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Deep Seabed Mining and the Environment: Consequences, Perceptions, and Regulations

Jan Magne Markussen

Introduction

This article focuses on environmental consequences of deep seabed mining. The first part deals with environmental impacts. The second concentrates on national and international response in terms of rules and regulations passed to protect the environment.

Considerable efforts are currently under way under the auspices of the secretary-general of the United Nations to create a basis for universal acceptance of the 1982 United Nations Convention on the Law of the Sea. As of 13 October 1993, fifty-nine countries have ratified the Convention, which will enter into force one year after sixty ratifications have been received. The remaining ratification may come at the end of 1993. The Convention consists of eighteen parts. Broad agreement exists on seventeen of these. Part XI dealing with the Area (the deep seabed) is the problem. The USA, Germany, and Great Britain have refused to sign the Convention, holding that Part XI does not allow sufficient room for private enterprise while also paving the way for sizeable United Nations bureaucracy. Here we might add that none of the industrialized countries, except Iceland, have ratified the Convention.

The secretary-general has a list of eight so-called hard-core issues, which forms the basis for his informal consultations on outstanding issues relating to the deep-seabed mining provisions of the Convention. The list originally consisted of nine issues. In the autumn of 1992 'Environmental Considerations of Deep Seabed Mining' was removed from the list.

In 1991 the United Nations Preparatory Commission for the International Sea-Bed Authority and for the International Tribunal for the Law of the Sea had dealt with Draft Regulations on Prospecting, Exploration, and Exploitation of Polymetalic Nodules in the Area. The general attitude amongst participants at the informal consultations held in August 1992 was that the environmental consequences would be 'manageable'. Comprehensive studies of environmental consequences of deep seabed mining carried out in several countries concluded that the consequences would hardly be so serious as to, for instance, put a stop to future commercial exploitation. Environmental organizations in the USA are not particularly concerned about the issue, and do not represent a pressure group. One reason is the assumption that commercial exploitation is not yet imminent.

Was there justification for removing environmental considerations from the list of hard-core issues? Was this done on the basis of scientific considerations, or was it more in the hope of achieving universal acceptance for the Convention?

Environmental Consequences of Deep Seabed Mining

Polymetallic Nodule Deposits

The deep seabed covers an area twice the size of the land area of the earth. There are three main groups of deep-seabed minerals: polymetallic nodules, crusts, and sulfides. This article will concentrate on nodules, because it is with this category that the greatest progress has been made in exploration, evaluation of environmental consequences, development of technology, economic analysis, and the development of a legal and political framework.

Commercially interesting deposits of polymetallic nodules have been identified at depths of 4,500–5,500 metres in the Clarion Clipperton area of the central eastern Pacific Ocean, and in the Central Indian Basin of the Indian Ocean. To be regarded as commercial, the deposits should have an average content of nickel and copper of at least 2.25 per cent, and a nodule density of approx. 10 kilograms per square metre. The nodules contain some fifty metallic and non-metallic elements, of which nickel, cobalt, copper, manganese, molybdenum, and zinc are the most important metals. Nodule deposits represent major reserves of metals. Cautious analyses show, for instance, that there is twice as much cobalt in the Clarion Clipperton area alone as in total land-based reserves.[1]

Studies of Environmental Consequences of Deep Seabed Mining

The USA and Germany have long been the leading nations in terms of studies of environmental consequences of deep seabed mining. The USA was the pioneer; in 1975 the US National Oceanic and Atmospheric Administration initiated the Deep Ocean Mining Environmental Study. This five-year project was organized as a collaborative effort between the National Oceanic and Atmospheric Administration and four US-registered industrial groups. The project consisted of two phases: the first, to characterize the region environmentally, and the second, to monitor the effects of industrial pilot-scale equipment tests therein. The specific objectives of the project were to develop: (1) environmental baselines (biological, geological, physical, and chemical) at the three sites chosen as representative of the range of environmental parameters likely to be met during mining; (2) predictive capabilities, to identify potential environmental effects of nodule recovery; and (3) an information base, to prepare environmental guide-lines for government and industry.[2]

As a part of the second phase, the National Oceanic and Atmospheric Administration monitored test mining operations conducted by the industrial groups in the Pacific Ocean in the late 1970s. For example, Ocean Mining Associates conducted on 10 November 1978 an integrated test of approximately twenty hours of continuous mining at 15,000 feet, during which time 400 tons of nodules were collected and lifted to the ship as various system concepts were examined.[3] Ocean Mining Associates employed a passive towed collector unit for the tests, while another industry group, Ocean Minerals Company, used an active self-propelled collector unit for its integrated tests. In 1981 the National Oceanic and Atmospheric Administration published the first comprehensive Deep Seabed Mining Environmental Impact Statement.[4]

