap and safe storage/disposal and re-use of wastes.
- Water conservation, recycling, zero liquid discharge (ZLD), water positivity, rain water harvesting.
- Controlling emissions through deployment of cleaner technology and state-of-the-art pollution control equipment (PCE).
- Rehabilitation through backfilling and afforestation of mined areas; and rehabilitation of waste disposal sites by greening, e.g. legacy fly ash mound and bauxite residue dump.
- Promoting industrial recycling of waste like spent pot lining, fly ash, spent caustic, etc. through research, collaborations and advocacy.
- Enhancing ecosystems with respect to flora, fauna and habitat development, implementation of biodiversity conservation with scientific approach of Biodiversity management plan (BMP)- implementing the same.

Our environmental commitment (formulated in February 2021) is shown in Figure 1, below [2]:

Figure 1. Hindalco's environment, social and governance (ESG) commitment.

2. Hindalco Process Overview – Aluminium

At Hindalco, we are driven by our purpose of manufacturing products that make the world greener, stronger and smarter. The process chain in aluminium operation is depicted in Figure 2.

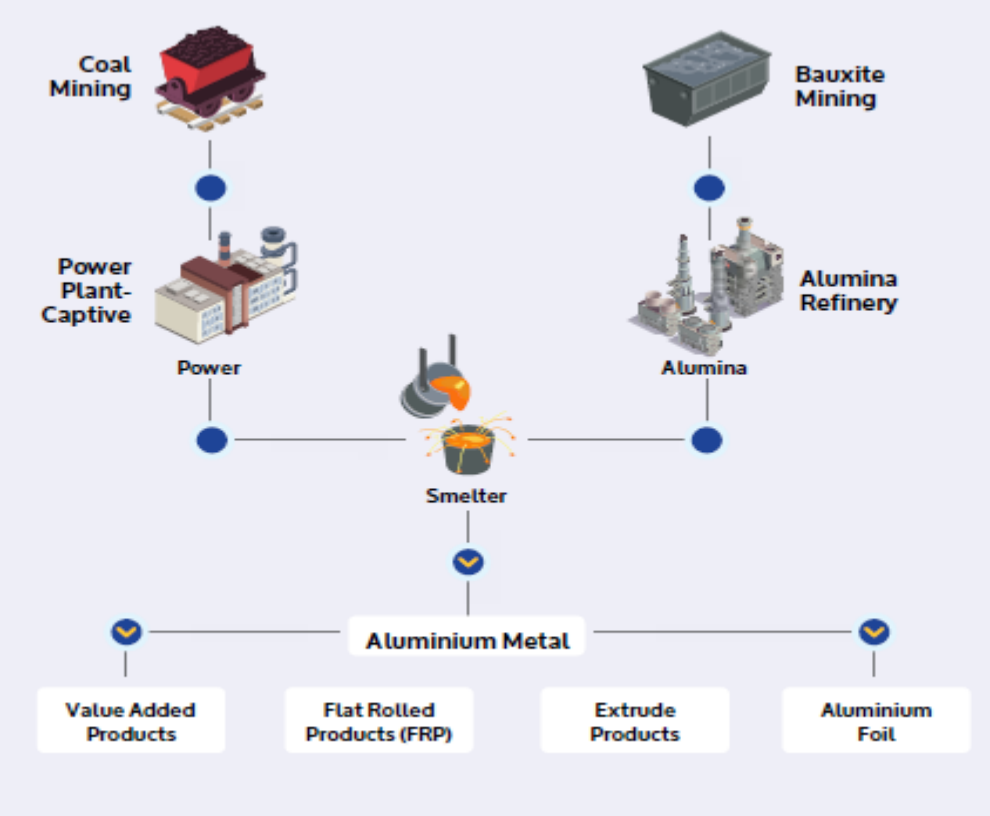

Figure 2. Aluminium operations at Hindalco.

3. Hindalco – Waste Generation

At Hindalco, we generate 200pprox.. 12 Mt of wastes every year. These wastes are broadly classified as detailed in Figure 3, below.

