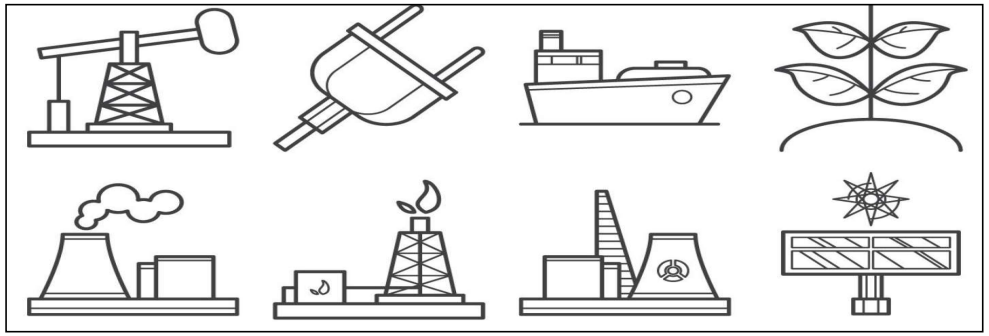
Recovery of Critical Minerals from Waste Dumps & Tailings - Way Forward

Date : 09th January 2026

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Why Critical Minerals is so Important



Energy, defence, electronics, food production, and communications requirements.

Category	Minerals
Battery / Energy Transition	Lithium, Cobalt, Nickel, Graphite (Natural), Manganese (High Purity), Vanadium
Electronics / Semiconductor	Gallium, Germanium, Silicon, Tungsten, Tantalum, Niobium, Indium
Renewable & Clean Energy	Rare Earth Elements (REEs), Scandium, Tellurium, Selenium
Aerospace & Defense	Titanium, Zirconium, Beryllium, Hafnium, Rhenium, Platinum Group Metals (PGMs: Platinum, Palladium, Rhodium)
Fertilizer & Industrial	Phosphorous, Potash, Molybdenum, Tin, Chromium, Antimony, Fluorspar

Material	Application	Major Consumer/ Requirement by 2030	Estimated Req... upto 2030
Silicon (Si)	PV modules (crystalline)	In Solar Energy, target 280 GW, already achieved 64GW	25,000 to 50,000 tonnes (25-50 kt)
Tellurium (Te)	Thin-film PV (CdTe) use		100 to 300 tonnes
Indium (In)	CIGS or thin-film PV		50 to 200 tonnes
Gallium (Ga)	CIGS thin-film PV		20 to 100 tonnes
Neodymium (Nd)	Permanent-magnet wind turbines	In Wind Energy, target 140 GW from 42 GW	3,000 to 10,000 tonnes
Dysprosium (Dy)	Permanent-magnet wind turbines for high-temp/coercivity		300 to 1,000 tonnes
Lithium (Li)	EV & grid battery packs	In EV's, target 80 million, achieved 6 million	About 6 lakh tonnes
Nickel (Ni)	EV battery cathodes (NMC)		About 22 lakh tonnes
Cobalt (Co)	EV battery cathodes (NMC)		About 8 lakh tonnes

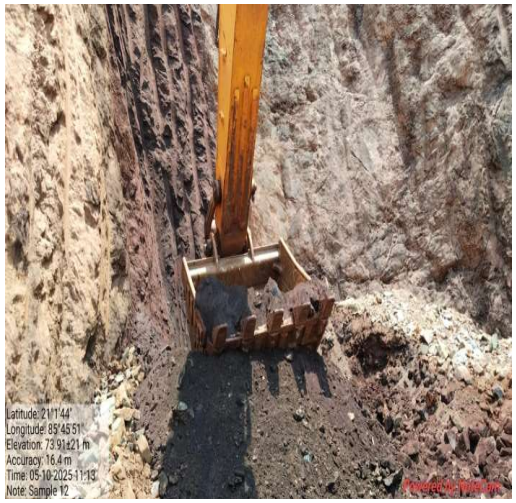
विकसित भारत अभियान
1947 TO 2047

Critical Minerals are vital in becoming Viksit Bharat by 2047 and achieving Net Zero by 2070.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