The Deep Ocean Mining Environmental Study concluded, *inter alia*, that there was a need to look more closely into the environmental impacts on the deep seabed—including the effects of the collector unit in and near the mining tracks, and the effects of the benthic (bottom) plume on benthic life, and its food supply, away from the mining activity. In line with these recommendations, the organization has over the past ten years concentrated its work on the deep seabed. The National Oceanic and Atmospheric Administration has designated Interim Preservational Reference Areas in the Clarion Clipperton Fracture Zone. These are stable reference areas which will be unaffected by nodule mining activities, but which are similar to mining sites so that they can effectively serve as controls. The National Oceanic and Atmospheric Administration has worked actively to establish collaboration with other countries. Research collaboration has been established with Japan, the Commonwealth of Independent States, and France; an exchange arrangement for scientists with the German project (see below) has taken place. The collaborative project between the USA and the Commonwealth of Independent States is a large-scale Benthic Impact Experiment. Japan and the United States plan to carry out joint monitoring of the Japanese mining tests in 1996, where Japan focuses on the surface problems, while the US side concentrates on the deep seabed. The Japanese scientists plan to create a model illustrating what happens at the surface level and in the water column. The planned monitoring is a part of a comprehensive Japanese environmental impact study, initiated in 1990 and co-ordinated by the Metal Mining Agency of Japan.[5]

The German 'Disturbance and Recolonization Experiment' was commenced in 1989 as the first long-term, large-scale disturbance recolonization project. The programme is financed by the German Ministry of Research and Technology and is co-ordinated by the University of Hamburg.[6] After obtaining pre-impact baseline environmental data, an area of 10.8 sq. km. in the eastern South Pacific was disturbed in February–March 1989 using a 'plough harrow' device. An initial post-impact sampling series was carried out immediately after disturbance; the site was revisited again for renewed post-impact sampling six months after the disturbance. Plans call for repeated visits to the site at two-year intervals to monitor the anticipated slow recolonization process until the area is inhabited by a new, stabilized community.[7]

The Disturbance and Recolonization Experiment is one of several projects in the German Tiefsee-Umweltschutz-programme for research for the precautionary environmental protection of the deep sea. DM17 million has been invested in the programme from 1989 to 1993.[8] Currently Germany has the highest level of activity in deep-sea environmental research.

To summarize: comprehensive work is currently being carried out to study the environmental consequences. This type of research is not new; it has been conducted in parallel with developments in technology. During the last four years we have seen considerable growth in efforts in this area. Environmental consequences thus constitute a major area of research in deep seabed mining today. Moreover, research in this area is far more than mere office work, the greater part of it being practical scientific work carried out at sea. However, it should be emphasized that up to the present it has only been possible to study the effects of small-scale, short-term mining. Not until very recently have long-term, large-scale disturbance-recolonization projects been started. The results from this research are already emerging, but many decades will pass before we can say anything certain about what actually happens on the deep seabed with regard to repopulation and recolonization. A large-scale project like the German one will, however, never be able to take the place of actual mining. There is broad agreement among scientists that only under long-term pilot mining operations will it be possible to study the environmental consequences satisfactorily. Here, it should be pointed out that the Japanese test planned for 1996 cannot be seen as a long-term comprehensive pilot mining operation, though this is not to say it may not prove useful in an environmental context.

Main Environmental Problem Areas

There are three main environmental problem areas to be expected from exploitation of nodule deposits.[9]

- *The first relates to what happens on the seabed.* As the collector unit gathers nodules, it will seriously destroy the top few centimetres of the seabed, causing major disturbance and disruption to the flora and fauna in the mining tracks. In addition, the propulsion system of the collector unit will stir up sediments; as a result, organisms in and around the tracks will be partially or entirely buried. In the mining tracks, for instance, a mortality rate of 95–100 per cent may be expected for organisms found there.
- *The second relates to the discharge of waste water from the mining ship.* After the nodules have been gathered by the collector unit, they will be washed clean by water jets. The nodules will then be crushed and brought to the surface as slurry containing both crushed nodules and water. When the slurry reaches the surface, there will be a partial discharge of waste water containing particulate matter and trace metals. This discharge may interfere with light penetration and reduce photosynthesis in the surface layers. Furthermore, the waste water will be considerably colder than the surface water.
- *The third relates to onshore processing.* This includes waste water, tailings, and slag. Here roughly the same problems will be encountered as in land-based mining operations.

Two of the three chief problem areas involve the mining operation, the effects on the deep seabed and the effects in the water column. To understand this better, it will be useful to look more closely at just what goes on in the various zones of the water column. There are four biological zones.[10]

Zone 1: the epipelagic zone

This zone extends from the surface down to approximately 200 metres. An important part of the zone is the portion through which sufficient light penetrates to enable photosynthesis to take place. This layer—the euphotic zone—is defined as the depth interval from the surface down to the depth where light intensity is reduced to 1 per cent of the intensity immediately beneath the surface. The lower limit of the layer will necessarily vary both as regards the geographical co-ordinates and the time of year. Typical examples from the Pacific and the Atlantic have the 1 per cent limit at about 50 metres, although in tropical waters this limit lies at about 90 metres. The epipelagic zone is by far the most productive part of the water column, estimates indicating that 80 per cent of the total biomass in the oceans is found here. The biomass in this zone comprises phytoplankton and zooplankton, fish, and fish spawn. It is here that almost all the world's fishery resources are to be found.