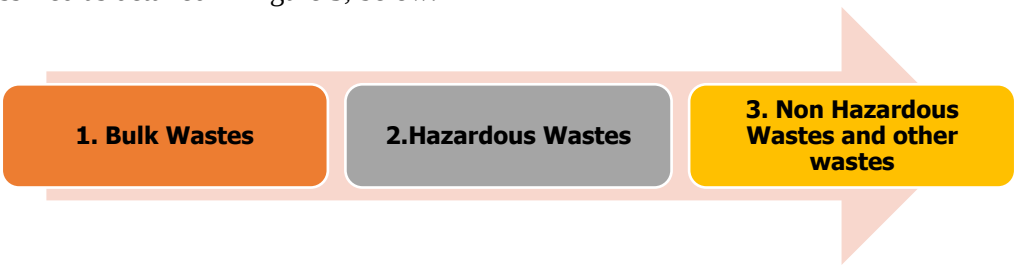

Figure 3. Classification of waste into three major categories.

Typical wastes covered under each category are:

- Bulk wastes – bauxite residue (BR), fly ash & bottom ash, spent pot lining (SPL), aluminium dross (AD) and vanadium sludge (VS)
- Hazardous wastes – oil sludge, effluent treatment plant (ETP) sludge, spent filter, earth material etc.
- Other wastes – plastic, electronic waste, municipal solid waste (MSW) etc**.**

Major constituent of waste is Buk Waste. Quantum of Total Wastes and Bulk Wastes generated in last 2 years are given in Tables 1 & 2 respectively.

Table 1. Total waste generation details at Hindalco.

	2020-21, Mt	**2021-22, Mt**
Waste generation at Hindalco	11.9	11.6

Table 2. Bulk waste generation details at Hindalco.

	2020-21, Mt	**2021-22, Mt**
Waste generation at Hindalco	11.45	11.13

4. Management Approach for Wastes at Hindalco

A holistic approach towards management of waste that covers the entire value chain, right from its generation to final storage consists of 6 key pillars: “5 R + 1 S”, which are described as :

- **R**eduction – Reduction in generation of waste through use of alternate raw materials and process
- **R**edesign – Process modification for alteration of waste quality
- **R**ecover – Extract valuables from waste
- **R**ehabilitate – Conversion of exhausted waste storage area into green area
- **R**ecycle – Use in different industrial applications
- **S**torage – Necessary steps to ensure minimal impact of stored waste on environment

Recycle pillar further comprise of 4 streams:

- To cement industries,
- For construction works like in roads, railway embankments, for making bricks, paver blocks and various construction materials,
- In-house pre-processing and converting it into the usable form,

- For rehabilitation of low-lying areas, mine pits to restore the topography with greenbelt, etc.

Three important aspects that are considered for prioritization and interplay of the 6 pillars of waste are:

- Maturity of technology and readiness to commercialize
- Size of impact
- Interconnectivity

We have taken a target of moving towards Zero Waste to Landfill (ZWTL), in all our operations by 2050 and we are working factory by factory; as of today two of our downstream factories are ZWTL.

4.1 Waste Utilization Outlook

At Hindalco, we have plans towards enhancement of utilization of wastes either in our process or at other industries. In financial year (FY) 2022, we have utilised 86 % of our wastes. Details are given in Figures 4 and 5.

