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EXPLORATIONS FOR POLYMETALLIC NODULES CARRIED OUT BY CONTRACTORS UNDER THE UNCLOS-III–

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Abstract

The real-time needs to limit global warming could spell an accelerated adaptation and a greater reliance on commercially-viable, mineral-intensive but low-carbon technologies. Metals and their compounds that are critical for such green transition include Cobalt(Co), Nickel (Ni), Copper (Cu), Silicon (Si), and Rare Earth Elements (REEs). This has led to a resurgence of interest to supplement land-based resources with those located on the deep seabed, continental slopes and rises, notably, polymetallic nodules found on the abyssal plains, seafloor massive polymetallic sulphides found around hydrothermalvents, and cobalt-rich crusts abundantly seen on seamounts. And yet it is being argued that some of the areas allocated to contractors for explorations, with a view to allowing exploitations of these deep seabed resources in the near future, are themselves vulnerable marine ecosystems and could have irretrievable environmental consequences and impacts for unique habitats and structures of marine species. The situation appears to have the characteristics of a Hobson's choice for the global comity or is it a race to choose between the devil and the deep-sea? This paper reviews the literature on the activities of the contractors permitted by the International Seabed Authority (ISA) under the principal public international law, viz. the United Nations Convention on the Law of the Sea (the "UNCLOS"), to carry out mineral explorations under 31 contracts, covering a combined area of about 1.477 million km^2. These activities have been guiding and shaping the development of global rules for governing commercial deep-sea mining. Draft Regulations on Exploitation of Mineral Resources in the Area related to polymetallic nodules (the "Draft Regulations"), seeking to resolve these competing public interest objectives were put out for consultations on 25 March 2019.

Introduction

The 2009 Copenhagen United Nations Framework Convention on Climate Change agreed on a target to limit increases in global temperature due to human activities to 2°C above pre industrial levels (UNFCCC, 2009). Subsequently, the Intergovernmental Panel on Climate Change 2018 reported a target to limit global warming to 1.5°C, which serve to ensuring a more sustainable and equitable society by reaching 80%zero-emission energy by 2030 and 100% by 2050 (IPCC, 2018). Sustainable development has been defined in the UN Sustainable Development Goals as "development that meets the needs of the

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present without compromising the ability of future generations to meet their own needs". Achieving these global climate change mitigation goals will require switching from fossil fuel-based energy supply and demand towards low-carbon technologies and practices, i.e., a low-carbon transition. It has been reported that the costs of transiting to renewable energy technologies, though significant, would be less than the costs and risks of the impacts of unmitigated climate change continuing on high-carbon practices. (Pearson et.al., 2012; Heinet.al. 2013; Sovacoolet.al., 2020).But, renewable energy and storage technologies, such as lithium-ion batteries, are mineral resource-intensive, and production of battery metals such as graphite, lithium, cobalt and nickel will have to increase by nearly 500% by 2050 to meet the growing demand for clean energy technologies (WEF Report, 2019).

The deep-sea ecosystem beyond the national jurisdictions of States has rich concentrations of mineral ores from which important metals can be extracted. These are considered as supplements for the increasingly stretched and depleting land resources of such necessary metals, including copper, nickel, cobalt, lead, zinc, molybdenum, platinum and rare earth elements that are required for various industrial as well as domestic purposes. Deposit concentrations of commercial interest:(i) polymetallic nodules, which contain rich concentrations of manganese, nickel, cobalt, copper, iron ore, precious metals, and rare earth elements, found mainly in four ocean basins/fields at 4,500 to 6,000 metres depth,(ii) cobalt-rich ferromanganese crusts, found on seamounts at around 800 to 2,500 metres depth, and (iii) seafloor massive sulphides, found in underwater volcanic and seafloor areas at depths of 1,000 to 4,000 metres(UNEP, 2007). Total Economic Value (TEV) of the deep-sea ecosystem as a whole, taking into account carbon sequestering at market prices in the carbon market and also social costs resulting from increased carbon emissions, is estimated in the Food and Agriculture Organisation (FAO) studies at USD 423 billion per yearin 2014reference year (Ottaviani, 2020).

The international seabed outside of national jurisdiction, called "the Area", accounts for about 54 per cent of the seabed area (ISA, 2018). More than 80 percent of currently known polymetallic (manganese) nodule fields are located in areas outside national jurisdiction (OECD, 2016). The four known fields, along with estimated average abundance of nodules, are in the Clarion-Clipperton Zone (the "CCZ") in Equatorial North Pacific Ocean (>15 kg/m^2), Peru Basin in Southeast Pacific Ocean (>10 kg/m^2), Penrhyn Basin (Cook Islands) in Central South Pacific Ocean (>5 kg/m2), and Indian Ocean Nodule Field (>5 kg/m2) (Mukhopadhyay, R. et.al. 2017). The Indian Ocean for instance has been estimated in a study to have a nodule abundance of $1.5x10^{11}$ tonnes (Cronan and Moorby, 1981).

