Exploring Seabed Mining in the Indian Ocean Region (IOR): Policy and Governance Insights for Pakistan

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Abstract

Deep Seabed Mining (DSM) has emerged as a critical avenue in the Indian Ocean Region (IOR), primarily for key stakeholders like China and India. These nations have already identified DSM as a way to secure critical energy minerals and metals – necessary for green technology transformation, which could boost their economies and industrial capabilities. Despite having significant maritime territorial claims under UNCLOS, Pakistan is lagging behind in utilizing such an opportunity. This research paper aims to examine the deep seabed exploration and mining strategies of China and India to identify actionable policies for Pakistan to advance in DSM industry. This research relies on extensive qualitative and thematic analysis to analyze the technological, legal and environmental frameworks these nations have implemented to gain upper edge in DSM capabilities. Furthermore, this study identifies gaps that challenge Pakistan in its healthy participation in DSM program. Subsequently, the findings reveal that China's centralized governance approach contrasts with India's multi-institutional strategy. Based on these models, Pakistan should follow a coordinated step-by-step approach. This piece of research puts forth recommendations to reform the policy framework, enhance technological advancement through international collaborations for a balanced approach to initiate its seabed mining industry and addressing both environmental and economic concerns.

Keywords:

Deep seabed mining, Green technologies, Strategic resources, Blue economy, Sustainable mining practices, International Seabed Authority (ISA)

1. Introduction

The seabed or the "final frontier" for resource exploration is increasingly evolving into a strategic axis for the major nations in constant pursuit to gain economic viability and regional dominance by securing strategic minerals (Baird, Stephen L, 2006). Recently, China and India have made substantial headway in the DSM efforts, motivated by their interests to enhance and modify their supply chains and industrial capacity, respectively. Conversely, Article 76 of UNCLOS grants Pakistan rights to exercise sovereignty on the maritime territory expanding up to 290,000 square kilometers. (Persand, 2005) This expansion appoints the nation as a critical player in regional maritime affairs, having a significant legal victory Pakistan has the leverage to unveil the untapped potential for the exploration and exploitation of seabed

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resources. Subsequently, an emerging avenue for economic growth and resource development awaits a productive exploration (Mehmood, 2024).

In this regard, the United Nations Convention on the Law of the Sea (UNCLOS) and the International Seabed Authority (ISA) provide the legal framework for deep seabed mining exploration. (Singh, 2024) However, laws to regulate the sustainable extraction of resources are underway. Primarily, Articles 140 and 143 of UNCLOS highlight that the conduct of mining activities in high seas will bear equitable benefit for mankind as a whole keeping in view the regulation of environmental protection of marine resources (UNCLOS (1982), n.d.) DSM signifies a $20 trillion prospect to extract critical minerals to drive green technologies. (Ilya Epikhin, 2024) Taking note of the preceding framework, DSM activities have become more relevant lately due to the continuous depletion and dislocation of terrestrial resources such as nickel, aluminum, manganese, lithium and cobalt. Additionally, increased dependence on valuable minerals, economic interests, and strategic opportunities stimulate the sustainable exploration of yet-to-be-explored rare earth metals and minerals (Ashford, 2024). This endeavor offers a potential alternative to land-based exploration opening new frontiers of mineral discovery.

Therefore, the world has shifted its eyes towards deep-seabed resources. China's seabed mining expeditions fueled by advanced technologies and institutionally centralized governance make it a leading nation in this venture. (Zhong, 2023) In contrast, India is demonstrating its intent to secure the "seabed hegemony" driven by a multi-institutional approach within the Indian Ocean Region (IOR) as a counterbalance to China. Regrettably, despite having established bodies like the Ministry of Energy, Ministry of Maritime Affairs, and the National Institute of Oceanography, Pakistan remains notably behind in this program. Concerning this, Pakistan is over-hauled by numerous challenges encapsulating technological limitations, weak or no concerned regulatory framework, poor environmental preservation techniques, and marginal investments. (Desk, 2024) This DSM industry calls for advanced technologies coupled with complex regulations to ensure sustainable practices further supported by crucial funding- areas where Pakistan currently lags.

While drawing valuable insights from their strategies and legal frameworks, this paper aims to analyze the upward trajectories of China and India in the deep sea mining industry. By studying the experience of these key stakeholders in the Indian Ocean Region, this research is focused on suggesting actionable policy recommendations for Pakistan to kick-start its seabed mining venture. However, this initiative might be addressed by a focused approach merely by structural refinement or perhaps by establishing a dedicated body exclusively for this domain. Additionally, this study investigates the potential for offshore resource exploration and exploitation in Pakistan, analyzing the current organizational structure, capabilities, and challenges.