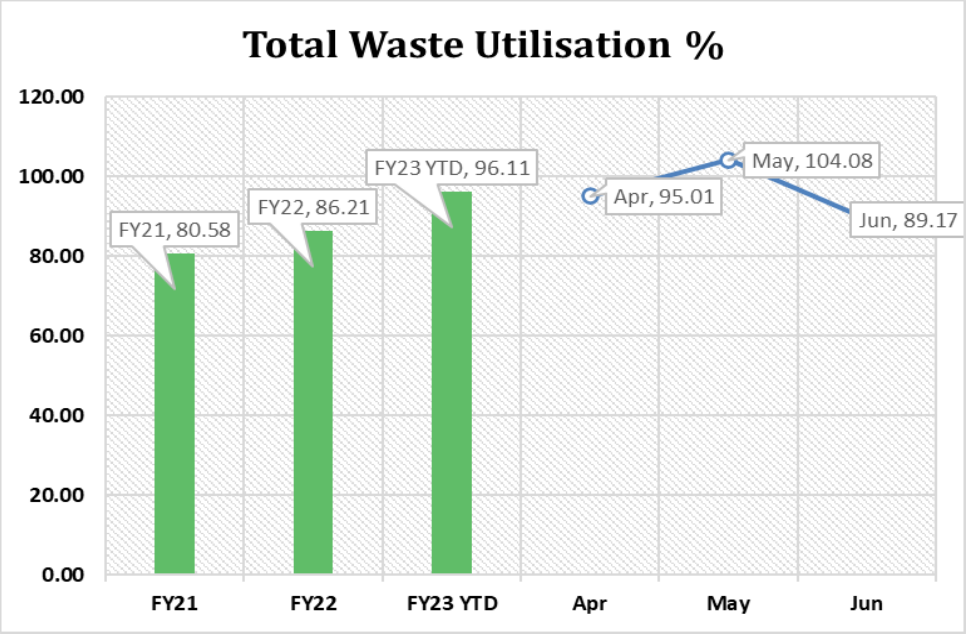

Figure 4. Total waste utilization details at Hindalco.

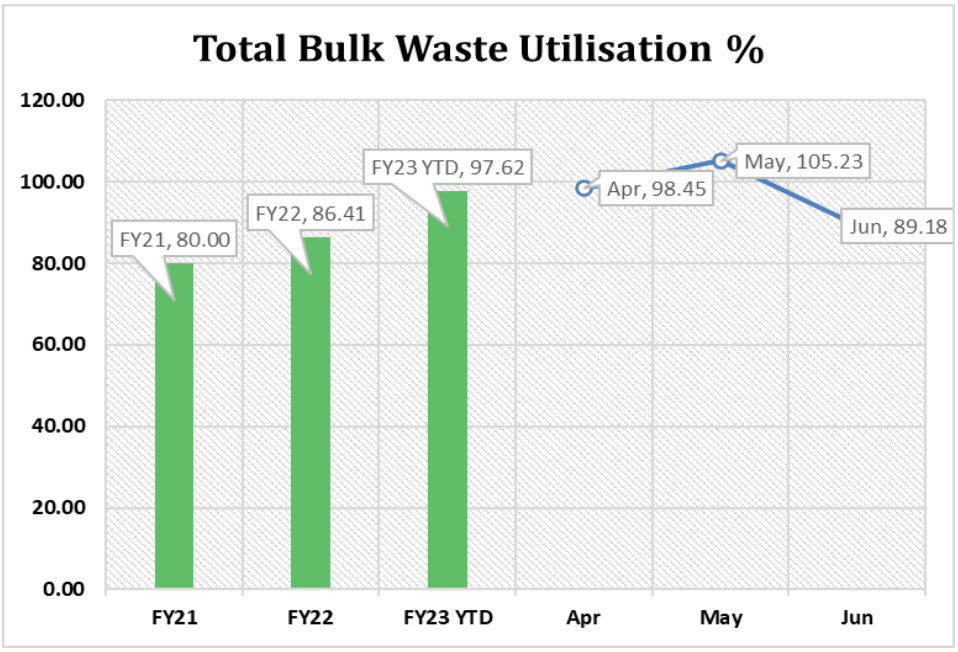

Figure 5. Bulk waste utilization details at Hindalco.

At Hindalco, we have plan for scaling up our waste utilization and move towards 100 % i.e. Zero Waste to Landfill. Our plan for utilization of waste till FY 25 is as depicted in Figure 6. Introducing the role of embedded relationships and inter-firm business networks in the adoption and diffusion of circular economy we could achieve some of our milestones ahead of targets. Massive networking, collaborations, approvals from pollution control boards and contracts with long term visibility lead to this status of 86 % in FY 22. Downstream operation, refineries, smelters and power plants will be taken to this status as per the roadmap; today two of our downstream operations have achieved this status [3, 4, 5].

