

DEEP SEA MINING : ENVIRONMENTAL MONITORING AND MANAGEMENT

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Abstract

A variety of deep sea minerals have been identified in the Indian Ocean, which are expected to serve as an alternative source for metals, when the land deposits get depleted. Mining of some of these exploitable resources, is bound to have an environmental impact in the mining area. The sediment plume due to 'digging up' of these minerals from seabed and disposal of the waste material, will not only disturb the ecology of the seafloor, but also of the entire water column. Increase in turbidity, decreased transmissivity of light and different temperature, pressure conditions are some of the negative factors for the benthic organisms, whereas supply of nutrient-rich bottom water and sediments to organisms on the surface and in the water column could be a positive factor. A concentrated, multi-disciplinary investigation of physical, chemical, biological, geological and meteorological baseline data of the proposed mining areas and the potential environmental impact, is necessary. The environmental monitoring can be done by combining long-term measurements using continuous recorders at pre-determined locations over a period of time as well as intermittent observations over a particular area from time to time. A careful approach for waste disposal also needs to be worked out, to make seabed mining as less a pollution hazard as possible for the marine ecology.

Introduction

As a result of increased use of the seas for navigation of ships, dredging for development of ports and harbours, trawling for living resources and exploration for mineral resources, marine pollution has become an environmental hazard. Like the other oceans in the world Indian Ocean also is a busy shipping area, with a possibility to become a seabed mining site as well due to its potential mineral deposits like the polymetallic nodules (Cronan and Moorby, 1981), hydrothermal deposits (Nagendernath and Mukhopadhyaya, 1987) and phosphorite deposits (Fig. 1), (Rao, 1986).

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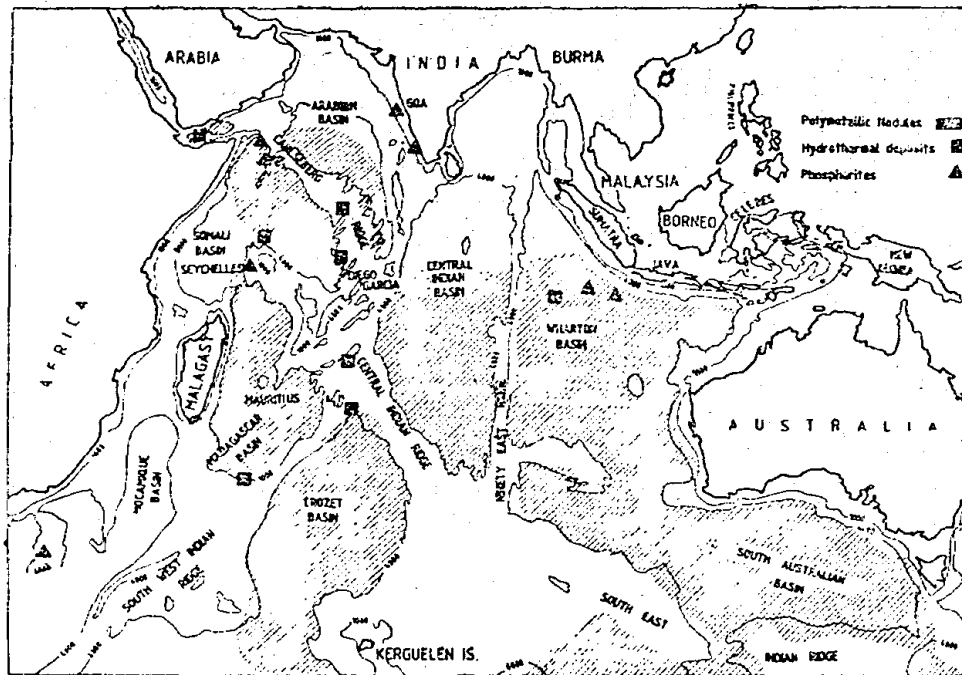


Fig 1 Location of Deep Sea Minerals in Indian Ocean

India has taken up extensive surveys for polymetallic nodules in Indian Ocean which are expected to be alternative source for metals in the coming century. Availability of certain metals in India, their depletion and need for prospecting marine resources in Indian Ocean have been evaluated in a separate study (Gujar and others, 1987) (Table 1). The economic and legal considerations of ocean floor mining have also been worked out (Pearson, 1975). The mining of these minerals will result in recovery of bottom sediments, addition of these to water column as well as mixing of cold, nutrient rich bottom water to the surface.