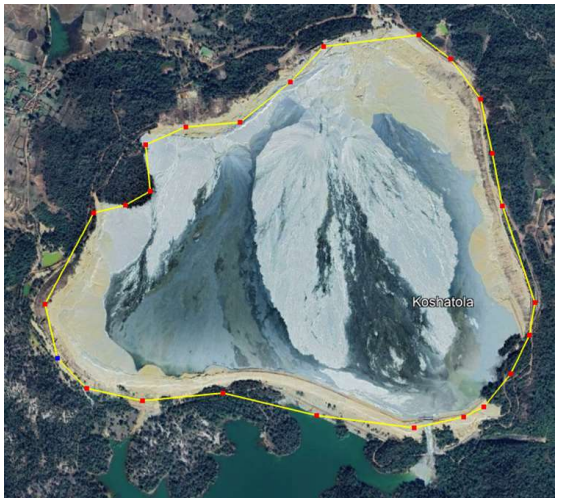
Critical Minerals- Potential Sources

From Primary Ore



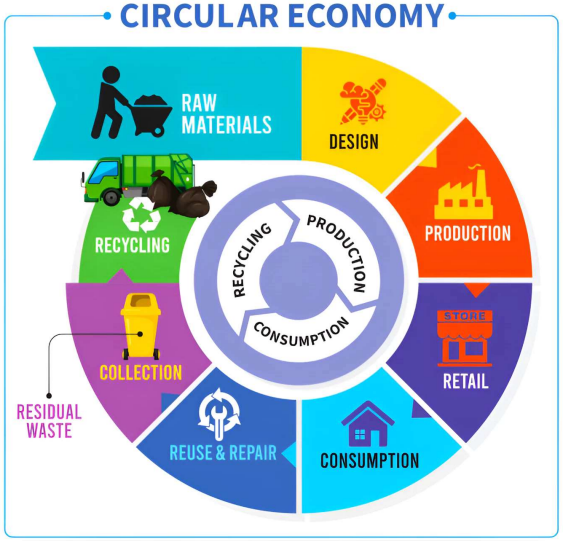
Long Gestation Period

Recovery from waste dumps and tailings



Promising opportunities

Recycling from end of life products



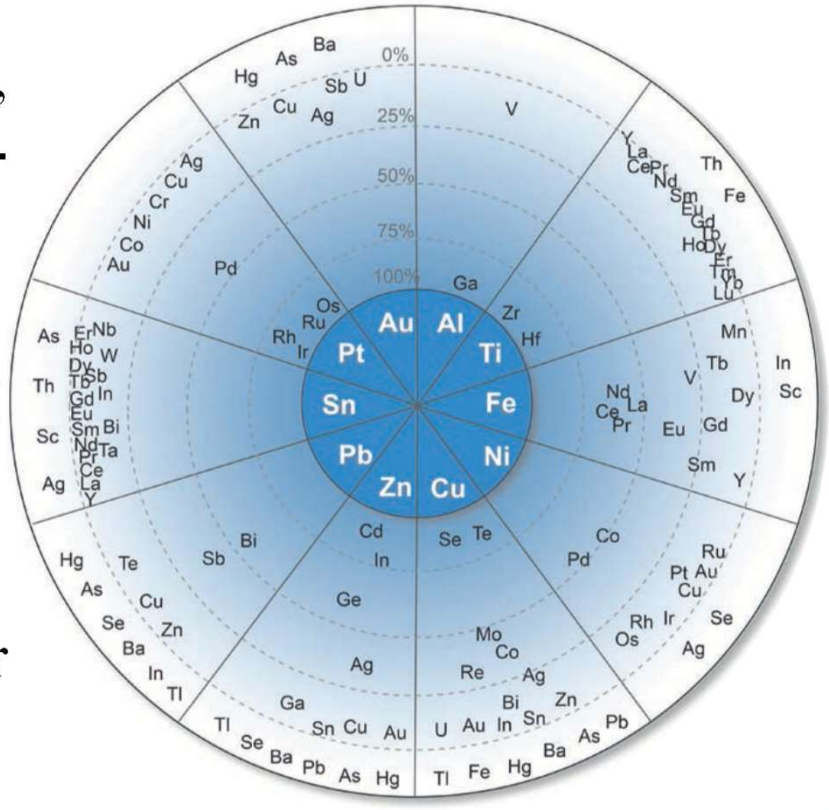
Limited Scope

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Recovery From Waste Dumps and Tailings

- ✓ Mine waste and tailings represent a hidden, above-ground ore body for critical minerals. -- Large legacy tailings