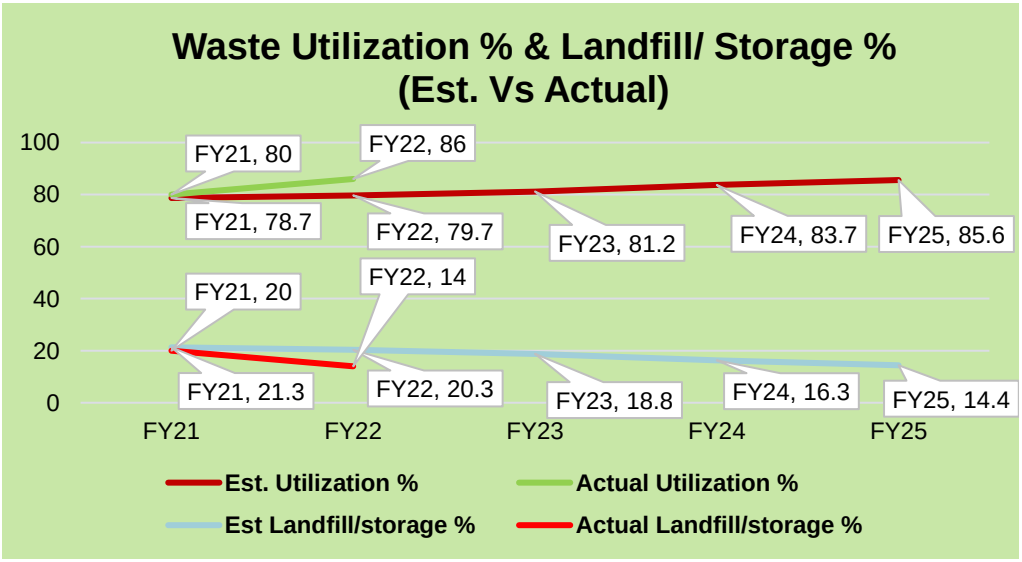

Figure 6. Targets for enhancing waste utilization- YoY.

5. Technical Evaluation of Waste for Suitability

Careful technical evaluation is required to establish the suitability of any given waste for an application. A series of examples are listed in Table 3.

Table 3. Waste suitability for various streams.

Sr. No.	Type of Waste	Application	Technical Evaluation details
1.	Bauxite Residue	Clinker for Cement	• High Iron Content (55-60 %) – Raw Material (Iron-Alumina corrective) for Clinker. Replace mined minerals like Laterite, Lithomarge. • Higher Alkali Content (6 – 8 %) – Facilitates use of high sulphur fuel • Benefits – Reduction Mining related Emissions; Reduction of SOX emissions when high Sulphur fuel is used; Energy Savings in avoidance of crushing Laterite • Enabling a Greener Cement – Reduction Mining related Emissions; Reduction of SOX emissions when Petcock is used; Energy Savings in avoidance of crushing Laterite etc.
		Bricks	• Bauxite Residue, Fly Ash, Composite with fly ash, ground granulated slag, quarry dust and activators. Compressive Strength of Brick > 7 Mpa
			• Recycled Polymer Composites from Plastic Waste using injection mould mechanism; blocks to be used for construction
		Road Construction [4]	• Physical – Lattice and Impervious Structure of silt & clay size fine particles. Shape of look like rounded as per SEM morphology • Very low Natural Moisture content and in almost dry state • Specific gravity is significantly higher than conventional soil • Low Swelling Characteristics, suitable for embankment • Low LOI Value, therefore very less organic content and settlement will be very less • Chemical – Mainly contain Mn, Cr, V, Ba, Pb, Cu and Zn with other trace elements. • As per Toxicity Characteristic Leaching Procedure (TCLP) / Soluble Threshold Limit Concentration (STLC) test results, leachable concentration of various elements such as Ni, Cr, V, Zn, Cu etc. are within the permissible limit stipulated in Hazardous Waste Management Rules, 2016 • Geochemical – Fine grained, non-plastic material and classified as low compressible silt.

Sr. No.	Type of Waste	Application	Technical Evaluation details
			• Its density is similar to conventional soil with high value of California Bearing Ratio (CBR) Test: Avg value of soaked CBR for Red mud 25 %. The value of CBR of red mud indicates its suitability as a sub-grade material in road construction. • which makes it suitable for the construction of embankment and subgrade. Hence, use in Road Construction.
2.	Fly Ash and Bottom Ash	TechPlast	Plastering Material using BR, Fly Ash, Sand and ordinary Portland cement (OPC) Cement. Strength 6 – 8 Mpa in 28 days
		Bricks	Bricks using BR, Fly Ash, Sand and OPC Cement. Compressive Strength: 110 kg/cm^2 – Grade A Brick as per IS Standard
		Cement Processing	Cement Manufacturing as Alternate Raw material
3.	Aluminium Dross	Metal Recovery	Pre-processing and Recovery of Metal – Crushing, Sieving and Melting to recover Aluminium Dross Residue with enriched aluminium oxide for Synthetic flux for Steel Industries.
4.	SPL	Cement Process	The density of SPL is typically within a range of between 1.8 – 2.2 t/m3 and it has a compressive strength that averages 20 to 30 Mpa with typical maximum strength approximately 50 Mpa. Primary Crushing → Secondary Crushing → Screening → Packing & Transport → Cement Kilns Both carbon and Refractory Portions used.
5.	Vanadium Sludge	Ferro Vanadium	Used as raw material for manufacturing of Ferro Vanadium

5.1 Bauxite Residue for Clinker, Bricks and Road

Typical raw cement clinker mix composition and technical comparison of BR and laterite are given in Table 4 while table 5-table 10 shows various characterisation studies for specific applications, below.