2. Deep Seabed Mining: Explained

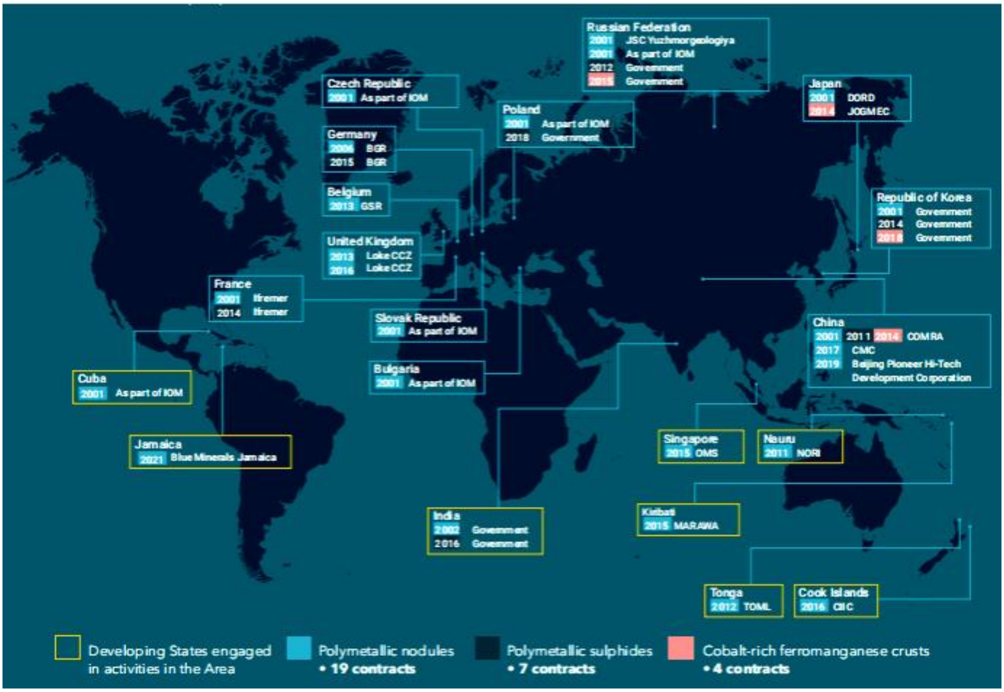
Extraction of critical mineral resources from the ocean floor from the depth greater than 200 meters is termed as deep seabed mining (Brief, 2022). This process involves collection of rare earth metals like polymetallic nodules, polymetallic sulphides, cobalt-rich ferromanganese crusts, and phosphorite from “the Area” (Monitoring, 2006). According to Part XI of UNCLOS (1994), the Area lies beyond the national jurisdiction of states while the rules and regulations to gain maximum common benefit out of the area were approved by the International Seabed Authority (ISA) (Anderson, 1995).

In 1994, The International Seabed Authority (ISA) was established under the ambit of UNCLOS with primary mandate to deal with the issuance of exploration and extraction licenses, regulating the set of rules to ensure sustainable practices, and verifying environmental protection (Britannica, 2024). Additionally, ISA oversees the enhanced capacity building of the developing countries coupled with the transfer of necessary technology to pursue the seabed mining. Moreover, ISA facilitates research and development programs to better understand the biodiversity and estimate the mineral potential of the seabed.

Notably, The International Seabed Authority has formulated a detailed verdict for its healthy contribution in 2030 Agenda for Sustainable Development, with specific focus on SDG 1 (poverty eradication), SDG 8 (Decent work and Economic Growth), and SDG 10 (overcoming inequality) (ISA, 2021). Currently, ISA is dedicated to assure a balanced extraction of deep-sea resources-with 31 contracts in hand. The contracts for exploration and to gather the significant data to initiate the extraction process spans 15 years (Lopez, 2023). Among aforementioned contracts, a few got extensions under the sub-organization of ISA, Legal and Technical Commission (LTC). This extension leveraged the states to continue exploring more relevant geographical data until the formal laws and regulations for extraction of resources get finalized (Gales, 2023).

Within this scope of working, ISA ensures the equitable participation of the less privileged nations. As this venture is quite economically demanding with having access to advanced technology another tool, developing nations cannot afford this program. So, to ensure their participation, privileged nations applying for exploration contracts have to divide their application into two parts based on the commercial value of their findings within the high seas. The ISA, after gaining the data and required information from the applicant (developed nation)-will designate some portion of the area as a “reserved site” which will later be accessible for the developing nations (ISA, Status of Exploration Activities in the Area, 2024)

Figure 1: *International Seabed Authority, Status of Exploration Activities June 2024*



3. Intersecting Deep Seabed Mining and Global Energy Needs

Deep-sea mining offers prolonged yet sustainable potential to supply critical minerals to interface with Clean Energy Technologies and its growing demands. In this regard, International Seabed Authority has already outlined a plan to regulate the deep-sea mining by 2025-reflecting its growing recognition in today's world.

