

Strategy for Polymetallic Nodule Mining

Rahul Sharma

Introduction

Mining of nearshore and shallow water minerals on a commercial scale¹ as well as the exploration of deep seabed minerals is being extensively carried out by various countries and consortia². Since the economic viability of deep seabed mining is already established, deep seabed minerals such as polymetallic nodules and sulfides are being looked upon as an alternative to the existing but fast dwindling land resources. Land reserves of strategic metals like copper, cobalt, nickel and manganese are getting depleted at alarming rates and are projected to get exhausted by the turn of the century. In an attempt to anticipate and provide contingency reserves for the projected scarcity of these metals, India started a programme of exploration for polymetallic nodules. The intensive surveys have resulted in identification of paramarginal nodule deposits. India has been recognised as a 'Pioneer Investor' by the United Nations leading to the allotment of an area of 1.5 lakhs sq. m. in the Central Indian Ocean Basin with exclusive rights for detailed exploration.

Different mining systems are being developed and tested in pilot stage³. The hydraulic and airlift systems are being preferred over the continuous line bucket (CLB) mining system due to operational considerations. The suction systems (hydraulic and airlift) will have a mobile collector head attached to a long pipe suspended from the mining ship to lift the nodules from the seabed. The possibility of using shuttles launched from a mother ship to collect nodules is also being explored.

However, mining of nodules will not only disturb the ecological balance for the seafloor, but also of the entire water column. The discharge of waste material (like sediments) at the surface will lead to formation of a dense plume and restrict penetration of sunlight for photosynthesis. The at-sea processing wastes and fallout during transportation will cause additional problems for marine life as well as nearby coastal areas. Besides environmental impact, nodule mining may also have certain political and international implications.

This article lists out the factors to be considered for nodule mining, review the possible impact of seabed mining and describes the approach for delineation of a mine site and collection of baseline data.

Criteria for delineation of mine site

The term 'minesite' is defined as an ocean bottom area where under specific, geological, technical and economic conditions, a single polymetallic nodule mining operation can be carried out for a period of time⁴.

There are several factors for selection of a mine site⁵ such as:

Nodule distribution, grade and abundance

Distribution and abundance of nodules is measured either by spot sampling using various types of grabs or underwater photography systems and grade is calculated after ascertaining the metal contents by chemical analysis. The cut off abundance accepted is 5 kg/sq. m., which is the lowest concentration that can be feasibly mined. The cut off for average grade is suggested to be 1.8% of copper + nickel. However, since these metals will not provide sufficient returns, manganese and cobalt have been added and the concept of 'metal equivalent' was introduced. Metal equivalent is expressed as grade of a reference metal that would produce the same revenue as the sum of revenues produced by all the metals recovered from polymetallic nodules.

The survey area is divided into a number of blocks and average abundance is calculated. However, since nodule distribution is not uniform, even the most abundant area can have patches of less nodules. Another method that can be utilised is by combining grade and abundance, to calculate the quantity of metal contained in nodules per unit surface area. Nodule distribution varies drastically over short distances and needs to be surveyed continuously with a closer interval between the lines. So, for more reliable data, acoustic systems towed near the seabed can be continuously used for abundance values at every point. Similarly, radiometric sensing needs to be developed for fast and accurate measurement of metal content.

Seafloor conditions

The seafloor topography and sediment characteristics need to be studied in detail for delineating unmineable areas. Rough topography and sediments with low shear strength may pose problems during mining. The proportion of unmineable areas due to unsuitable topography (A_u), with respect to total area (A_t) can be calculated as; A_u/A_t , which is generally accepted to be less than 20%. Since the abyssal hills in the nodule areas are several kilometres wide, bathymetry maps should be at a scale 1:50,000 or above. This can be done by multi channel echosounders in a close grid or by high resolution deep tow acoustic systems. Echostrength measurements and geotechnical studies (preferably in situ) should be done for properties of bottom sediments.

Mineable area and its size

The factors described above can be used to estimate the total mineable area (M) as follows:

$$M = A_t - (A_u + A_g + A_a)$$

where A_t = total area

A_u = area below cut off grade

A_a = area below cut off abundance

The size of a mine site (A_s) can be calculated as:

$$A_s = \frac{(A_r) (D)}{(C) (E) (M)}$$

Where A_s = annual nodule recovery rate (dmt/year)

D = duration of mining operation (years)

C = average nodule abundance in mineable area (dmt/sq.km)

E = overall mining efficiency (percent)

M = proportion of mineable area

Technological factors

With any of the mining systems, the overall efficiency (E) is expected to be more than 50% and can be calculated as:

$$E = e_d \times e_s$$

where e_d = dredge efficiency, which is the ratio of polymetallic nodules effectively gathered by dredge head, versus the nodules on the seabed before dredging,

e_s = sweep efficiency, which is the percentage of bottom area dredged.