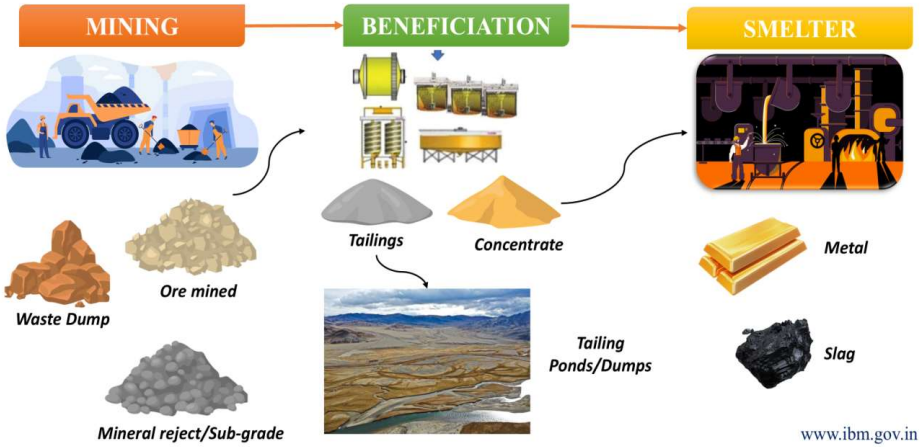
  -Metals previously considered "uneconomic
- ✓ Already mined & crushed: Lower energy and capex than greenfield mining
- ✓ Capex: 30–60% lower than new mines
- ✓ Time to production: 2–5 years vs 7–15 for greenfield,
- ✓ Carbon footprint: Often 40–80% lower



Association of Critical Minerals with Primary Minerals

खान मंत्रालय
MINISTRY OF MINES
सत्यमेव जयते

Sampling Process : Flow of Events



www.ibm.gov.in

April, 2025
Pan India Sampling

10 Commodities
Chromite, Lead & Zinc, Copper, Tin, Fluorite, Bauxite
Gold, Baryte, Manganese, Graphite

367 Sites Covered
311 Mines
32 Beneficiation Plant
27 Refine... Smelte...

2383 Samples
Samples Generated

Geochemical Analysis
- 2,378 Samples

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Key Findings and Action initiated

Φ Promising opportunities in the tailings and waste of copper, lead, zinc, tin, fluorite, bauxite and chromite ore.

Φ Significant quantities of REEs, molybdenum, nickel, vanadium, gallium, PGE, antimony, niobium, selenium, tellurium and tantalum in the waste dumps , tailings, and slag of the above-mentioned minerals.

Φ Stake holder consultation with HCL, OMC, Tata Steel, HZL, Vedanta, GMDC, NALCO, Hindalco, CMDC, PMSL);

Φ Action plan/milestone for the recovery of critical minerals available with different companies.

Φ Regular follow up and updates on the promising projects for recovery of critical minerals.

Φ Second phased commenced from 1st of January wherein we will cover 125 mines and collect 1500 samples

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Chromite

- Samples collected across the Chromite value chain from OMC, TSL, IMFA, and FACOR, have shown significant presence of Nickel, Cobalt and PGE in waste dumps.

- Odisha has around 442 million tonnes of waste dumps, with about half owned by the OMC. These dumps contains

  - Nickel up to 1.3 % with an average of 0.6 %.
  - Cobalt up to 1853 ppm with an average of 571 ppm.
  - PGE (Pt+Pd) up to 5.8 ppm with an average of 2.25 ppm

- **Preliminary assessment suggest Nickel worth around 0.40 lakh Cr.**

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Potential in Chromite Dumps

- OMC & TSL acknowledged the presence of Nickel & Cobalt in waste dumps
- Nickel is in form of oxide posing challenge for extraction.

Simultaneously,

- TSL is working on the development of feasibility of making Nickel Pig Iron.
- OMC in partnership with CSIR–IMMT is working on a pilot-scale project for assessing the economic extraction of nickel; expected to be completed by December 26

It is expected that by December 2028, Technology for Nickel recovery from the dumps may be developed at commercial stage, Nickel worth around 0.40 lakh Cr.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Copper

Φ Samples collected from copper mining value chain shows significance presence of Molybdenum, Selenium, Tellurium, and PGE.

Φ Molybdenum can be extracted from concentrate, while Selenium, Tellurium, and PGE may be extracted during smelting and refining of copper. The tailings also offer potential for extracting PGEs.

- In Concentrate samples, Mo contains upto 3080 ppm, Co upto 1378 ppm, Se upto 152 ppm and Te upto 106 ppm.
- PGE (Pt+Pd+Rh) up to 600 ppb in tailing.
- TREE upto 3640.75 ppm in Mineral Stack sample
- Te upto 39.67 ppm in Mine Face sample

Φ **HCL acknowledged the presence of critical minerals** in concentrate and tailings.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Copper

- Φ 1764.25 tonnes of Molybdenum, 179.64 tonnes of Selenium and 13.22 tonnes of Tellurium is estimated from Malanjkhand, Surda and Kendadih copper mine with gross worth approximately **INR 804.59 crore.**

- Φ 15.91 tonnes of Platinum Group Elements (Pt+Pd+Rh) have been assessed from the Khetri tailings with gross worth **INR 3,771 crore.**

- Φ HCL are in discussion with CSIR–IMMT Bhubaneswar and IIT–ISM Dhanbad to establish a pilot plant for the extraction of critical minerals from copper ore, concentrate and tailings.