This growing recognition is accentuated by recent global trends, where a steep climb of electric-vehicles purchase hit 60% in 2022 (surpassing 10m units) (Diaz, 2023) and notable call for green technologies have been observed. It is to be noted that only between 2017-2022, global energy sector need for lithium upsurged trippling overall demand of lithium with 70% and 40% rise in requirement of cobalt and nickel, respectively. (IEA, 2023) The necessity of such minerals extended beyond this point as statistics project 400%-600% sharp surge in global energy needs within coming decade-driven by augmented reliance on zero-carbon technologies and wind and solar power batteries (News, 2023) Additionally, the International Energy Agency claims that need for copper is going to get double by the end of 2050 surpassing supplies by 2.7 million tons unless new sources take an alternative shift. This scenario has propelled the energy related market size to double hitting the staggering worth of US $320 billion in 2022 making such minerals a top-notch need of mining industries (IEA, Net Zero by 2050, 2021).

In this regard, the global push has been noticed where major nations are formulating the policies and initiating the exploratory programs to save themselves a pertinent opportunity for economic growth (WEF, 2023). The International Energy Agency's Critical Minerals Policy Tracker has already identified around 200 regulations globally, out of which 100 regulations have been implemented successfully recently. List of regulations started to surface in the contest of deep-sea mining, such as, the European Union's Critical Raw Materials Act, the US's Inflation Reduction Act, Australia's Critical Minerals Strategy, Canada's Critical Minerals Strategy and a lot more (IEA, Introducing the Critical Minerals Policy Tracker, 2022)

3.1Seafloor Mineral Riches

The DSM increasingly offers a potential remedy for the expected global shortage of transition-critical raw material (McKie, 2023). As the global demand for such raw material increases, the world is seemingly to extract three primary types of mineral resources namely polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts from four internationally designated ocean floors I.e., Clarion Clipperton Zone (CCZ) which lies between Hawaii and Mexico, Penryhn Basin - situated in South Pacific Ocean, Central Indian Ocean Basin (CIOB), and the Peru Basin (Singh P. A., 2020).

3.2Polymetallic Sulphides:

Pollymetallic Sulphides, also referred as the Seafloor Massive Sulphides (SMS) are found at the pits of colossal volcanic activities. SMS are formed as a product of the process through which metal-rich superheated water passes through the seabed cracks in the form of black and white steams via chimney like structures (German, 2016). These deposits are usually found at the depth of 1000-4000 meters, while around 300 SMS deposits have been identified to date only a few holds commercial value (Fouquet, 2016). Accordingly, the mining method of SMS is similar to the land mining process "open-pit mining method" in which the ore is crushed and is forced to come-up the surface. However, this method is not that eco-friendly as the sediment plumes might contaminate the marine environment (Markus H.A. Piro, 2020). The marine ecosystem around the hydrothermal vents (chimneys) contains diverse biodiversity that take longer time to recover, retain and sustain compared to other marine areas. The ISA has designated the area of 10,000 square kilometers for the exploration of SMS, divided into the 100 blocks each 10x10 area.

3.3Polymetallic Nodules:

Polymetallic Nodules follow a historic course of gradual evolution and transformation with the plodding precipitation of metallic compounds. Typically, having 5-10 cm diameter - these nodules lie in the deepest part of the ocean ranging from 4000-6000 meters, scattered predominantly in the Clarion Clipperton Zone (CCZ) and Central Indian Ocean Basin (CIOB) (Kuhn, 2017). As far as the mining technique is concerned, these nodules are extracted from soft sediments and are bring up to the surface via customized vehicles. Due to fragile and dispersed composition of these nodules, mining operations are pursued under critical observation in the economically viable areas (Mewes, 2014). However, mining programs can potentially cause disturbance in the marine ecosystem such as down-slope. Down-slope is the phenomenon of the dislocation of the useful sediments from higher to the lower areas (Dale, 2015). In this condition, the biodiversity present in the depth of 4000-6000 meters (abyssal plains) are characterized by low-biomass and slow growth which make them highly vulnerable to such disruption in ecosystem as recovery from such negative impacts maybe slow (Darlene Trew Crist, 2013). The ISA grants the area of 150,000 square kilometers for the exploration of polymetallic nodules to each contractor (ibid).

3.4 Fromanganese Crusts:

The Western Pacific Ocean harbors the highest degree of cobalt-rich ferromanganese crusts which accumulate at the rate of 1-6 mm per million years and is further expected to reach up to 25 cm in solidity. These minerals can be found at the seafloor where the sediment ratio is low at the maximum depth of 800-2500 meters (Hein, 2013). The technique to extract such mineral involves the careful removal of crust without disturbing the underlying structures to ensure the purity of the metal. The obtained material is usually crushed and transported to surface in a slurry (Koschinsky, 2014). The ecosystem at the subjected depths hosts diverse range of coral reefs, sponges and mostly flora which are long-lived and have relatively slow reproduction process. The mining operations can significantly cause damage to marine world existing there (Halfar, 2007). The ISA has limited the exploration area to maximum of 3,000 square kilometers at a time with the divisional support of 150 blocks not exceeding than 20 square kilometers in size (ibid).