Some studies have been carried out in other oceans on the potential environmental impact and the community analysis (Jumars, 1977), on various generated models and mining impact (Anderson, 1978), and the environmental studies necessary for nodule mining suggesting the approach to the problem of waste disposal (Pearson, 1975; Amos and others, 1977; Ozturgut, 1978). There are only a few studies on marine pollution along shipping routes in the Indian Ocean (Oostdam, 1980; Sengupta and Querishy, 1981; Price and Smith, 1986), but now detailed studies should also be taken up for environmental monitoring in the potential deep sea mining area.

Mining Activities And Possible Effects

Different mining systems have been developed for the nodule deposits (Fig. 2) (Pearson, 1975; Ozturgut, 1977; Anonymous, 1984). The different activities and their effects are :

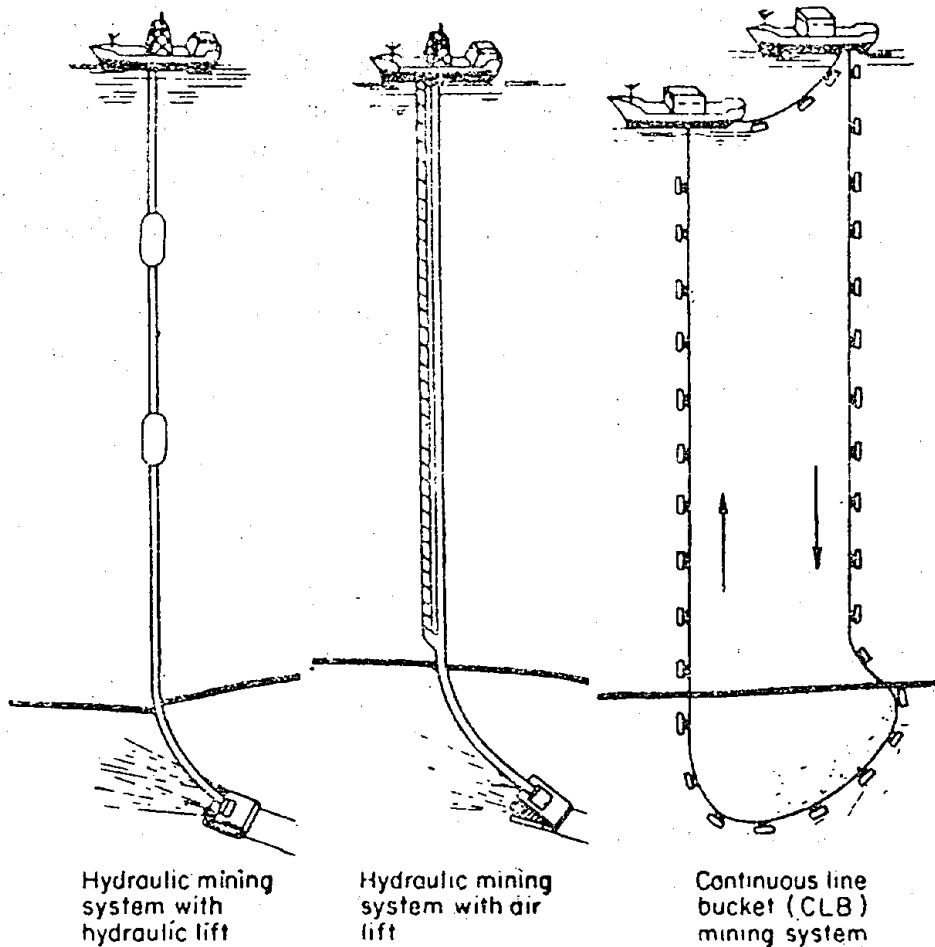


Fig. 2. Three alternative seabed mining systems

a) Seafloor mining and disturbance :