HCL agreed for two strategic initiatives.
To explore the possibility for recovery of molybdenum from copper concentrate and Comprehensive analysis to identify the exact quantity of critical minerals present.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Lead & Zinc

Φ Samples collected from HZL processing plant have significant presence and opportunities for recovery of **Cadmium, Antimony, Selenium and other critical metals.**

- Pb Concentrate : Cd up to 2561 ppm, Sb up to 3217 ppm, Se up to 119 ppm
- Zn Concentrate : Cd up to 2495 ppm, Sb up to 702 ppm
- Jarofix/Jarosite: Cd upto 4399 ppm, PGE (Pt+Pd) upto 4.1 ppm
- Silver Slime: Sb upto 20%, Bi upto 3064 ppm, Se upto 288 ppm & PGE upto 3.8 ppm

Φ **Production of Cadmium is being reported** after commencement of sampling by IBM.

Φ Regarding antimony and selenium, HZL acknowledged that these critical minerals are present in higher quantities in their process waste, jarofix and slag.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Lead & Zinc

Preliminary economic assessment :

Available Stock across HZL	MT (Approx)	Sb PPM (Avg)	Sb MT	Cd PPM (Avg)	Cd MT
Jarosite	8000000	222	1776	552	4416
Process Slag	599063	2570	1539	644	385
Total			**3315**		**4801**

Gross metal value estimation in Jarosite (Jarofix) and Slag available in stock across HZL worth estimated **INR 331.5Cr for Antimony, and INR 164.7 Cr** *for Cadmium.*

HZL is exploring the possibility to setting up a pilot plant to recover Antimony, which is available in higher quantities as high as 20 % in silver slime.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Tin

Φ Tin leases and slag present significant opportunities for recovery of **tantalum, niobium and REE.**

Φ The tin slag contains potential concentrations of tantalum, niobium and REE **(REE upto 5030 ppm, Nb upto 4104 ppm and Ta upto 2122 ppm.); Total quantity** approximately 1,20,000 Kg.

Φ PMSL indicated that a DAE license is necessary for processing as it contains small amounts of U and Th, but DAE is ready to assist in this regard, if processing is carried out domestically

Φ PMSL are in discussion with IREL for recovery of Nb, REE, and Ta from slag;

Φ CMDC was advised to take up the matter with BARC, and IMMT for establishment of Pilot

M/s Earth Mineral, Raipur informed that they have the technology for recovery of Tantalum and Niobium from Tin Slag.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Fluorite

- **Samples collected from** Fluorite mine of GMDC present significant opportunities for recovery of Niobium and REE.

  - Waste Dump REE – 4466 ppm, Niobium -794 ppm,
  - Tailing REE – 11000 ppm, Niobium - 2084 ppm

- **GMDC acknowledged that REEs are present in the mine waste (10 mt) and tailings.(1.2 mt))**
  - estimated values of REE - 1,458 crore
  - estimated value of Nb 3,728 Crore

- GMDC is already undertaking 5,000 meters of exploratory core drilling in the lease area, expected to complete entire area by December 26

GMDC in the process of development of flow sheet and commissions a pilot plant by 2027, with a commercial plant targeted for 2029–30 for recovery of REE.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Bauxite

Φ148 mines and 8 smelting Plant were covered for Bauxite generating 845 samples

ΦOdisha and Jharkhand has around 150.05 million tonnes of Red Mud worth Rs. 50,832 Cr lying with HINDALCO, NALCO and Vedanta.

- In Mine samples Ga up to 305 ppm, V up to 1.9% ppm, REE upto 3593 ppm and TiO_2 upto 11.34 wt.% is recorded.
- Red mud samples shows Ga upto 92 ppm and V upto 970.5 ppm.