Table 1: *Fromanganese Crusts*

	Polymetallic Nodules	**Polymetallic Sulphides**	**Ferromanganese Crusts**
Water Depths	4000 - 6000 m	1000 - 4000 m	800 - 2500 m
Deposit characteristics	15-25 kg/m2	20m deep	25-78 kg/m2
Mineral Resources	Manganese, Cobalt, Copper, Nickel	Iron, Copper, Zinc, Lead, Gold, Silver	Cobalt, Titanium, Cerium, Nickel, Platinum, Manganese, Thallium, Tellurium
Commercial Use	Steels, Batteries, Wires, Wind Turbines	Steels, Batteries, Wires, Jewelries	Steels, Batteries, Automotives, Electronics, Jewelries
Mined/year for 2 million tons of ore	80-130 km2	200 x 200 m	25-80 km2
Regulation for Exploration?	Introduced in 2000 and revised in 2013	Regulation was adopted in 2010	Adopted and initiated in 2012

Abundance of Resources w.r.t. Ocean Patches	■ Clarion Clipperton Zone (CCZ), ■ Central Indian Ocean Basin (CIOB)	■ Mid-Atlantic Ridge, ■ Central Indian Ocean Basin (CIOB)	■ North-West Pacific Ocean, ■ Western Pacific Ocean
Major Players	✓ COMRA (China) ✓ Government of India ✓ Government of Korea ✓ JOGMEC (Japan) ✓ Ministry of Natural Resources and Environment of the Russian Federation	✓ COMRA (China) ✓ Government of India ✓ Government of Korea ✓ BGR (Germany) ✓ Government of Poland ✓ Government of the Russian Federation ✓ Ifremer (France)	✓ COMRA (China) ✓ Government of Korea ✓ JOGMEC (Japan) ✓ Ministry of Natural Resources and Environment of the Russian Federation

4.Central Indian Ocean Basin (CIOB), Potential Energy Power Bank for Pakistan

The Indian Ocean Region has become a prime focus as a DSM avenue with hosting five out of thirty-one contracts awarded by International Seabed Authority (ISA, Status of Exploration Activities in the Area, 2024). These contracts are largely dedicated to the exploration of Polymetallic Sulphides (SMS) and Polymetallic Nodules by the Government of India and other nations like China-leading the game (Kuo, 2019). India has already secured two exploration contracts and has submitted two more applications for the exploration of such critical minerals. This shows the resilience and eagerness among the nations to get their mark on seabed mining (Agarwal, 2016). The exploration area within Central Indian Ocean Basin (CIOB) accounts for 0.1 million square kilometers which makes 7.1% of total ISA zones of contracts (ibid).

The Indian Ocean floor encompasses rich minerals, including terrigenous, biogenous, and anthigenic types. The wet hot climate of the nearby land speeds up the breakdown of source rocks. This, along with heavy river flow and strong waves and currents, helps create various sediment deposits (Nidhi, 2023). It's worth mentioning that the coast and offshore sediment deposits in the Indian Ocean are some of the biggest in the world. Moreover, life-derived deposits in the Indian Ocean include coral reefs on shallow banks, and continental shelves, and deep-sea sediments.

Experts say that people have found Phosphorite deposits along continental margins in places like South Africa and Western India, and around seamounts in the

Eastern and Western Indian Ocean (H.N. Siddiquie, 1984). Strong upwelling along the continental margins of South Africa, East Africa, Southern Arabia, Western India, and the Andamans creates environments that suppress deposits to form, which helps phosphorite to develop. The polymetallic nodules in the Indian Ocean cover an area of about 10-15 million square kilometers, with resources of around 150 billion tonnes (Prasad, 2007). After analyzing more than 900 chemical samples from 350 locations, scientists discovered that whereas reserves in most basins are not lucrative enough, those in the Central Indian Ocean are (Kuhn, 2018). In this area, nickel, copper, and cobalt make up more than 2.4% of the deposits, and they're found in densities greater than 5 kg/m^2 (Michel, 2012).

At the start of this talk, we should keep in mind that Pakistan has big problems with how it uses energy. About 46% of its electricity goes to homes that do not produce anything, while 28% goes to factories. The same thing happens with natural gas - homes use 20%, but factories use just 18%. Making things worse, Pakistan depends a lot on fossil fuels. These make up 64% of all the energy it uses, with hydro-power at 27% and other clean energy and nuclear power at 9%. Not only does this dependence increase the cost of electricity, but it also puts Pakistan in danger in the event that its supply is cut off (Sattar, 2024).