Table 4. Comparison of laterite and BR.

	Laterite, %	Bauxite Residue, %
Moisture	11.9	21.2
SiO_2	22.3	17.1
Al_2O_3	18.9	17.4
Fe_2O_3	41.0	36.5
CaO	0.1	0.7
MgO	0.2	0.7
TiO_2	2.2	7.3
K2O	0.3	0.7
Na2O	0.0	6.4
LOI	14.7	12.4

Table 5. Typical raw mix clinker composition.

Ingredient	% In Cement
Lime	60-65
Silica	18-25
Alumina	4-8
Magnesia	<5
Iron oxide	2-6
Calcium Sulfate	3-5
Sulfur Trioxide	1.8-3.5
Alkaline	0-1

Table 6. Technical specification of Techplast.

Technical Details	
Parameters	**Details**
Appearance	Pinkish granular ready to use mix powder
Main Binder	Ordinary Portland Cement (OPC)
Ordinary Portland Cement (OPC)	Water soluble eco friendly material for better efficiency, binding, water retaining and strength
Max grain size	Less than 1.5 mm
Bulk Density	1.2 to 1.3 kg/cm3
Compressive strength(Mpa)	More than 6 to 8 in 28 days
Thickness of layer	8 to 12 mm
Proportion of water(%)	: 18 to 20 % as per weight

Table 7. Technical specification of brick.

RPD Bricks			IS Code Limits		
Comp. Strength in Kg/cm2	Water Absorption (%)	Efflorescence Test	Comp. Strength in Kg/cm2	Water Absorption (%)	Efflorescence Test
111.83	16.9	Moderate	Grade Ä =>100 Grade-B =75-100 Grade C =50-75 Grade D = Below 50	Max 20%	Shall not be more than Moderate
108.89	18.6	Moderate			

Table 8. Technical specification for embankment material as per MORTH and MORD norms [4].

Sl.No.	Properties	Red mud	MORTH	MORD
1	Maximum grain size, (mm)	< 75	< 75 < 2/3 of Compacted thickness	< 75 mm < 2/3 of Compacted thickness
2	LL (%)	27	< 50	< 70
3	PI (%)	NA	< 25	< 45
4	Dry density (kN/m^3)	21.28	>15.2, upto 3 m height >16.0, more than 3 m height	>14.4, upto 3 m height >15.2, more than 3 m height
5	Free Swelling Index (%)	15	< 50	< 50

Table 9. Technical Specification for subgrade material as per MORTH and MORD norms.

Sl.No.	Properties	Red mud	MORTH	MORD
1	Maximum grain size, (mm)	< 50	< 50 < 2/3 of Compacted thickness	< 50 mm < 2/3 of Compacted thickness
2	LL (%)	27	< 50	< 70
3	PI (%)	NA	< 25	< 45
4	Dry density (kN/m^3)	21.28	>17.5	>16.5
5	Free Swelling Index (%)	15	Expansive soil should not be used	< 50

Table 10. Geotechnical characterization of red mud by CRRI

Grain Size Analysis: Red mud contains 18% sand, 72% silt and 10% clay size particles.

Atterberg Limit Test: Red mud is non plastic material and liquid limit to be 27%. Red mud classified as ML (Low Compressible silt) as per IS 1498 (2007).

Proctor Compaction Test: Maximum dry density (MDD) and Optimum Moisture Content (OMC) for Red Mud were found to be 21.28 kN/m3 and 17.40% respectively. The density of Red Mud is insensitive with moisture contents.

California Bearing Ratio (CBR) Test: Avg value of soaked CBR for Red mud 25%. The value of CBR of red mud indicates its suitability as a sub-grade material in road construction.

Direct Shear Test: The normal stress varied in the range of 50 to 150 kN/m2. Shear stress increases with horizontal displacement and reaches peak value and thereafter decreases to constant value (residual strength).