ΦPreliminary assessment suggest Gallium worth more than 32,928 Cr. and Vanadium (V_2O_5) worth Rs 17,904 Cr in bauxite ore of Odisha, Jharkhand and Chhattisgarh.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Future Action Plan

- Φ Subsurface and close-spaced sampling of tailings and dumps and tailing dams is required to assess vertical and lateral variations of potential areas;
- Φ detailed mineralogical characterizations study to understand the amenability to recovery.
- Φ Periodically review and monitor the progress of pilot studies, feasibility assessments, and technology development initiatives;
- Φ Feasibility outcomes, and technology readiness levels (TRLs) shall be compiled by IBM and shared with the concerned stakeholders.
- Φ Assessment of Recovery efficiency, scale-up potential, and commercial viability of the proposed technologies
- Φ Inter-agency coordination for address technical, regulatory, or policy-related issues impacting implementation.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Current Status of Promising Project (1)

- Cadmium production ramped up to in 537 tonnes in November 25
- Recovery of Antimony – Global EoI issued by HZL; proposals are under evaluation
- HCL has engaged MECL to take up a detailed assessment of their tailing dumps, drilling at KCC completed
- REE, Tellurium and Selenium - HCL is in process of engaging IMMT Bhubaneswar
- Molybdenum - discussion for preparation of DPR/TEFR for extraction of Molybdenum in Copper Ore/Copper Concentrate by developing alternate beneficiation route.
- Vanadium - Hindalco established a 6,000-tonne-per-annum vanadium capacity
- Gallium - 400-kg-per-annum gallium plant is under construction by Hindalco to be completed by March 2026.

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Current Status of Promising Project(2)

- NALCO has signed an MoU with BARC to establish a 15 kg/year pilot plant for Gallium extraction as a by-product of alumina production, targeted for completion by Nov 2026.

- PGE : Pilot Plant is being setup at IMMT Bhubaneswar by OMC for PGE extraction.

- Nickel: OMC has entered into a partnership with IIT (ISM), Dhanbad, a CoE under National Critical Mineral Mission (NCMM) for dev of Technology.

- Pig Iron: TSL is working on the development of feasibility of making Nickel Pig Iron, About 295 ton of Nickel Pig iron (NPI) of Nickel content upto 1.8% was produced.

- Tin : Action being taken for the technology from BARC and permission from DAE for handling of radioactive substance, IBM also in discussion for exploring pilot scale plant at IMMT Bhubaneswar

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Expected Timelines

- Cadmium production from HZL already commence and expected to reach 2600 tonnes by Mid of 2026
- Production of vanadium is already reported by HINADALCO, and a 400-kg-per-annum gallium plant is under construction, to be completed by March 2026.
- By mid 2027, HCL be in position to extract Molybdenum in Copper Ore/Copper Concentrate by developing alternate beneficiation route.
- Commercial technology for recovery of Nickel and PGE is expected to be developed by December 2028.
- Regarding Antimony recovery, extraction is subject to availability of technology by 2029

खान मंत्रालय
MINISTRY OF
MINES
सत्यमेव जयते

Way Forward

- Detailed mapping of waste dumps (mine tailings, overburden, slags, industrial residues), Re-characterize old wastes using modern tools (XRD, XRF, ICP-MS)

- Use AI/ML models to predict recovery potential and economic viability. Build digital databases of legacy waste for national planning.

- Classify waste dumps as “secondary mineral resources; provide tax incentives and recovery credits, Fast-track permitting for re-mining, Public–private partnerships;

