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Environmental Issues of Deep-Sea Mining

Rahul Sharma

CSIR-National Institute of Oceanography, Dona Paula, Goa 403004, India

Abstract

As terrestrial mineral deposits are either depleting or of low grade, minerals from the deep-sea like the polymetallic nodules, cobalt rich crusts and polymetallic sulfides are considered as alternative sources for metals such as Cu, Ni, Co, Mn, Fe, that could be exploited in future by developing suitable technologies for mining as well as extracting metals from them. As most of these deposits occur in the international waters, several 'contractors' have staked claims over large tracts of the seafloor in the international waters under the UN Law of the Sea. Simulated seafloor mining experiments have revealed significant information on the potential impacts that may occur as also several measures for conserving the environment have been suggested.

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Keywords: Polymetallic nodules, polymetallic sulfides, cobalt rich crusts, deep-sea mining, environmental issues

1. Introduction

Deep-sea mining has generated significant interest around the world for over five decades, due to the potential of deep-sea minerals such as polymetallic nodules, cobalt rich crusts and polymetallicsulfides that occur on the deep seabed (Fig. 1) and are considered as alternative source of strategic metals, such as Cu, Ni, Co, Pb, Zn, Cd besides Fe and Mn, for industrial development. It is estimated that the value of imports in ores and minerals account for more than 20% amounting to about 190 billion Indian rupees[1]. The terrestrial reserves of many of these metals, that have many industrial uses, are depleting fast (Table 1), emphasizing the need for deep-sea mining.

Until 2010, eight 'Contractors' had been allotted areas in the international waters to explore in the Pacific (France, Russia, Japan, China, Korea, Interoceanmetal and Germany) and Indian (India) Oceans by the International Seabed Authority that regulates activities related to seafloor minerals in the 'Area' (outside the Exclusive Economic Zones of any country). Subsequently, 7 more have laid their claims in the Pacific Ocean (viz. Nauru, Tonga, Kiribati, UK, Belgium) for polymetallic nodules, and 5 countries (China, Korea, India, Russia, France) have claimed areas for exploration of hydrothermal sulfides in the Indian as well as Atlantic Oceans[2].

However, mining of deep-sea mineral deposits have several technological challenges in terms of extreme operating conditions such as high operating depth (3-6 km), distance from shore (>1000 km), high pressure (300-500 bars), low temperatures ($0\text{-}10^0$ C), as well as physical forces like currents,

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waves, winds and others. Also, the ensuing environmental impacts due to mining activities are a cause of concern, which are discussed in this paper.

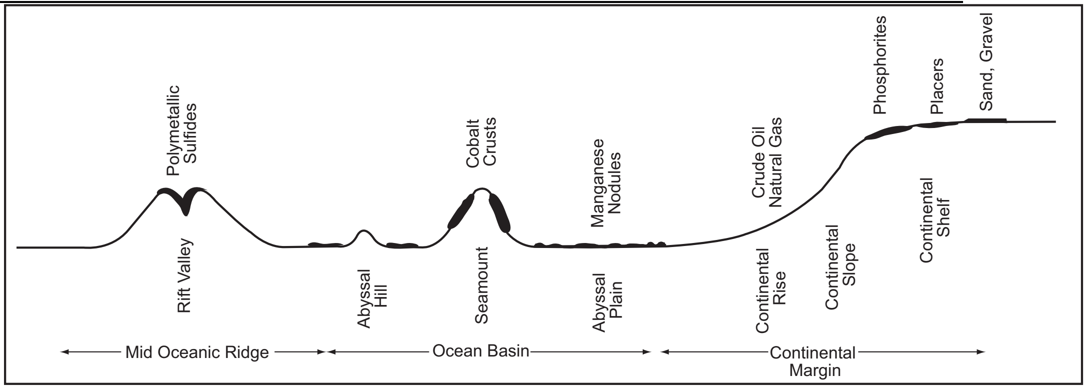


Fig.1. Distribution of marine minerals on different seafloor topographic features[3]