Activities under Exploration Contracts Signed by the International Seabed Authority

All activities in relation to the deep seabed resources in the Area are regulated by the ISA established in 1994 under the 1982 UNCLOS and the 1994 Agreement relating to the Implementation of Part XI of the UNCLOS(www.isa.org.jm). Currently, ISA is working on regulations (the 'mining code') to govern large-scale exploitation of polymetallic nodules, polymetallic sulphides and cobalt-rich ferromanganese crusts, the three mineral compounds that are the object of commercial interest and mining projects in the Area.

As of 30 September 2022, ISA has signed 31 contracts with governments, and government-subsidised international consortia and private and public enterprises sponsored by the State concerned, to carry out mineral explorations indifferent oceans encompassing a combined seabed area of about 1.475 million km^2. Of these exploration contracts, 19are for polymetallic nodules, 07 for polymetallic sulphides, and 05 for ferromanganese/cobalt-rich crusts.

An annual report on its activities under the 15-Years contract (as may be extended),is sent by each contractor to ISA, which is maintained under conditions of confidentiality. However, this report includes information as per the "ISA Contract for Exploration – Public Information Template", which has been sourced for examination for the purposes of this paper for each of the first 18 contracts for polymetallic nodules (for its contract entered in the year 2021,Blue Minerals Jamaica Co. Ltd. has not submitted its annual report).The template requires the contractor to provide (i) the details on coordinates of each turning point and "Illustrative Chart of the Exploration Area" awarded to it, and (ii) standard clauses under the contract. With regard to its activities, the information is to be provided under the following heads: (i) Plan of Work (approved by ISA), (ii) Programme of Activities and Exploration Expenditure, and (iii) Training Programme. The plan of work and activities submitted by contractors are seen to have typically covered the follows:

- Undertaking exploration and evaluation of polymetallic nodules in the contract area; conducting research on distribution of nodules; delineating mining areas; estimating the indicated and measured resources within certain domains; and delineating mining test areas.
- Carrying out environmental investigation survey and assessment in High Abundance Area and Preservation Reference Zone; conducting research on the features of physical, chemical, geological, biological, and sedimentary baselines and their scope of natural variability; establishing environmental baselines; collecting information about the physical properties of seafloor sediments for use in designing mining equipment; and samplings where a disturbance test on the seafloor and other environmental impact surveys have been conducted.

- Establishing test platforms for key mining technologies and equipment performance experiments in laboratory; conducting verification tests for key technologies; and completing the design of a commercial mining system of nodules.

- Undertaking tests on and evaluating the ore beneficiability of nodules; developing metallurgical process technology; conducting research on the comprehensive recovery technology for associated rare elements; and carrying out laboratory tests on metallurgical processes.

- Analysing the market situation and dynamics of constituent metals (including Cu, Co, Ni, Mn and Fe); carrying out a scoping study for nodules resources; and conducting an economic and financial feasibility analysis.

Broad Conclusions

It is seen that quite extensive baseline data collection on ores and their metallurgical contents as well as on environmental impacts has been carried out since 1987, when India became the global-first Pioneer Investor in the field of deep-sea mining explorations along with seven other Pioneer Investors, and since 2002 by the governments and the State-sponsored industrial explorers and government-funded researchers, who are ISA contractors, for their exploration contracts under UNCLOS-III. A host of oceanographic studies have also been completed which relate directly to key environmental parameters that could usefully feed into the drafting of the three respective mining codes to balance out the competing public interest objectives in sourcing scarce resources for the deployment of mineral-intensive low-carbon technologies that serve to meet global ‘green’ norms on the one hand and sustainable exploitation of deep-sea resources on the other.

With respect to the entire mining systems value-chains, it is seen that decades of evolutionary experimental ocean-based industrial activities undertaken by a few pioneering countries, like India, have had very useful results. Revolutionary advances have been reported in the basic scientific knowledge, experimental procedures, mining platform design, and engineering know-how, including equipment industries related to remotely-guided and controlled continuous mining operations of commercially viable quantities of polymetallic nodules. These developments, which suggest that geologically, technologically and commercially viable exploitation of polymetallic nodules is possible under certain market conditions, include:

(i) a horizontal seafloor component for physically extracting and collecting mineral ores (3-4 technological variants);
(ii) a vertical component for transporting the extracted ores and slurry to the sea surface 4,500 to 6,000 metres above the seabed;

(iii) a surface mother vessel (i.e.,a ship-based component functioning also as a platform for separating the ores from the transport slurry);
(iv) other vessels transporting collected material to the port(s) closest to land-based metallurgical facilities; and
(v) processing to extract metal ores in land-based metallurgical facilities.