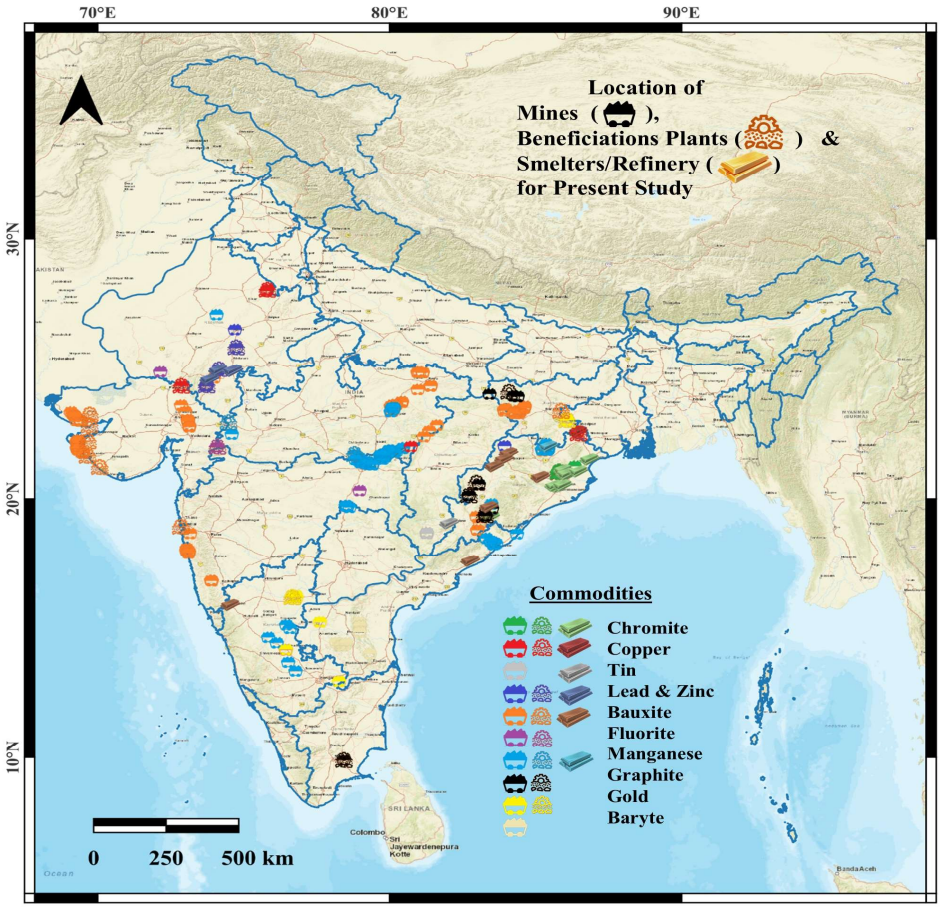
- Start with pilot and demonstration plants set up pilot processing units near dump sites

- Invest in inter-disciplinary R&D Collaborate across center of excellences, Mining companies, Startups and clean-tech firms.

THANK YOU

Location of Sample Collected

S.No.	Mines Dumps and Tailings	Beneficiations Plant	Smelters	Total
Chromite	12	5	11	28
Copper	6	5	1	12
Tin	4		1	5
Lead & Zinc	9	3	3	15
Bauxite	132	9	9	150
Manganese	102	2	2	106
Fluorite	3	1		4
Gold	7	2		9
Graphite	11	5		16
Baryte	23			23
Mica	2			2
Total	311	32	27	370



Mineral wise sample collected

S.No.	Mines	Tailings	Slag	Total Collected	Analyzed
Chromite	154	12	29	195	194
Copper	73	26	1	100	100
Tin	22		4	26	25
Lead & Zinc	155	80	75	310	308
Bauxite	771	30	45	846	845
Manganese	632	4	3	639	639
Fluorite	22	1		23	23
Gold	85	7		92	92
Graphite	40	11		51	51
Baryte	98			98	98
Mica	3			3	3
Total	2055	171	157	2383	2378

Commodities covered in PSU/Private Sector

Commodity	PSU	Private	Total
Copper	6	0	6
Bauxite	14	118	132
Baryte	1	22	23
Manganese	13	89	102
Tin	0	4	4
Gold	4	3	7
Lead & Zinc	0	9	9
Graphite	0	11	11
Chromite	3	9	12
Fluorite	3	0	3
Mica	0	1	1

Quantity of Material in Major Dumps/ Tailings

Commodity	Number of Dumps	Quantity in Dumps (MT)	Number of Tailings	Quantity in Dumps (MT)
Copper	17	119	3	130
Bauxite			6	150
Gold			4	41
Lead & Zinc	3	714	3	170
Chromite	12	482		
Fluorite	2	10	1	1.2

Samples Analysis at Different Labs

	Laboratory	Samples Send for Analysis	Analysis Completed
1	**MPD, IBM**	450	450
2	**GMRDS, CGM**	347	347
3	**JNARDDC**	1162	1162
4	**MECL**	421	421
Total		***2378***	***2378***

Major Findings

- Scoping study highlights significant opportunities for recovering critical minerals, particularly from the tailings and waste of **copper, lead, zinc, tin, fluorite, bauxite and chromite**.

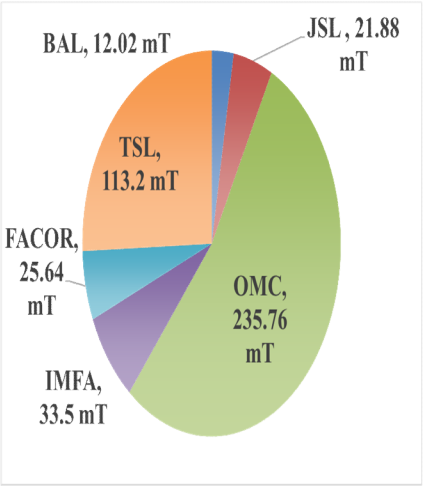
- **REEs, molybdenum, nickel, vanadium, gallium, PGE, antimony, niobium, selenium, tellurium and tantalum** have the potential to be recovered from waste, tailings, slag and dumps of the above-mentioned minerals.

