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**CSIR, INDIA -Mining, Minerals, Metals & Materials (4M) Research Theme**

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# ABSTRACT

The Council of Scientific and Industrial Research (CSIR) is one of India’s largest publicly funded R&D organizations and is internationally recognized for its contributions across a wide spectrum of science and technology domains. Over the past eight decades, CSIR has significantly advanced research and technological solutions in sectors such as chemicals, petrochemicals, pharmaceuticals, agriculture, minerals, mining, metals, nanotechnology, functional materials, environment, biotechnology, geophysics, genomics, electrochemistry, batteries, building materials, aerospace, instrumentation, and more. With a pan-India presence comprising 38 national laboratories, 39 outreach centers, one innovation complex, and three specialized units, CSIR continues to serve strategic sectors, industries, and society through impactful innovation.

Among its nine thematic areas, the 4M theme—Mining, Minerals, Metals, and Materials—has driven critical advancements in mineral processing, extractive metallurgy, and resource efficiency. Over the years, CSIR laboratories such as CSIR-IMMT (Bhubaneswar), CSIR-NML (Jamshedpur), CSIR-CECRI (Karaikudi), CSIR-CIMFR (Dhanbad), and CSIR-NIIST (Thiruvananthapuram) have contributed to the development and deployment of innovative technologies for mineral beneficiation, dry processing, pneumatic conveying systems, transport of minerals and extraction. These technologies are widely used in commercial operations both in India and Internationally.

CSIR’s current focus includes dry beneficiation, enrichment of low-grade ores, and hydrogen-based direct reduced iron (DRI) processes. With capabilities ranging from pilot plants to specialized testing facilities, CSIR has become a national leader in critical mineral research, developing technologies for the extraction and purification of elements such as nickel (Ni), cobalt (Co), Rare Earth Elements (REEs), Tellurium (Te), Selenium (Se), and others. Of the 30 critical minerals identified by the Government of India, CSIR has technological capabilities for nearly 21, leveraging both primary and secondary resources.

Significant progress has been made in recovering rare earth elements (REEs) from fly ash, and extracting valuable metals from red mud. CSIR-IMMT, as the nodal institution for deep-sea mineral metallurgy, houses dedicated pilot facilities for processing polymetallic nodules and sulphides under collaboration with the Ministry of Earth Sciences.

CSIR’s national missions—Mapping and Tapping of Critical Minerals, Battery to Battery, SEAS (Solar Panels, Electronics, Appliances & AC waste), and Lithium from Primary Resources—are in progress across key laboratories with active support from ministries including Mines, Coal, Steel, New & Renewable Energy, Heavy Industries, Environment, and NITI Aayog. These coordinated efforts aim to enhance India’s self-reliance and sustainability in the critical minerals domain.

# KEY WORDS

# *Critical Minerals, Mineral Processing, Rare Earth Elements (REEs), Sustainable Resource Utilization, Marine Minerals Metallurgy*

# BIOGRAPHY

Dr. Ramanuj Narayan is the Director of the Council of Scientific and Industrial Research-Institute of Minerals and Materials Technology (CSIR-IMMT) in Bhubaneswar, India. He also serves as the Director of CSIR's Mining, Minerals, Metals, and Materials (4M) thematic area, overseeing research and development across approximately 25 laboratories nationwide. Under his leadership, CSIR-IMMT has initiated significant collaborations, including a partnership with Australia's CSIRO to develop technologies for recovering titanium dioxide and vanadium from Indian minerals. Dr. Narayan is committed to advancing sustainable mineral processing technologies and fostering international collaborations to enhance India's capabilities in critical minerals research.

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