Economic factors

The quantity of polymetallic nodules required to be extracted from a given mine-site is three million dry tons per year at least for a duration of twenty years. Since this target can be achieved at the (highest) limit of technical feasibility, it may not be viable using a single ship, so use of two ships is envisaged by most of the pioneer companies.

Impact of nodule mining

Environmental impact

Seafloor mining and disturbance:

According to one estimate, along with each tonne of nodules lifted, 2.5 - 5.5 tonnes of

bottom sediments are disturbed⁶. The suspension, distribution and sedimentation of stirred up particles will affect the near bottom water mass, areas of seafloor from where the sediments are removed and areas of resedimentation. This will have a certain impact on deepsea fauna, especially sessile animals which have slow reproductive cycles.

During the CLB mining test in the Pacific Ocean⁷, when the STD sensor accidentally hit the seabed, particulate matter in the bottom bottles was very high (167,000 mg/sq. m) which shows that if much a much larger mine head is dragged along the seabed, turbidity of surrounding water will be increased by several orders of magnitude over the baseline condition. Even if the area being mined is small, the area affected due to plume and transportation of sediments will be large and similarly the time taken to re-establish the same environment will be much more than that of the mining activity.

Sediment discharge and ecological imbalance:

After lifting polymetallic nodules from the seafloor to the mining vessel, the associated sediments will be sieved off and discharged into the seawater. According to a study, for every tonne of nodules lifted, 6 tonnes of bottom water will be brought to the surface⁸. As a result, there will be dense suspension in the entire water column, less penetration of light for photosynthetic activity of marine organisms, inducing an ecological imbalance in the environment. The organisms lifted from the seafloor may also not survive in the totally different conditions (low pressure and high temperature, etc.) at the surface. At the same time certain dormant species of phytoplankton may be revived on the surface, due to suitable temperature, light and oxygen conditions, but they may lead to over population and depletion of available oxygen for existing species, creating a further ecological imbalance.

During a suction lift mining test in the North Atlantic Ocean⁹, the bottom water discharge at the surface remained in the euphotic zone due to warming up during airlift and due to lower salinity of bottom water. So, modification in the discharge technique, like spraying over sea surface to ensure rapid mixing, should influence behaviour of bottom water. It will increase the phytoplankton growth only if the concentration of deepwater after mixing with surface water is considerably high (>10%), whereas maximum observed was only 0.3%.

Transportation and at-sea processing wastes

The discharged wastes may perhaps not settle down where they are disposed of, but may also travel along with currents to the nearby shores, causing a new type of problem to the beaches, marine life and settlements. Material falling off during transportation and oil spillage may also become pollution hazards. In the case of at-sea processing, the discharge of waste material could be far more dangerous to the marine environment, due to use of chemicals.

Political and International Implications

Some developing countries have vast mineral reserves, which play an important role in industrializing their economies. Of the known mineral reserves these countries have nearly 50% of the nickel reserves, over 50% of copper reserves, 75% of cobalt reserves, and about 25% of manganese reserves, and are major suppliers to the world markets of these minerals. These countries face the combined effect of lost markets and reduced price levels brought about by deep seabed nodule production. They depend on revenue earned from mineral exports more than do developed nations and have less flexibility in transferring production to other product lines. They lack the technological and economic requirements necessary to mine the oceans.¹⁰

Measure for 'safe' nodule mining

In order to monitor the impact of nodule mining on the environment, it is necessary to collect detailed oceanographic data on physical, chemical and biological aspects of the area before, during and after the pilot mining stage. The data collected before will serve as a reference with which the data collected during and after pilot mining can be compared to know the extent of impact of the mining activity in the area. It will also help to determine the time required for a disturbed ecosystem to return to its original state, which can be used to predict the impact of large scale mining. This information, along with meteorological, geological, geotechnical and hydraulic data, will be useful for improvement in the design of the actual mining system so as to have minimum possible impact on the environment. In order to collect this data, a time series study needs to be undertaken for environmental monitoring and management in and around the proposed mining area.¹¹

Criteria for safe mining

Seafloor mining and disturbance

There should be minimum interaction of the mining system with the seabed environment to keep it disturbance-free. Strip-wise mining should be done, leaving alternate strips of undisturbed seafloor, to allow repopulation in mined out areas.

Sediment discharge

It should be minimum at the surface, to allow sufficient sunlight to penetrate. There should be uniform distribution of the waste in negligible quantities in the entire water column (and not only on the surface). The discharge must have positive effects, such as artificial upwelling and no negative effects on the ecology.

At sea processing

Necessary precaution must be taken during processing to avoid pollution, proper treatment of waste before disposal, and until the above are ensured, processing must be done on land.