- Preliminary discussions with concerned stakeholders (HCL, OMC, Tata Steel, HZL, Vedanta, GMDC, NALCO, Hindalco, CMDC, PMSL) were held to inform them about the findings and **seek proposals or suggestions** for the recovery of critical minerals available at their different sites.

- A presentation has been made to Ministry in this regard, and as per directives , monthly reports on various activities undertaken for recovery of critical minerals has been compiled

Chromite: Sampling Analysis

- **12 Active Mining Leases** of Chromite mine in Odisha for Chromite Ore
- **196 samples** drawn from the mines and smelters plants.
- The results show promising values for recovery of **Nickel, Cobalt and Vanadium mine waste dumps.**
- Waste dump of Chromite Mines :



Mine Face

Samples collected from Limonitic horizons and nickeliferous limonite mine face **highly enriched in nickel (upto 1.3%) and cobalt (up to 2163 ppm).** (often end up in waste dump).

Waste Dump

i. The Nickel content up to **1.3 wt.%** in waste dump. Average (69) **is 0.6 wt.%.**
ii. The Cobalt content up to **1853 ppm** in waste dump. Average (69) **is 571 ppm.**

Samples collected across the Chromite value chain from OMC, TSL, IMFA, and FACOR, from mine faces to final refinement, have shown significant presence of Nickel, Cobalt and PGE in waste dumps.

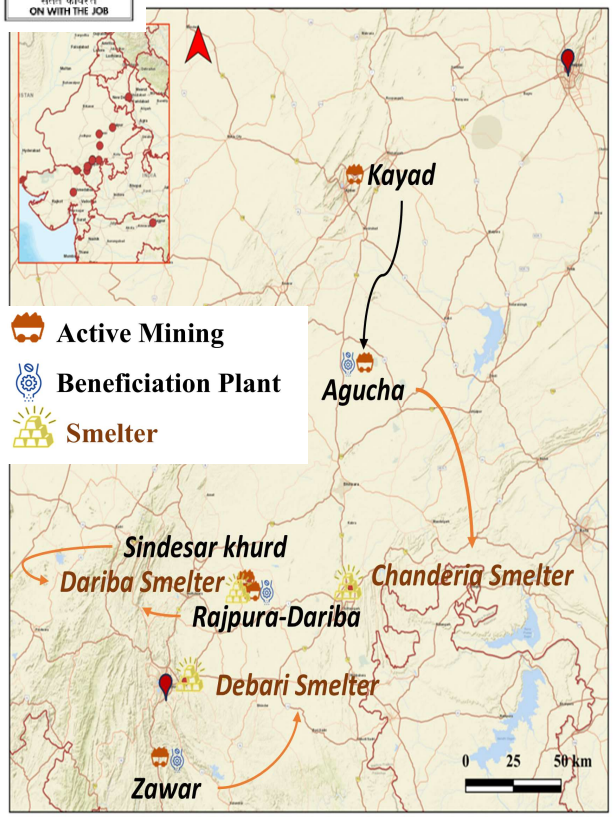
12 Working Leases, 442 Million Tonnes Dumps, Mine and Concentrate Contains high to very high Nickel(1.3%) & Cobalt Value(Average 571 ppm).

Copper: Mine Sample Analysis Results

06 Mining Leases of Copper operated by HCL in Rajasthan, Madhya Pradesh & Jharkhand, 99 samples were drawn from the mines and smelters plants.

Name of Mine/Processing Plant	Key Findings
Malakand Copper Mine and Processing Plant, MP	➢ Molybdenum (Mo) up to **117.08, 150.8** ppm and **3080** ppm in Mine face, waste dump and Concentrate sample respectively. ➢ Selenium (Se) **72.8 ppm**, Tellurium (Te) 1.06 ppm and Silver (Ag) **28.10** ppm in concentrate sample
Khetri Copper Mine, Rajasthan	➢ Cobalt (Co) up to **297.6** ppm in Mine face and **299.5** in Waste Dump ➢ Selenium (Se) up to **10.11** and Tellurium (Te) up to **1.18** ppm in mine face samples ➢ PGE (Pt+Pd+Rh) un to 266 ppb in mine face, 269 ppb in Mineral Stack, **493 ppb** in waste Dump
Kolihan Copper Mine, Rajasthan	➢ Cobalt (Co) up to **197** ppm in mineral stack samples ➢ Selenium (Se) up to **3.81 ppm** in mineral stack and Tellurium (Te) upto **1.07** ppm in waste Dump samples ➢ PGE (Pt+Pd+Rh) is 442 ppb in mine face, 161 ppb in Mineral Stack, **561 ppb** in waste Dump.
Khetri Copper Complex Processing Plant (ROM from Khetri and Kolihan Mine Processed here)	➢ Co **1378 ppm** , Ni 403 ppm, Mo 50.89 ppm, **Se 15.57** ppm and Te 1.33 ppm in Concentrate Sample. ➢ **PGE (Pt+Pd+Rh) up to 600 ppb in Tailing, Results for Feed and Concentrate are awaited**