Table 1. Uses and status of key metals found in deep-sea minerals

Metal	Used in[4]	Reserves on land & status[5]	
		In India	In World
Nickel	Making steel (46%) , nonferrous alloys and superalloys (34%); electroplating (11%) , coins, ceramics, batteries, hard discs	Nil, totally depend on imports	71 mi. t
Cobalt	Alloys, magnets, batteries, catalysts, pigments and coloring, radio-isotopes, electroplating	Nil, totally depend on imports	6.6 mi. t (52% in Congo)
Copper	Electrical, telecom and electronic applications such as generators, transformers, motors, PCs, TVs, mobile phones (65%), automobile (7%), anti-bacterial agent and consumer products (coins, musical instruments, cookware)	4.3 mi. t	140 mi. t (low grade)
Manganese	Steel production (> 85% of ore used for this), corrosion resistant alloys (cans), additive in unleaded gasoline, paint, dry cell and alkaline batteries, pigments, ceramic & glass industry	142 mi. t (ore)	540 mi. t (metal)
Iron	Pig iron / sponge iron / steel (>90%), alloys, automobiles, ships, trains, machines, buildings, glass	8.09 bi. t (ore), Rich reserves available	160 bi.t (ore) and 77 bi. t (metal)

2. Potential environmental effects of deep-sea mining

The impact of offshore mining is expected to be in the form of 'plume' at the seafloor, turbidity in the water column and addition of bottom sediments to the surface resulting in change in the marine ecosystem (Fig. 2) as well as on land owing to collection, separation, lifting, transportation, processing and discharge of effluents (Fig. 3). According to an estimate, an area of 300-600 sq km will be disturbed every year for mining of 1.5 - 3 million metric tonnes of nodules per year[6]. With every tonne of manganese nodule mined from seabed, 2.5-5.5 tonnes of sediment will be resuspended[7]. Hence, for an average 10,000 metric tonnes of nodules mined per day, about 40,000 metric tonnes of sediment will be disturbed (at 1 tonne nodule: 4 tonne sediment).

The adjacent areas will not only have higher sedimentation rates, but the suspended loads may remain over long periods and also travel laterally, causing clogging of filter feeding apparatus of benthic organisms in the area. Sudden increase in the amount of suspended matter due to sediment plume and mining discharge, will increase the turbidity of these waters, and may also affect pelagic organisms[8]. The debris and sediments mixed with water, which are lifted and transported with the minerals, discharged at the surface, would create turbidity and decrease the available sunlight for photosynthesis causing long term effects on biological productivity. At the same time introduction of bottom water with its higher nutrient values could result in artificial upwelling increasing the surface productivity[9].

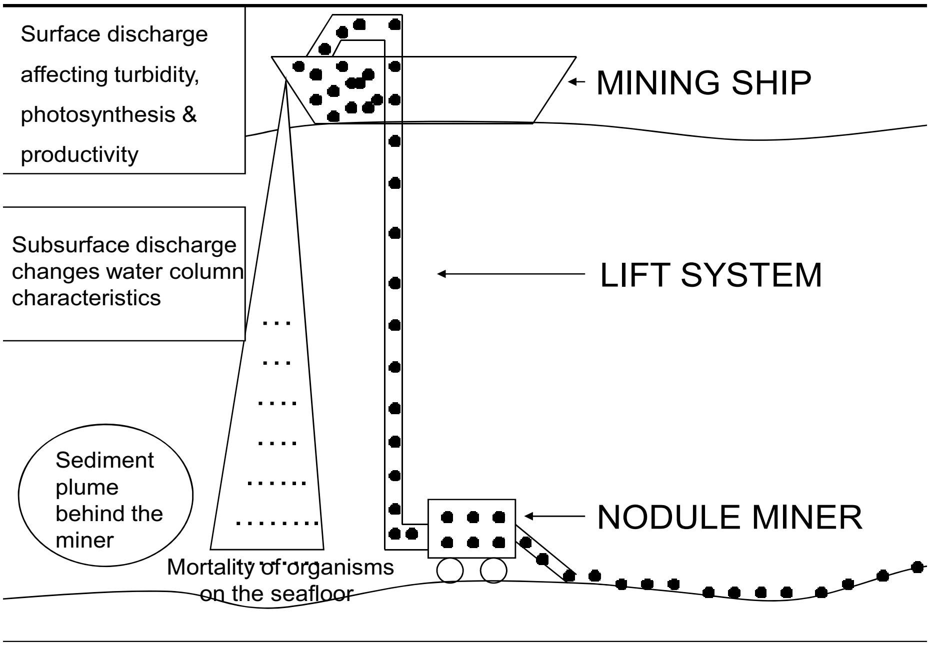
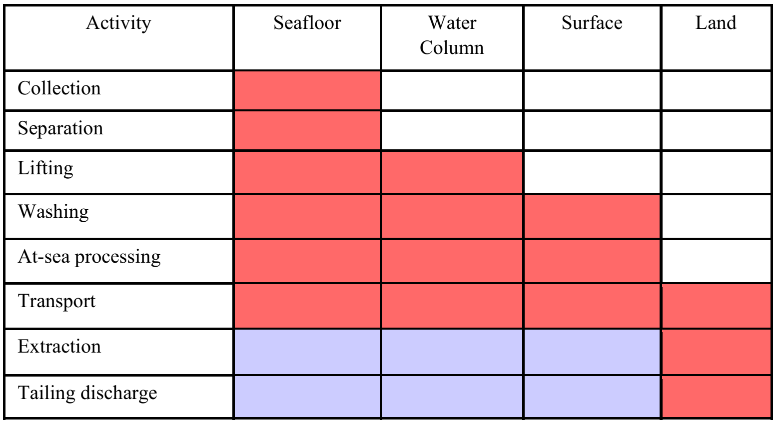