Conversely, India has been investing profoundly in the buildup of renewable energy sources such as wind and solar electricity with the aim to make such facility cost-effective and affordable. India's this preemptive approach has made it distinguished from Pakistan, which relies heavily on the fossil fuels. By pondering more in the sustainable energy sources, India has attained relatively stronger position in the region's energy field.

The Pakistan Energy Outlook Report (2021-2030) estimates that the energy demand of the nation is likely to go high due to increased transportation need, augmented industrialization requirements and economic advancement. The report expects total energy use to go up from 17.03 million tons in 2020 to 24.15 million tons by 2030. Motor spirit and high-speed diesel (HSD) demand will reach 20.8 million tonnes by 2030 up from 13.86 million tons in 2020 (GoP, 2022). By 2030, the 33% share of furnace oil (FO) in power generation will be gone (Bhutta, 2017). Gas use for power will drop from 400 billion cubic feet to 200 billion cubic feet each year because reserves are running out. The government plans to use more local coal. This will almost double the coal demand for power and industry. Coal will become the second-biggest primary energy source by 2030 (Malik, 2024). Its use will grow from 26 million tons in 2020 to 50 million tons in 2030. These forecasts show we need to plan to handle the expected rise in energy demand and the switch to different energy sources (GoP, 2022).

In essence, the DSM avenue could bring an economically viable opportunity for Pakistan to bridge he energy gap by diversifying its energy sources and strengthening its energy supplies. As outlined by the Pakistan Energy Outlook Report 2021–2030, Pakistan would want more energy-based industry and transportation in the wake of increased energy demands and shrinking on-land fossil fuels. By putting money into DSM, Pakistan can tap new marine mineral deposits, which could cut down its heavy use of coal and other limited resources. This smart move could help close the energy gap, boost economic strength, support smart resource use, and make Pakistan more competitive in the global energy market."

5.Chinese Driving Mechanism in the Deep Seabed Mining Business

China is the only country that has five out of the thirty-one ISA exploration contracts ever issued, having rights to potentially explore the area of 238,000 square kilometers. The size of that area is almost the same as New Zealand. China remains one of the leading actors in global supply chains for critical minerals, especially those that are requirements for green technologies like batteries, electric motors, and turbines (Zhong, 2023).

5.1 Legal Framework

The Deep Seabed Law enacted in 2016 supports state-owned DSM in China. This provides a legal framework for exploration and development, scientific and technological research, marine environmental protection, sustainable use of resources and human common interests (Zhixiong, 2017). Article 5 assigns the oceanic administration of the State Council, specifically the SOA, to manage these activities under the deep seabed law (Chen, 2020). However, with the 2018 State Council's Institutional Reform Plan, the SOA's roles are split between the Ministry of Natural Resources, in charge of oceanic administration, and the Ministry of Ecology and Environment, in charge of marine environmental protection (Council, 2014).

5.2 Commercial Policy

Within the licensing scheme, the Chinese government, further stipulates that any Chinese citizen, legal person, or organization desirous of applying for an exploration and development contract with the ISA should first lodge an application with the SOA. Following an examination of the application documents and qualification review and those who qualify, the SOA is obligated to hand over the permit within 60 working days. Once this permit is secured, the entity can then contract with the ISA and provide a copy of the signed contract to the SOA within 30 days from date (Xiangxin Xu, 2015).

This dual-track approval mechanism of requiring a national license from the SOA and having a contract with the ISA, is similar to what is obtaining in some other countries, like the Czech Republic, Fiji, Germany, Japan, Nauru, New Zealand, Singapore, Tonga, Tuvalu, and the United Kingdom, where the applicants have to possess a valid national license or state sponsorship before participating in DSM operations (Zhang, 2016).

5.3 Deep-Sea Mining Research and Development

Under the arm of China Minmetals Corporation as a state-owned entity, deep-sea mining research and development have been majorly concentrated, a reflection of China's commitment to this sector. The Ministry of Natural Resources plays the role of a regulator operating under the framework of the Deep Seabed Law. The SOA, now absorbed in the Ministry of Natural Resources, still operates under its brand for public convenience and supervision and administration of deep seabed activities conducted by Chinese nationals (Lam, 2024). The role played by the Ministry of Ecology and Environment is also significant, especially in the context of issues relative to environmental protection.

5.4 Tech Advancement

Chinese deep-sea ships are actively prospecting, searching, and taking all these minerals from the Pacific, Indian, and Arctic Oceans. Recently in July 2024, "Kaituo 2", a 14-tonne vehicle, has presented its debut performance by hitting the depths upto 4300 meters (Tong, 2024). Not only this, in fact in June 2024 China developed a series of equipment under the ambit of world's first intelligent electric deep sea vehicle- a project which was designed for multi-point drilling and sample collection. In case of successful identification and extraction, it will further solidify the Chinese position leading the world to discover new finds of nickel, copper, cobalt, manganese, zinc, silver, and gold (Atkinson, 2024).