Lead & Zinc Metals



- There are are 8 active mining leases primarily for Pb and Zn Mineral.
- 302 samples were drawn from the mines concentration and smelters plants.
- The results shows promising values for recovery of Antimony, Cadmium, Indium and Selenium from the smelter samples.
- In the mine samples collected from different litho units, Cadmium (Cd) concentrations are found to be notable.

  (i) Agucha mines, values reach up to 1114 ppm

  (ii) Zawar, particularly Balaria mines, concentrations rise to 1668 ppm

  (iii)Rajpura -Dariba mines, up to 576 ppm

  (iv) Kayad mines, up to 261 ppm.

Lead & Zinc :Waste dump & Tailings

	Waste Dump Quantity (in mT)	Tailing Area (Ha)	Tailing Quantity (in mT)
Rampura Agucha	712	1200	84.8
Rajpura Dariba	0.4646	155.08	23.87
Sindesar Khurd	1.921839		
Zawar Group		120.68	60.96

Insignificant concentrations of metal near the surface, as extensive leaching possibly causes their enrichment at depth; hence, subsurface sampling is essential to assess their true potential.

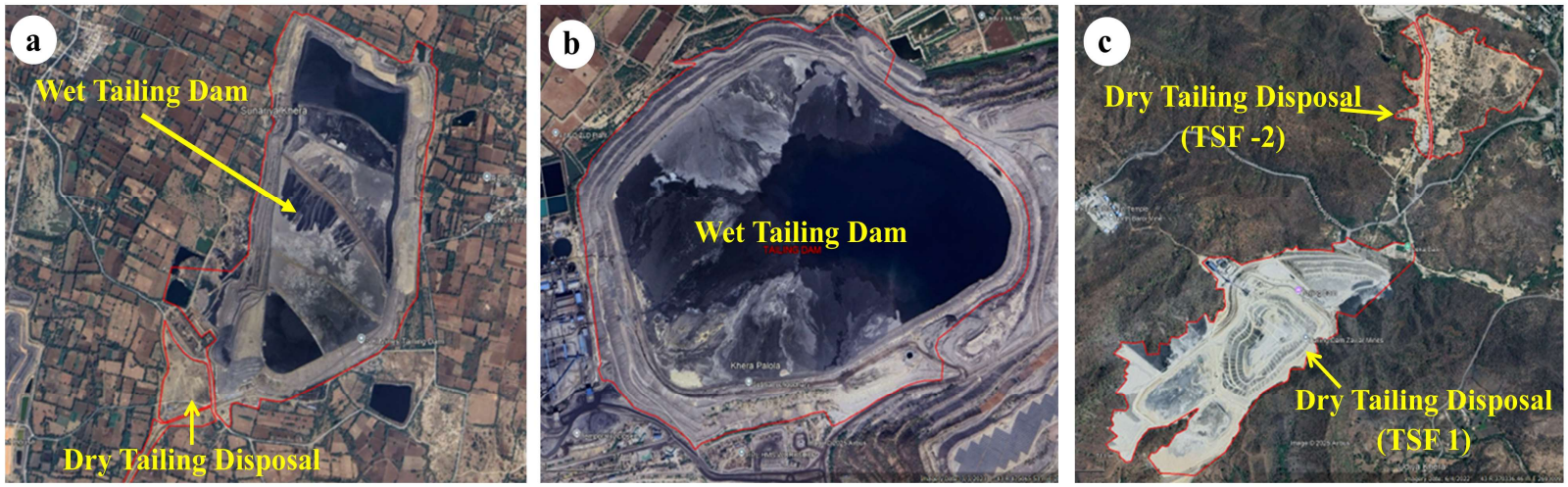


Fig. Tailing Storage facility at (a) Rajpura Dariba Mines (b) Rampura Agucha and (c) Zawar.