Measures against adverse political implications

Several United Nations proposals would diminish the impact of deep seabed mining on the land based mining industries in developing countries¹². These proposals include:

- limited production to levels that would not disrupt land based production or prices,
- controlling both deep seabed and land based mining equally so as not to discriminate against seabed production,
- limiting ocean mining licenses to an amount judged appropriate to maintain a balance between land and sea production,
- limiting annual production and new licenses for market and price stability,
- having an international authority compensate the countries affected by decline in mineral export revenues, and
- providing preferential technical assistance to developing countries adversely affected by seabed production to help them broaden their economic base.

Strategy for nodule mining

A long term strategy needs to be worked out for large-scale nodule mining which involves a number of stages. These comprise of tasks dealing with exploration, metallurgical processing, mining and environmental monitoring as well as decisions related to the economics of mining and worldwide implications on metals market.

The stages under various heads and the tasks involved in each before deep seabed mining have been described in Table 1.

Approach towards data collection for nodule mining

This has been divided into 2 phases:

- Phase 1: Delineation of application area.
Phase 2: (i) Delineation of mine site.
(ii) Collection of base line data on environmental parameters.

The Central Indian Ocean basin has been extensively surveyed to collect data on nodule abundance and grade. On the basis of this application area of 150,000 sq. km, each were identified and subsequently allotted to India by the UN for exclusive rights for detailed exploration and later exploitation of the resources from one of the allotted areas. In the first phase (delineation of application sea), the survey was carried out at 1⁰ interval and narrowed down to 0.25⁰ between stations. An area of 4mm. sq. km. was covered using freefall grabs, underwater cameras, sediment samplers at 1800 locations and 700 tons of bulk samples dredged for development of metallurgical methods for extracting the metals.

A preliminary bathymetry map, based on sonar records, was prepared with 100 m contour interval. Several seamounts have been identified in the area. Based on these (abundance, grade and bathymetry) the application area was selected.

The second phase constitutes selection of mine site and collection of data for designs of mining system. This objective is being achieved by a multidisciplinary approach as follows:

1. Narrowing down the exploration grid (interval) to 0.125° ($1/8^{\circ}$) = 7.5 nm for collection of grade, abundance and photography data.
2. Collection of undisturbed sediment cores (using spade cores and box cores) to study geotechnical properties and relation between nodules and sediments.
3. Collection of baseline environmental data (in the entire area) at an interval of 1° over 3 seasons in a year (March-April, July-August, Nov.-Dec.). This involves data collection on biological, chemical and physical parameters from the deepest part of the water column to the surface.
4. Detailed bathymetry survey using Swath mapping system, which covers 10 km on either side of the ship's track and produces real time contour map of the seafloor with 10m resolution.

Summary

In order to have a safe and efficient mining operation, it is necessary to have careful planning and execution in the exploration stage, to:

1. Establish the economic mineability of the deposit and have a feasibility study for mining based on associated seabed conditions.
2. Acquire knowledge of potential environmental impact on the sea, through environmental monitoring in the pilot mining stage.
3. Understand the implications (environmental and political) before large scale mining commences.
4. Develop mining techniques having positive environmental effects, such as artificial upwelling, rather than destruction of the existing ecological balance.

The nodules explored in the Indian Ocean meet the criteria for mineable deposits on the basis of their grade and abundance, and as a result India has been allotted the area for detailed exploration. Since land deposits are depleting fast, nodule mining may have to be taken up to support the industry and economy. Detailed studies have been taken up for delineation of mine site as well as identifying a suitable method for metallurgical processing of the nodules.

Rahul Sharma is a scientist at the National Institute of Oceanography at Goa in India.

Notes

1. Baam, M., W. Lee and David Rice (1978), *Marine Mining of the Continental Shelf*, Ballinger Pub., Cambridge, p. 301.
2. Anonymous (1987). "Delincation of Mine Sites and Potential in Different Sea Areas", UNOET, Seabed Minerals, Vol. IV, Graham & Trotham, London, p. 79.
3. Anonymous (1984). "Analysis of Exploration and Mining Technology for Manganese Nodules", UNOET Seabed Minerals, Vol. II, Graham and Trotman, London, p. 140.
4. Op.cit. supra note no. 2.
5. See note no. 2
6. Amos & Roels, (1977). "Environmental Aspects of Manganese Nodules Mining", *Marine Pollution. Int. Bull.*, Vol. 1, pp. 160-162.
7. Pearson, J.S., (1975), *Ocean Floor Mining*, Publ.: Noyes, Data Corp., N.J., p. 201.
8. Roonwal, G.S., (1986), *The Indian Ocean - Exploitable Mineral and Petroleum Resources*, Springer Verlag, p. 198.
9. Op. cit., supra note 6.
10. Anonymous, (1978), *Deepsea Mining, Actions Needed to Make it Happen*, NTIS, p. 70.
11. Sharma, R. (1988), *A Multidisciplinary Approach to Environmental Monitoring and Management for Deepsea Mining in the Indian Ocean*, Technical report no. NIO/TR-1/88, p. 27.
12. Op. cit., supra note 8.