The lifting of nodules with sediments (or even separating them from sediments at seabed) will 'churn up' the seafloor giving rise to a dense sediment plume several metres above the seafloor. According to an

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estimate along with each tonne of nodule lifted, 2.5 - 5.5 tonnes of bottom sediments are disturbed (Amos and Roels, 1977). This will lead to destruction of benthic organisms and affect reproductive cycle of deep sea fauna.

b) Sediment discharge and ecological imbalance :

After lifting manganese nodules from seafloor to the mining vessel, the associated sediments will be sieved off and discharged into the sea water, in addition to fall out of sediment during lifting (in CLB system) and addition of sediment particles on surface (in hydraulic system). According to a study, for every tonne of nodules lifted, 6 tonnes of bottom water will be brought to the surface (Roonwal, 1986). 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 the totally different conditions (low pressure and high temperature etc.) at the surface.

c) Transportation and at-sea processing wastes :

The discharged debris may not settle down where they are disposed off, but may also travel along with currents to the nearby shores, causing a new type of problem to the beaches, marine life and settlements. The fall out of material during transport and oil spillage may also become a pollution hazard. The discharge of waste material from at-sea processing could be far more dangerous to marine environment due to use of chemicals.

Strategy for Environmental Monitoring and Safe Mining

a) Objectives for study on environmental data :

- 1) Predict potential environmental impact.
- 2) Design mining system.

b) Plan for study of environmental impact

In order to evaluate the impact of deep sea mining on the environment, a time-series approach is required (during pilot mining) to determine the changes and time required for disturbed ecosystem to return to their original

state. This will comprise of three phases : pre-mining, mining, post-mining. The pre-mining will provide baseline environmental information on the physical, chemical and biological processes in the area just before it is mined. The observations made during and after mining will be evaluated on the basis of this reference information. The physical, chemical and biological data will be co-ordinated to evaluate the environmental impact of the pilot mining system and to project effects of large scale mining. Whereas, other data (Geological, geotechnical, meteorological and hydraulic) will be used for improving the design of mining system.

c) *Requirements of environmental data and survey methods :*

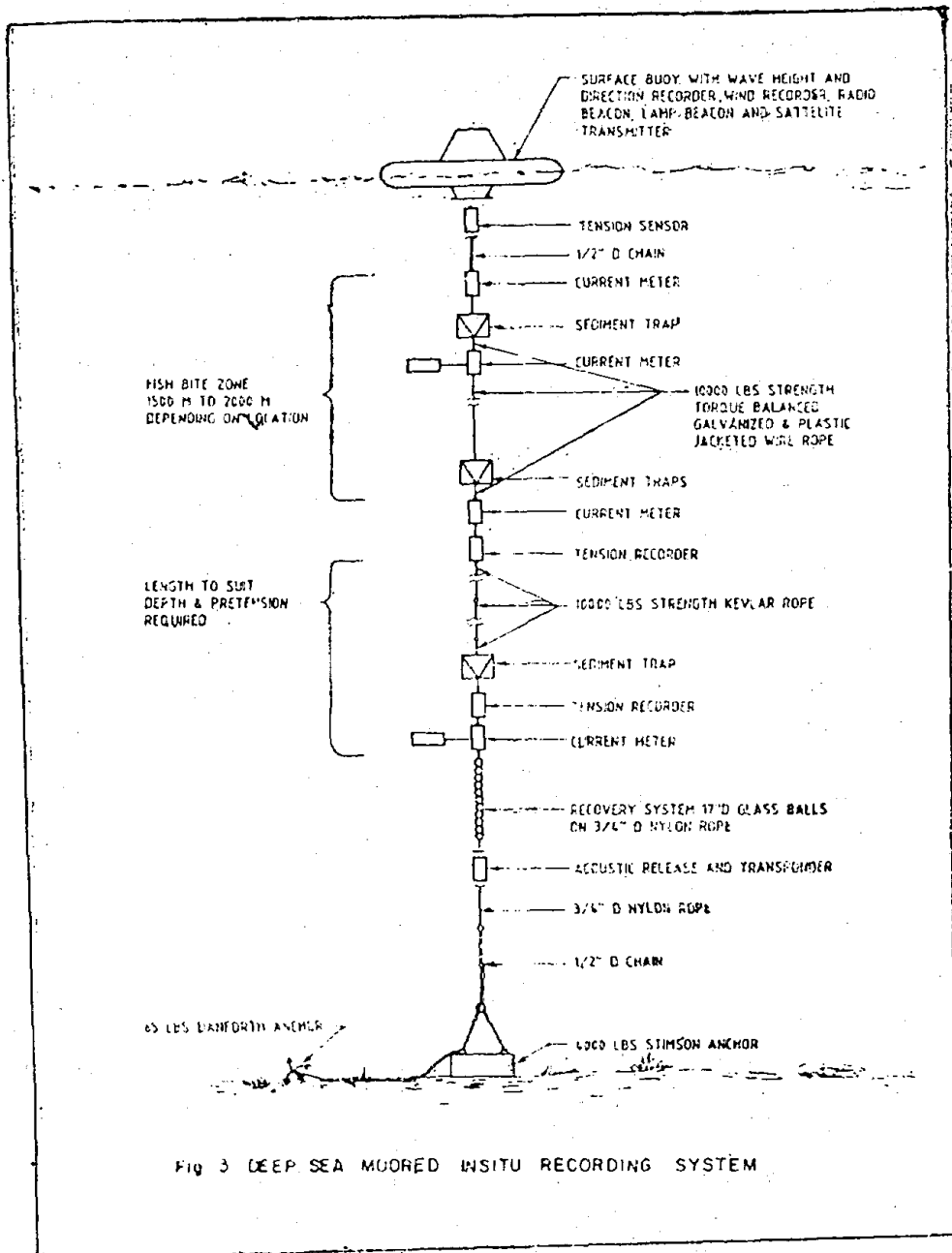
- 1) Permanent measurements by continuous *insitu* self recording system at predetermined locations.
- 2) Measurements covering specified area but intermittently (as it depends on operators).