5.5. Chinese gains of Deep-Sea Mining

Deep-sea mining ventures led by state-owned companies have derived the Chinese Government to huge investment benefits. As early as 2025, private firm Jinhang Group has already secured 20 million RMB in angel investment and is accelerating efforts to develop China's first commercial deep-sea mining robot and sophisticated mining control systems (Cheng, 2024).

In supplying these resources, China dominates the mineral industry and its ownership of critical foreign mineral resources, such as cobalt from the Democratic Republic of the Congo. The country also accounts for being the world's largest processor of minerals and handles most of the global operations (John Coyne, 2024). According to a recent study by S&P Global Inc, it has established that 11 of the 16 nickel sulfate manufacturer companies are placed in China, which is expected to produce 824 billion metric tons annually by 2030 been while North America and Europe would manage only 146 billion metric tons combined (Karan Bhuwalka, 2024). This dominance stems from long-term strategy, securing mineral resources, building large capacities for processing, and offering them at competitive rates. This strategy has been allied with government support-through state-owned enterprises and direct financial investments.

Beijing has a strong-hold on the resources, and thus the global supply of critical minerals may be expected to experience disruptions caused by any kind of trade restrictions, political instability, natural disasters, or other shocks. As green technologies increasingly gain acceptance and give a multiplier effect on the demand for critical minerals, this supply risk is going to increase in the long run. According to the International Energy Agency, demand for nickel and cobalt is going to be six to twenty times more than in 2020 to meet the objectives of the Paris Agreement by 2040.

6. Indian Seabed Mining Efforts and Mechanism in Central Indian Ocean Basin (CIOB)

India has been involved in this ocean floor exploration and was assigned almost 1.5 lakh km² of the Central Indian Ocean Basin (CIOB) for the extraction of nodules. In 2002, the Indian government had a 15-year deal with International Seabed Authority, ISA, to extract from the Central Indian Ocean Basin polymetallic nodules containing nickel, cobalt, copper, and manganese (NIO, 1982).

6.1Commercial Policy

To further the endeavor, the Hydrocarbon Exploration and Licensing Policy (HELP) was launched to oversee the production of oil and gas in the Indian sedimentary basin. Noted in the vision, this initiative is to reduce 10% hydrocarbon import dependency by 2022. Additionally, New Delhi plans to add 500 gigawatts in renewable energy capacity by 2030 and will look to meet half of its energy needs through renewable sources (Varadhan, 2019). India wants to bring its greenhouse gas emissions to net zero by 2070, with securing critical minerals, including deep seabed supplies likely playing a key role (Bureau, 2023).

HELP introduces a Revenue Sharing Contract (RSC) model, while through the Open Acreage Licensing (OAL) mechanism, investors can carve out blocks of their choice using data from the National Data Repository (NDR) and submit Expressions of Interest (EoI) year-round, leading to biannual formal bidding processes. Key features of HELP include a single license, covering all types of hydrocarbons, revenue sharing simplified, royalty rates reduced and graded, fiscal incentives including tax exemptions on crude oil and custom duty exemptions on equipment, full marketing and pricing freedom, extended periods for exploration and production, and Reconnaissance Contracts (RC) for early exploration activities (IEA, Hydrocarbon Exploration and Licensing Policy (HELP), 2023).

6.2Attainment of Deep-sea Mining Capability

Notably, India has established deep-sea mining capability focused on polymetallic nodules and intends to start commercial mining in the CIOB once the ISA releases the mining code. India is among the eight contractors with client status and coordinates a long-term exploration and utilization program under the auspices of the Ministry of Earth Sciences (MOES), that encompasses survey and exploration, environmental studies, technology development in mining and extractive metallurgy for which significant contributions have been already made (PIB, 2017).

According to the latest reports, India has submitted applications for the exploration of the Carlsberg Ridge and Afanasy-Nikitin Seamount located within the Central Indian Ocean Basin. One application targets the polymetallic sulphides with an area of 10,000 km² along the Carlsberg Ridge; this area will be further divided into 100 blocks, 10 km² in size. Another application targets the cobalt-rich ferromanganese crusts along the 3,000 km² area around the Afanasy-Nikitin Seamount, which will be further divided into 150 blocks up to 20 km². A keen interest to exploit the Indian Ocean basin's huge rare deposits, it is estimated to have 380 million tons of polymetallic nodules which would be worth more than 102 billion euros (ISA, 2024).

Besides the polymetallic nodules, CIOB possesses a deposit of 4.7 million tons of nickel, 4.29 million tons of copper, 0.55 million tons of cobalt and 92.59 million tons of manganese (PIB, 2017). This geological assessment is made apparent by the extensive governmental investments, such as 887 million euros in 2019, as well as another 452 million euros over five years in 2021. Such investments make clear the desire of India to extract the wealth from the ocean. India has identified 11 potential sites for exploration of hydrogen sulphide, developed a dedicated multi-purpose vessel for detailed surveys, and has now produced a hydrogen sulphide plan (Najafizada, 2023).