Fig.2. Schematic for environmental impact of deep-sea mining



Activity	Seafloor	Water Column	Surface	Land
Collection	🟥			
Separation	🟥			
Lifting	🟥	🟥		
Washing	🟥	🟥	🟥	
At-sea processing	🟥	🟥	🟥	
Transport	🟥	🟥	🟥	🟥
Extraction	🟦	🟦	🟦	🟥
Tailing discharge	🟦	🟦	🟦	🟥

Fig.3. Areas likely to be affected due to different activities of deep-sea mining

A summary of the probable impacts at various levels in the water column have been given in the following section[10]:

2.1. Potential seafloor impacts

It is anticipated that the primary benthic impacts caused by mining will be:

- direct impacts along the track of the nodule collector, where the sediments and associated fauna will be crushed or dispersed in a plume and the nodules removed;
- Smothering or entombment of the benthic fauna away from the site of nodule removal, where the sediment plume settles; and clogging of suspension feeders and dilution of deposit-feeders food resources.

2.2. Potential water-column impacts

Discharge of tailings and effluent below the oxygen-minimum zone may cause some environmental harm to the pelagic fauna, such as:

- mortality of zooplankton species
- Effects on meso-and bathypelagic fishes and other nekton, impacts on deep-diving marine mammals, on bacterioplankton and depletion of oxygen by bacterial growth on suspended particles.
- effects on fish behaviour and mortality caused by the sediments or trace metals;
- mortality of and changes in zooplankton species composition caused by discharges;
- dissolution of heavy metals (e.g. copper and lead) within the oxygen-minimum zone and
- the possible clogging of zooplankton by filtering particles in the plume.

2.3. Potential upper-water column impacts

If tailings consisting of sediments (including clay) and other effluent are discharged in near-surface waters then there are additional impacts to those listed above, will be e.g.

- the potential for trace-metal bioaccumulation
- reduction in primary productivity due to shading of phytoplankton and
- effects on phytoplankton from trace metals and
- on behaviour of marine mammals and especially the
- Duration of tailing suspension, especially with at-sea processing.

3. EIA studies for deep-sea mining

In order to understand the potential impacts of deep-sea mining, several studies with simulated mining have been carried out, as follows:

3.1. Deep ocean mining environment study by OMI and OMA, USA

The **D**eep **O**cean **M**ining **E**nvironment **S**tudy (DOMES, 1972-1981) conducted by NOAA (USA) monitored environmental impacts during two of the pilot scale mining tests conducted by the Ocean Mining Inc. and the Ocean Mining Associates (OMA) in 1978 in the Pacific Ocean[11]. During the study the concentration of particulates was measured in the discharge and the biological impacts in the surface as well as benthic plumes were assessed.

3.2. Disturbance and re-colonisation experiment by Germany

The **DIS**turbance and Re-**COL**onisation (DISCOL) experiment was conducted by the scientists of the Hamburg University, Germany in the Peru Basin in the Pacific Ocean from 1988 to 1998. Collection of pre-disturbance baseline environmental data was followed by the disturbance caused by a plow harrow in a circular area of 10.8 sq.km[12]. Post disturbance studies were carried out to monitor the impact and recolonisation after 6 months, 3 years and 7 years. The results have shown that over a period of time, although certain groups of benthic organisms may show a quantitative recovery, the faunal composition is not the same as the undisturbed one[13].