These technologies and processes have thus far been aimed at finding the best mine sites and to mapping their extent. Their ambit thus remains restricted to explorations for commercial deposits, small-scale mining equipment and prototype tests, and commercial recovery mining system simulation experiments, and land-based metallurgical processing related to minerals from the deep seafloor. However, it has been reported by contractors that such mining activities (refined and modified by them to fit their particular goals and their basic methods by adhering to well-developed disciplines of geological, physical, and biological oceanography) could be sustained in the 15-20 years of commercially viable mining contracts.

Mining manganese nodules is unique for mineral extraction. Since the deposits' occurrences are essentially 2-dimensional, their mining does not have all the environmental pit-falls of strip-mining or open-pit operations for the land-based ores. However, because it involves disturbances of sediments and transport of the ore through 4,500 to 6,000 metres ofseawater, there are non-conventional environmental impacts the extent of which can be mitigated through suitable mining technologies and processes. Environmental impacts of these different systems which have been tested in actual scale-model tests by some of the contractors include (1) different hydraulic systems, which pick up the nodules with a towed or self-propelled harvester and then lift the ore to the surface with simple hydraulic or air-assisted lift systems, and (2) continuous-line bucket system, which consists of dragline buckets connected together on a loop. Other, more speculative types of systems also appear to have been conceived.

Nevertheless, there remains some technological uncertainty and risk due to the lack of actual facilities operating at scale which are capable of extracting metals from nodules. For commercial mining operations, this could translate into slower ramp up to, and/or delayed onset of, full-scale mining, and longer down-time during regular nodule-collection operations. So far, off-shore metallurgical processing has not been foreseen under these contracts. Obviously, further improvements in technology over time would permit faster, cheaper, more efficient and sustainable development of the deep-seabed and its sub-surface could serve to substantially reduce the large public investment currently taking place in R&D and pilot mining projects at contract-site.

Now that the complex scientific and technological capabilities are largely proven, the spotlight has turned more recently towards the financial call for investments in, and on the environmental impacts of, mining polymetallic nodules from international waters.

Contracts for nodules are typically granted for an area of about 75,000 km^2. The values of some constituent metals in the nodules have been estimated to show high volatility. Interest in commercial mining has thus wavered over the last five decades (Cameron et.al., 1981; Johnson et.al., 1986; Herrouin et.al., 1989; Hoagland, 1993). In 2004 the total value of contained commercial metals (Ni, Cu, Co, lead, zinc, and titanium) in the CCZ had been estimated at USD 183 bn per year (Antrim, 2005). A typical contract area of 75,000 $km^2$with an estimated nodule resource >200 million metric tonnes (MMT) is expected to yield about 54 MMT of four metals (Mn, Ni, Cu and Co). The gross in-place value of metals is estimated between USD 21 bn and USD 42 bn (depending upon annual rate of mining) in amine’s 20-year life-span (Sharma, 2011).

However, because of environmental constraints, it has been assessed that only between 20-30 percent of the overall deep-sea contracted area is mineable (Hein, 2016; Volkmann, Kuhn and Lehnen, 2018). Viability studies of CCZ deep-mining operations estimate a potential annual recovery of dry nodules of about 1.5 MMT/year (Sharma, 2018), 2.0MMT/year (Volkmann, Kuhn and Lehnen, 2018), and 3.0MMT/year (Van Nijen, Van Passel and Squires, 2018; Sharma, 2018).

Many recent-year studiesalso find that this financial call is established subject to suitable management of the volatility in market demand for the nodules or the processed minerals and metal ores, notably, Mn, Ni, Co, and Cu(Nam et.al., 2004; Sharma, 2011);Sharma, 2018; Van Nijen et.al., 2018; Volkmann et.al., 2018; Mukhopadhyay et.al., 2019; Abramowski et.al, 2021; Li et.al. 2021). It is seen that these studies typically draw upon life-cycle cost, net present value, return on investment, and/or total cost of ownership models to analyse the triple-bottom-line paradigm of economy, society and environment, broadly covering thereby the usual standards of sustainable development.