7. Technological Advancement and Deep-Sea Mining Strategies

As far as the technological axis is concerned, India is investing into the development of submersibles that can reach six kilometers depth inside the ocean. With these technological advances and limitless deposits, the country of India has a good chance to become thoroughly independent regarding mineral resources. In 2021, the Indian Cabinet formally approved the Deep Ocean Mission to be executed officially for exploration activities (Khadka, 2024). The DOM has been projected as a mission-mode project that would support the Blue Economy initiatives of the government and MoES would be the model ministry implementing the multi-institutional mission. It will cover some of the themes: impacts of climate change on oceans, deep-sea technology development for biodiversity and mineral resource exploitation, underwater robotics, and climate advisory services. Other areas include sustainable marine conservation, desalination in the deep sea, energy generation from the offshore renewable energy, and mineral extraction from ocean belts to ensure clean drinking water (Staff, 2023).

As a sequel, in 2023 the National Institute of Ocean Technology released an announcement of the deployment of Samudrayaan Mission with three crew strength on board, of a submersible called 'Matsya' to the deepest areas and survey the environmental impacts. This is further continuation of the achievements of the National Institute of Oceanography in terms of extraction of polymetallic nodules brought out using the underwater remotely operated vehicle supported by RV Gaveshani from a depth of 4800 meters (Banerjee, 2023).

Apart from MoES, a chain of institutions such as Indian Space Research Organization (ISRO), Bhaba Atomic Research Center (BARC), Council of Scientific and Industrial Research (CSIR)-National Institute of Oceanography (NIO), Defence Research and Development Organization (DRDO), Indian Meteorological Department (IMD), and the Department of Biotechnology, is working in tandem. Union Minister Jitendra Singh stated that the Deep Ocean Mission is the bedrock of the Blue Economy initiative, crucial for the country's economic prospects. The mission received accolades from ISA Secretary General Michael W. Lodge, who confidently said that India has the potential to emerge as the global leader in deep sea mining.

7.1 Corresponding Legal Framework

On legal front, India has provided framework for the Deep seabed mining ventures including National Offshore Mineral Policy-2019 that creates a strategic and sustainable way of offshore mineral exploration and exploitation by clearly defining rules and regulatory mechanisms, while the Mineral Laws (Amendment) Act, 2020, brings important reforms to increase transparency, refine extraction processes and to make them more systematic, in addition to regulating the entire process in a fair manner. These are complemented by the National Ocean Policy (2019), which aims to fully integrate comprehensive management of ocean resources, promotes sustainable development and effective governance. Among other policies, these complement each other to provide robust and transparent regulatory frameworks that would promote investor confidence and promote efficient operation in DSM.

7.2 International Collaboration

In fact, India is moving fast for international collaborations to push its seabed mining projects. India and Australia announced $280 million investment in 2022; out of which $27.2 million will go to a strategic research fund to strengthen the potential of seabed mining. Critical minerals, cyber and critical technology, science and innovation are the priority areas. And as a matter of fact, Green Steel Partnership includes commercialization of extracted minerals, so India will move up the global rankings of critical resource holding countries. Rare Earth Elements (REE) mining along the coastal belt of Odisha is planned in near future with major collaboration with Japan which is developing robotic deep-sea mining technology for rare earth metal extraction from 2024 (MSrivastava, 2023).

India's R&D investment in seabed mining is to strengthen national capabilities and technology. By training personnel India is moving towards more sustainable extraction methods and becomes stronger in global seabed mining. This proactive move also encourages neighboring states to venture into seabed mining as regional states fear China's growing influence in deep sea resources. India is further benefited by ISA's membership on the Finance Committee of the International Seabed Authority (ISA). This is the body constituted under Part XI of the Agreement of 1994. The mandate of this body is the supervision of the financial management of ISA. These members are elected, five each, from the Assembly for a term of five years. This ensures that all relevant geographic areas and special interest groups are represented, and thus India has a seat in determining critical decisions and recommendations on the financial rules, regulations, and program implementation of the authority. This means that India's interests, especially on DSM, will be brought and dealt with effectively.

8. Lessons for Pakistan

Country-wise, the challenges in deep-sea mining range from being technical to economic and organizational, right through to environmental and legal hurdles. In Pakistan's case, it lacks modern technologies and advanced equipment, and governance structure may not provide funding for large ventures. Organizational and leadership challenges exist, as well as stumbling blocks in communicating with stakeholders or setting up specific bodies. Legal and jurisdictional challenges include the need to comply with international maritime law. Other challenges include environmental and diplomatic issues, including gaining membership in international organizations, strategic and military concerns, competition with India, and other factors which are a threat to security as well as regional stability.