3.3. Benthic impact experiment by NOAA, USA

The benthic impact experiment (NOAA-BIE) by the National Oceanographic and Atmospheric Administration (NOAA, USA) was conducted in the Clarion Clipperton Fracture Zone (CCFZ) of the Pacific Ocean (1991 to 1993). After baseline studies in a pre-selected area, the Deep-Sea Sediment Resuspension System (DSSRS) was used for 49 times in an area of 150x3000 m. The post-disturbance sampling indicated changes in the faunal distribution in the area[14] and monitoring observations after 9 months indicated that, whereas some of the meiobenthos showed a decrease in abundance, the macrobenthos showed an increase in their numbers probably due to increased food availability[15].

3.4. Japan deep-sea impact experiment by MMAJ, Japan

The Japan deep-sea impact **e**xperimen**t** (JET, 1994 - 1997) was conducted by MMAJ (Metal Mining Agency of Japan) in the CCFZ of the Pacific Ocean in 1994 with the DSSRS. Disturbance was created during 19 transects over two parallel tracks of 1600 m length[16]. The impact was assessed from sediment samples, deep-sea camera operations, sediment traps, and current meters and the results show that the abundance of meiobenthos decreased in deposition areas immediately after the experiment and returned to originals levels 2 years later, but the species composition was not the same; whereas the abundance of certain groups of mega and macro-benthos was still lower than the undisturbed area[17].

3.5. Inter ocean metal – Benthic impact experiment by East European Consortium

A benthic impact experiment was conducted by Interoceanmetal (IOM) Joint Organisation, in CCFZ in Pacific Ocean in 1995, using DSSRS. In all, 14 tows were carried out on a site of 200x2500 m and the impact was observed from deep-sea camera tows and sediment samples[18]. The results have shown that no significant change was observed in meiobenthos abundance and community structure in the re-sedimented area, alteration in meiobenthos assemblages within the disturbed zone[19].

3.6. Indian deep-sea environment experiment by NIO, India

The **In**dian **D**eep-sea **E**nvironment E**x**periment (INDEX) was conducted by National Institute of Oceanography (Goa, India) in 1997 in the Central Indian Ocean Basin. The DSSRS was used 26 times in an area of 200x3000 m, during which about 6000 m^3 of sediment was re-suspended. The post disturbance impact assessment studies have indicated lateral migration and vertical mixing of sediment leading to changes in physic-chemical conditions (Fig. 4) and reduction in biomass around the disturbance area[20]. Subsequent monitoring of the conditions showed that restoration and recolonisation process had started and the natural variations had taken over in the impacted areas.