Four economic feasibility studies have also been presented to ISA or in various public for a, which include the (a) African Group’s submission on ISA’s Payment Regime,07 September 2018, (b) China Southern University Model, 07 September 2018, (c) German Federal Ministry for Economic Affairs and Energy Model (BMWi), 30 September 2016, and (d) Massachusetts Institute of Technology model (MIT), 03 June 2019, (Kirchain, R. et.al., 2019; ISA, 2020). These financial models are based on discounted cash flows from 3-4 metals’ recovery (Mn, Cu, Co and Ni)and formulated financial flows of capital and operating expenses applied to the results of pilot projects executed on “contracts” granted by ISA, which have been duly scaled up in each model to collect 3.0MMT of dry nodules per year from the deep-seabed. A comparison of their results reveals project viability, over a 20-year mining period under either an integrated contract or in separate contracts granted to mining entity(ies), across a range of fiscal assumptions being considered by ISA.It has been estimated that the internal rate of return (IRR) for such an industrial venture for 3-4 metal ores recovery may range between 17% (assuming constant ad valorem royalty payment to ISA) and 27% (assuming variable payments). It is seen that unit prices of the main targeted deep-sea metals, including precious metals (gold, silver) and REEs(molybdenum, lithium, yttrium, thallium),are highly volatile. Economic viability of deep-sea mining operations will thus depend on the prices of these metals in future, capital and operating costs of ocean mines, costs required to ensure environmental sustainability, continuing terrestrial supply of metals, and royalties and duties that will eventually be required to be paid to ISA.

For estimating the TEV of nodules alone, taking the quantities of collectable nodules from only 12 active exploratory contracts granted by ISA in the CCZ as of 2014, their average metal grades' content recorded in the area were valued at 2014 worldwide average unrefined/ unprocessed metal ore unit prices. At an annual recovery between 1.5 and 3.0MMT of dry nodules/year per contract, after extraction of metal ores (Ni, Cu, Co,Mn, and Molybdenum) an economic value of USD 1.6 bn and USD 3.2 bn/year is obtained. The total for all 12 contracts of CCZ adds to USD 19 bn/year and USD 38 bn/year, respectively. This works to an average USD 29 bn/year being contributed to the afore-mentioned TEV of entire deep-sea ecosystem. (Ottaviani, 2020).

Currently, capital expenditures and operating expenditures assessed for polymetallic nodules exploitation of 20-year mine life are estimated at between USD 12 billion (Sharma, 2011) and USD 24 billion (Van Nijen, Van Passel and Squires, 2018). Post-operation costs also include additional expenses, to which inadequate attention has so far been given, related to the disposal of waste material after metal extraction (Sharma, 2018). Extremely high-quantity debris will be produced by the extraction of nodules. The discarded debris will represent 76 percent and 98 percent of mined ore, respectively, in the case of four- or three-metal extractions (Sharma, 2018). Clearly, there is economic value to be derived from useful metal extractions from this debris, and equally lowering of the costs of waste disposal.

With regard to mine-site restoration costs, a hypothetical scenario was created and assessed to cost of USD 5.4 mn. An area of 0.007 ha of Solwara-1 mining site could undergo a 5-years restoration program meat a cost of USD 771/ha (that is, at 2-3 times the cost of marine restoration programmes in shallow waters)(Van Dover et al., 2014).

However, deep-seafloor entire ecosystem service restoration is highly complicated. Besides very high costsof restoration, the effort is hamstrung by limited knowledge on the very functioning of the ecosystem and decades/centuries over which the ecosystem processes operate there. (Van Dover et al. 2014; Le et al., 2017; Cuyvers et. al., 2018). Deep-sea mining itself is complicated, unlike terrestrial mining, because while the mining activity in most likelihood would have an impact on the marine environment, the reverse is also true. The impact of the environment itself on mining activity is high because the prevailing conditions such as atmospheric, hydrographic, seafloor topography, mineral characteristics, and associated substrates at the mine-site are critical for designing and efficiently operating different sub-systems of the mining system. It's a case of double environmental-cost jeopardy.

Thus, on the one hand, the commencement of nodule mining activity will hereafter depend on the one hand on the nodule abundances in geographically-favourable contract locations coupled with regional demand for supplementing certain land-based minerals and metals either in short-supply globally or are within the reach of only a few States, and on the other the totality of environmental costs of mining activity and the long-term environmental impact of the mining activity. As per the US Geological Survey(USGS, 2020), the global land-based reserves were copper (0.83), nickel (0.089), cobalt (0.0069), and manganese (0.76) all in billion metric tons (BMT). On the other hand, 4.25 mnkm^{2}of commercially-mined Pacific Ocean seabed alone can deliver reserves of copper (0.3), nickel (0.39), cobalt (0.078), and manganese (8.6) all in BMT(ISA, 2004). The environmental costs' estimates today are conjectural at best, ranging between the ridiculous and the sublime depending upon the leanings of the researcher towards the two competing public interest objectives.

Needless to say, early finalisation of suitable enabling international regulations on environmentally-sustainable exploitation of polymetallic nodules along with its implementing regime by the global comity is vital. In this exercise, the costs of compliance with legal regulatory frameworks, including mechanisms for royalty and fiscal duties payments to the ISA, and the costs of avoiding, mitigating or remediating environmental impacts, environmental sustainability) and any conservational preferences for the Blue Ocean ecosystem would need to be carefully and meticulously weighed in.

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