For the purpose, Pakistan can avail following lessons to ensure the feasible means for the deep sea mining industry:

1- Pakistan may follow the best practices that integrate practitioners with the energy of young researchers under a single program. By inducting more young professionals from key disciplines, such as marine geology, environmental sciences, and engineering while retaining the experience of people, Pakistan's effort at mapping and exploring deep sea resources might be energized.

2- Like India and China, Pakistan will have to establish specialized research vessels and sophisticated technology for deep-sea operations along with training programs for quality data acquisition. This would ensure that the country adheres to international standards that instill confidence in data accuracy as well as strengthens international partnerships. However, it is a very challenging task for which Pakistan will have to look forward to foreign aid.

3. Pakistan needs to capitalize on its research and development field. This will enhance Pakistani expertise across fields of research into the seas, and support the scientists to publish their findings in international journals. This, like others, will enhance the profile in international seabed mining, as well as achieving recognition of the specific individual researchers and hence assist in securing a specific spot in the business of seabed mining for Pakistan.

4. Pakistan must strengthen its legal structure. Gaining insights from China's Deep Seabed Law and India's National Offshore Mineral Policy, by launching crystal clear legal frameworks into legislation in respect of exploration, environmental protection and resource sharing-Pakistan can thrive on the mining program. A central regulatory authority should be established for streamlined oversight and Pakistan must get aligned with the international seabed governance.

5- As in the case with India, Pakistan should also look out for a cooperation arrangement with China which would bring technical expertise, research and development and investment for a country in the form of seabed mining technologies. Pakistan could then avail cutting-edge tools and best practice and build sustainable mining capacities.

6. A graduate program needs to be undertaken that can enable capacity building and expertise through knowledge transfer, training, and a few pilot projects. That process of step-by-step development will go hand-in-hand with cooperative agreements and strategic partnership thereby letting Pakistan develop its expert cadre and infrastructure without pouring in billions in the next immediate instalment, thus reducing fiscal pressure.

9. Way Forward:

- It is viable for Pakistan to opt a coordinated step-by-step approach. Increased capacity build, forge partnerships and tap foreign experience to enhance seabed mining capabilities-are the prime areas. In order to initiate the deep-sea mining program, Pakistan needs a strong strategic collaboration with foreign developed countries like China. In this regard, Pakistan Navy may extend its logistical and security support to China, whereas, China can collaborate on the economic and technical level by mining and shared benefits. That way, Pakistan can send young researchers over to China for technical training, and they would make their contribution to the country.

- To ensure the legal framework, Pakistan must see that the Special Investment Facilitation Council, SIFC, is promoting facilitation of investment while assuring coordination with the energy sector entities as well so as to ensure overall oversight regarding offshore resource exploration.
- Thereby, a central authority is a must for Pakistan to ensure the elimination of the hardships interlinked with deep-sea mining. So, under the Ministry of Maritime Affairs, a National Seabed Authority (NSA) would be needed to be established. With the concept of "one window operation," the NSA would straighten the process of resource discovery thereby accelerating the whole process and thereby eliminating bureaucracy.
- The aim of conducting hydrographic surveys, coordinating the other relevant international organizations, formulating policies and rules, and monitoring the development projects must be under the NSA. It will ensure environmental protection, monitoring of the activities undertaken on the seabed, and research into new means of exploration. In this way, the NSA will strengthen coordination with international organizations, manage seabed resources better for more economic benefits, and increase transparency and accountability. The whole process shall be guided by a feasibility study, stakeholder consultation, production of a comprehensive proposal, and approvals from the relevant authorities, recruitment of personnel and establishment of the NSA secretariat. The NSA will then implement policies, rules, and regulations for seabed exploration and start coordination with international organizations. With the institution of a National Seabed Authority, Pakistan can be assured of having a coordinated, focused and sustainable deep-sea mining approach towards unlocking potential for economic growth, environmental protection, and an international collaboration.

10. Conclusion

In a nutshell, Pakistan's pursuit of deep-sea mining needs a well-structured, step-by-step strategy that addresses challenges faced currently in terms of available technologies, financial, and organizational issues. Therefore, the establishment of an NSA will provide the country with just the much-needed regulatory oversight of streamlining processes; transparency with international maritime laws and compliance will also be guaranteed. In this direction, International partnerships, especially with China, will be one of the essential acts with respect to trading needed expertise, equipment, and investment to ensure sustainable seabed exploration. To fully capitalize on the deepsea mining industry, Pakistan needs to focus on capacity building, including the training programs for young professionals in key maritime disciplines. A phased process that balances economic goals with diplomacy and the environment can be used to help position Pakistan as a serious participant in the global seabed mining sector for increased economic growth, regional stability, and environmental security.

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