1) Permanent measurements : Temperature, pressure, conductivity (from which salinity is calculated), sensors, current meters are fixed on vertical taut wire with sinker weight at one end and floats at the other (Fig. 3). This instrument should withstand corrosion and several underwater forces. The design of this system and mooring depends on local conditions, water depths and type and duration of recording of the system. In case of shallow water there is a surface buoy for warning the ships. In the event of accident, the floats enable the instruments still attached to the wire to come to surface. For additional safety and buoyancy, intermediate buoys may also be used. The series of these sensors and recorders can be used to collect data at various depths. The data is recorded directly on magnetic tape which can be subsequently processed using computer.

The addition of sediment traps to this system, gives information on particulate flux in the water column, which will give an idea of vertical and horizontal transport of the particles. Another authentic method to study the seabed process, is the time laps photography where camera system is allowed to take pictures at the same spot at regular intervals over a period of time. This can extend over days, weeks, months, depending upon economic considerations, operational feasibility, instrumental capabilities and expected duration of such

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processes. Such sets of instruments should be deployed at a number of sites so as to decide the more favourable location among them or least hazardous one from pollution point of view.



2) *Intermittent measurements :*

Meteorological : The climatic and weather conditions should be known to determine available working time in a year, adverse weather conditions, likely frequency of storms, cyclones, in order to reduce loss of any kind. The parameters required to be studied are temperature, pressure, humidity, wind speed, wind direction, sea state, wave height, tidal variations, clouds, frequency of rain and visibility at different times of the year.

Oceanographic : Physical and chemical oceanographic studies shall be carried out to study the existing conditions, seasonal variations or any such phenomena in the area (Quetin, Rouville, 1986). These can be done by,

- (i) Using drogue floats for current and trajectory measurements at various depths.
- (ii) Colour tracers for measurement of diffusion coefficient, using aerial photography.
- (iii) Instantaneous salinity and temperature measurements using reversing thermometers at various depths for determination of temperature profile to define density gradients in order to predict varied adverse effects of stratification on dispersion dynamics.
- (iv) Measurement of salinity, pH value, dissolved oxygen, turbidity and lead, copper, chlorine ion concentration.
- (v) Calculation of dilution and concentration of seawater with waste material to determine acceptable conditions or level of pollution.
- (vi) Measurement of vertical profile of horizontal current velocities.