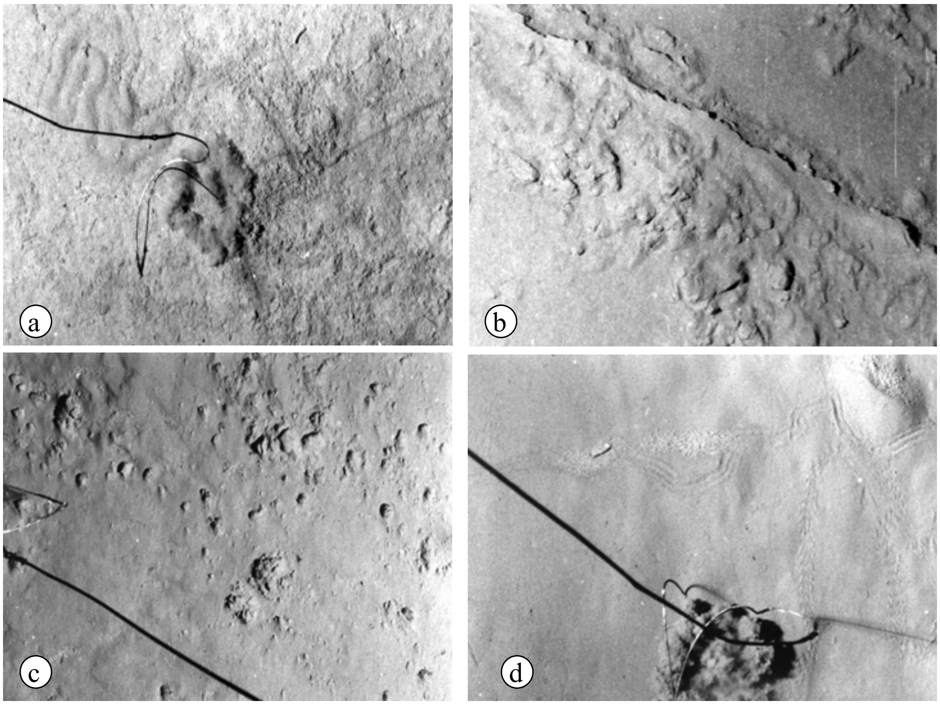


Fig.4. (a) Seafloor with animal tracks before the disturbance, (b) 'disturber' track on the seafloor, (c) sediment lumps close to the disturber track, (d) resedimented surface after disturbanceexperiment.

4. Environmental considerations for deep-sea mining

In order to limit the impacts to minimum levels, the following measures need to be taken in the design considerations of the deep-sea mining system:

4.1. Collector device

a. There should be minimum interaction of the collector system with the seafloor environment, to keep it disturbance free.
b. The separation of minerals from sediments (or other debris) should be as close as possible to the seabed, so that minimum water column is affected by the discharge.
c. Strip-wise mining to be carried out, leaving alternate strips of undisturbed seafloor, to allow re-population by organisms from adjoining areas.

4.2. Surface discharge

a. The surface water discharge can be sprayed over a large area so that it can get diluted without much delay. Sediment discharge should be minimum at the surface, to allow sufficient sunlight to penetrate for photosynthetic activity.
b. Discharge of bottom waters and debris should be at different levels of water column instead of only at the surface. There should be uniform distribution of the discharge in the entire water column.
c. The concentration of discharged material should be such that it will have positive effects such as artificial upwelling.

4.3. At-sea processing, ore transfer and transport

a. Proper treatment of waste disposal to be carried out before discharging. Biodegradable methods should be used for treatment of discharge.
b. Proper care to be taken during transfer of ore from mining / transport vessel to ore carrier to avoid spilling.
c. Oil spills from these ships also should be monitored.

Certain environmental factors must be considered to predict and control the negative impact of offshore mining[21]. These are:

a. The proportion of total area that will be affected, with respect to total area of the waterbody.
b. Influence of surface and subsurface currents in different seasons
c. Distance of coastal belts and inhabited areas from the area of influence.
d. Existence of fishing potential or any other commercial activity in the area of influence.

5. Some unanswered questions

In spite of all experiments conducted and calculations based on still limited data for the possible effects of future mining activities, many questions remain unanswered, due to the limited scope of these studies[22]. Some of the questions are:

a. What will be a likely mining system or systems in next 20 years that can be a basis of environmental tests? It is difficult to specify “commercial-scale” now but should assume instead, because commercial system size and type are likely different depending upon the use of nodule elements and can vary with metal market situation.
b. How do we generalize the test parameters from the tow-sled collector and miner/collector vehicle?
c. How much room do we leave in environment test planning for unidentified deep-sea questions?
d. How do we integrate the test data of bottom disturbance with other effects in a more environmental friendly mining system design and operations?

6. Conclusions

Since, offshore mining may become a reality in future to replenish the mineral resources for industrial development in future; steps should be taken to arrive at such design parameters that the mining operation will cause least possible damage to the marine environment. Marine biological communities survive in a fragile ecosystem by maintaining a very delicate balance with their environment. Time series collection of data on various oceanographic parameters (geological, biological, chemical, physical, meteorological etc.) before, during and after the offshore mining activities will have to be collected to design the mining system as well as to assess the effects of mining.

Based on the results of the deep-sea mining experiment conducted by India, the following environmental inputs have been proposed for minimizing the impacts of deep-sea mining[23]:

- Minimize sediment penetration
- Separation of nodules from the associated sediments near the seafloor
- Lifting of minimum possible sediment to the surface
- Discharge tailings below oxygen minimum zone
- Treat tailings before discharging
- ‘Constructive’ use of unwanted material after extraction of metals

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