Table 5.1 Geotechnical characteristics of red mud and fly ash

Materials	MDD (kN/m^3)	OMC (%)	LL (%)	PL (%)	FSI (%)	CBR (%)
Red Mud	21.28	17.40	27.0	NP	15	25

6. How all of This is Being Implemented

Utilization of these wastes could be achieved through implementation of multiple actions across Hindalco. We will explore how investors, corporations, and start-ups investing in and developing circular economy innovations can identify ways to scale them more quickly and to generate wider impact and growth. We have put up a CleanTech challenge in collaboration with the MIT-based start-up accelerator and running it for two of our bulk wastes. A few approaches are detailed in Table 11.

Table 11. Multiple approach for enhancement of waste utilization at Hindalco.

No.	Waste	Enhancement of Utilization through
1.	Bauxite Residue	Agreements with multiple cement manufacturing partners in co-processing this waste MOM with Industries for use in Bricks Approval from Ministry of Environment, Forest and Climate change (MoEF&CC) and State pollution control board (SPCB) for backfilling of bauxite mines with bauxite residue Collaborative project with Central Road research institute (CRRI), Indian road congress (IRC), National highway authority (NHAI) for use in road [4,5,6] Collaborative project with Institutes in identifying alternate application Piloting the alternate applications (e.g.: bauxite residue and plastic bricks, bauxite residue neutralization for man-made soil etc.) Collaborative project on recovering valuable materials from bauxite residue with industry association and research institutions
2.	Fly Ash / Bottom Ash	Agreements with multiple cement manufacturing partners in co-processing this waste Training and door delivery to all brick making ecosystem in the nearby locality, In-house brick making units MOU for use in road projects

No.	Waste	Enhancement of Utilization through
		Low lying area filling for rehabilitation
3.	SPL- spent pot lining	Reprocessing at authorized re-processer Agreement with cement industries for co-processing this waste Collaborative Project with Expert Institute for development of Alternate Applications
4.	Vanadium Sludge	Use of this waste in Ferro Vanadium manufacturers
5.	Aluminium Dross	In-house Processing of Waste Processing at Re-processors for recovery of Metal Use of Dross Residue in making synthetic flux for use in Steel Industry

To achieve all of this, we have adopted a multi-pronged approach which includes the items shown in Figure 7.

Figure 7. Approach towards alignment of all stakeholders

Some of the recent examples on waste utilization projects at Hindalco are shown in Figures 8-11.

Figure 8. Techplast from fly ash at Hindalco.

Figure 9. Bauxite residue bricks.

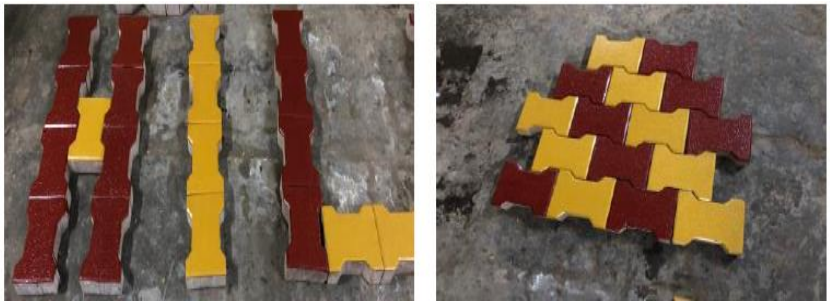

Figure 10. Bauxite residue in paver blocks.

Figure 11. Project on mine backfilling with BR using a scientific approach towards backfilling and rehabilitation.

7. Conclusion

With the abovementioned management approach, it is possible to achieve 100 % utilization of wastes generated from integrated aluminium operation coupled with the following:

- active support from industry partners
- collaborative research projects with expert institutes like IIT, NEERI, JNARDDC, IMMT, CSIR etc. in identifying newer application for the wastes
- technical support and approvals from statutory bodies.
- learning and replication from other countries [5]

8. Acknowledgement

Authors would like to thank Hindalco's management for giving us the opportunity to present this case study. Also, the authors thankfully acknowledge the contributions made by operations and sustainability professionals of Hindalco, industry partners, technical experts from institutes and all others towards enhancement of utilization of industrial wastes. This has helped protection of environment and also made virgin land available for development purpose.

9. References

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