Geological :

- (i) Sampling of mineral deposits using grabs, dredges or drilling to know its extent, distribution, grade, abundance. The extent and distribution will determine the type of collector head of the mining system, whereas grade and abundance will determine the exploitability of the mineral deposit.
- (ii) Rock sampling and sediment cores for studies of associated features and seabed characteristics to decide size and weight of mining head and the kind of filtering mechanism.

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- (iii) Bottom photography for study of *insitu* environment of mineral deposits to predict and monitor disturbance in ecology of the seafloor.
- (iv) Variations in topography have a control over distribution of mineral resources and will influence the type of mining head.
- (v) Certain remote sensing techniques using empirical relationships to give grain size, sorting of sediments and area covered by mineral on seabed.

Geotechnical : In order to understand the interaction between mining system and environment of the mineral deposit, the requirements are :

- (i) Extensive hydrographic survey before, during and after mining to evaluate change in seabed.
- (ii) Measurement of engineering properties by *insitu* penetration measurements based on pre-established penetration density index to know sub-bottom characteristics of different layers.
- (iii) Use of indirect means such as acoustic or nuclear-density measurements to predict certain properties of sediments before sampling.
- (iv) Grainsize, sedimentation characteristics and consistency, plasticity, grading of actual sediment samples, for designing waste disposal, transportation and beneficiation techniques.
- (v) Sediment shear strength and compressibility analysis and knowledge of seafloor bearing capacity for resting the mining head on bottom.

Biological : Regular sampling of megascopic as well as microscopic samples from various levels of seawater, including bottom dwelling organisms using nets, water samplers, grabs and photographs to determine food chain, state of equilibrium of marine life, clinical examination to locate sites of waste disposal. In order to study the impact of mining activity, specific biological conditions like suspended matter, nutrients, toxic substances etc. in water will have to be determined.

Operational : Precise positioning possibly using more accurate methods, like acoustic navigation with the help of seabed transponders.

Hydraulic Conditions : These can be studied using mathematical formulae and model studies under simulated conditions from knowledge of various parameters studied above. This will give some clue to the behaviour of the system as well as that of the effluent discharged in the marine environment (Quetin and Rouville, 1986). Regular model studies to be carried out depending upon feed back for evaluation of performance of mining subsystems, to improve their efficiency and reduce negative environmental effects.

(d) Criteria for safe mining

(i) Seafloor mining and disturbance

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

(ii) 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 surface. The discharge must have positive effects, such as artificial upwelling and no negative effects on the ecology.

(iii) 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.

Conclusion

The environmental monitoring of deep sea mining should lead to :

- 1) Knowledge of potential environmental impact on entire mining area,
- 2) Understanding of its implications before large scale mining begins,
- 3) Development of mining technique having positive environmental effects, such as artificial upwelling, rather than any adverse impact on ecology of the area.

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Table 1 Depletion time of Indian land resources and estimated resources from Indian Ocean for selected metals.

Metals	Depletion of the available land resource (Year)	Source minerals in deep sea	Estimated resources from marine minerals* (tonnes/year)	Remarks
Ni	1991—1993 AD	Polymetallic Nodules & hydrothermal deposits	38,700	No production presently in India. Only imports. Quite strategic.
Cu	2000-2003 AD	"	33,000	Low grade, less deposits. Quite strategic.
Co	No deposits in India	"	3,900	Only imports. Very strategic
Mn	2011 AD	"	5,10,000	High consumption rate, fast depletion of high grade ore.
Fe	(Not available)	"	3,00,000	Sufficient land deposits compared to other metals. So not strategic at present.
Pb	(Not available)	"	600	—
Zn	(Not available)	"	3,900	—
P ₂ O ₅	2000 AD	Phosphorite deposits	(Not available)	Less high grade land deposits. Although marine deposits also low grade, but may be locally exploited.

* Estimates basee on 3m tonnes/Year of nodules from single mine site in CIOB

(Modified from Gujar and others, 1987)