Zone 2: the mesopelagic zone

The mesopelagic zone extends from about 200 metres to about 1,000 metres. In this intermediate zone we find layers featuring extreme values as regards important chemical and physical parameters. Here we find, for instance, minimum values for the content of oxygen in solution. In this layer certain species of pelagic fish-stocks and deep-sea shrimp are found, rendering the mesopelagic zone of some importance for commercial fishery.

Zone 3: the bathypelagic zone

As a lower intermediate zone, the bathypelagic zone extends from about 1,000 metres down to about 4,000 metres below the surface. The biomass in this zone is relatively sparse, due to minimal energy in the form of sunlight penetrating to such depths, and a scant supply of nutrients. For the few animals living in this area, conservation of energy is a cardinal principle.

Zone 4: the abyssopelagic zone

In the high seas, this zone extends from about 4,000 metres below the surface down to the seabed, and is characterized by a high degree of stability. Temperatures are low, ranging between 1 and 4 degrees Celsius, and very stable. Stability characterizes the abyssopelagic zone in other contexts as well: low rate of sedimentation, extremely low light penetration, and limited supply of nutrients. The low supply of elements necessary to living organisms means that the few biological resources existing here are to be found on the sea floor and in the upper few centimetres of the seabed sediments. Although many species are found down at the deep seabed, there are relatively few specimens of each species.

Environmental Uncertainty on the Deep Seabed

It is important to distinguish between problems that are manageable and possible to live with, and significant adverse changes that cause serious harm to the environment. A 'significant adverse environmental impact' may be defined as: important harmful changes in ecosystem diversity, the productivity of the biological communities with the environment; or the threat to human health through direct exposure to pollutants, or through consumption of exposed aquatic organisms; or important loss of aesthetic, recreational, scientific, or economic values.[11]

The most significant environmental impacts will be those caused by the collector unit on the deep seabed. German scientists describe the effects on the deep seabed like this:

> Most of the nodules constituting a hard substrata for the settlement of organisms will be collected, a small number will be missed by the collector system, but these are likely to be buried from resedimentation of the plumes. The soft sediment around the nodules will be severely disturbed, compression of sediment will occur to several decimeters, and much of the fauna will be destroyed. Next to the collector system tracks sediment will be piled up. Small areas may remain undisturbed by these actions, but they will most certainly receive a cover of sediment from the plume. Sediment surface feeding fauna will die from food shortage if these manage to survive the direct mining impact. Some chance of survival remains only for stalked organisms penetrating high above the blanketing layer. Their food sources, drifting plankton or other particles, will pass by with the currents, after the plume has disappeared. In total the community will be tremendously altered and recolonization will be a very slow process. The reestablishment of a balanced community may finally take decades.[12]

It is yet too early to say how serious the environmental consequences on the deep seabed will be. US researchers have studied the effects of pilot mining operations conducted in the late 1970s, but these were limited and short-term test operations. As mentioned, comprehensive long-term studies started only three of four years ago, so limited empirical data is available. There is broad agreement on the need for more research—such as investigation of the direct bottom disturbance by the collector system and its indirect influence through resedimentation of the plume.

The second chief problem area is related to the discharge of waste water from the mining ship. The slurry loaded on board the mining ship at the riser outlet will have an approximately 10 to 20 per-cent content of mineral material. To minimize the volume-to-weight ratio of the material to be temporarily stored on board the mining vessel, a de-watering process will be carried out to separate the seawater from the mineral material and dispose of it outside the ship. Discharge of the waste water from this process implies adding to the euphotic zone a significant volume of water with different physical and chemical characteristics. Such waste water comprises seabed water, sediments, fragments of nodules, and benthic biota from the seabed. Its temperature is lower than that of surface-layer water—normal seabed water being between 1 and 4 degrees Celsius. This will rise somewhat in the course of pumping and de-watering, and is calculated to be between 7 and 10 degrees Celsius at discharge. By contrast, in the test mining area where these calculations have been made, normal surface temperature is 26 degrees Celsius; thus, discharging waste water involves a considerable reduction in temperature the moment the water meets the surface. Temperature is an important parameter for life in the euphotic zone.

US investigations have concluded that discharge of waste water is unlikely to represent any serious problem. Particles have been found to sink more rapidly to the bottom than had been anticipated. It will be interesting to see if the Japanese study fully confirms these results. The Germans have recommended further research in this area as well.[13] The discharge depth for the waste water is a much-debated subject. Rather than discharge everything at surface level, several sources have recommended a depth of 200 metres or even 1,000 metres. By choosing the former, disturbance of the most productive part of the water column, the epipelagic zone, would be avoided. Those recommending a discharge depth of 1,000 metres or more justify this by the need to avoid disturbing the processes going on in the mesopelagic zone as well.

The third chief problem has to do with processing operations ashore. Various hydrometallurgical and pyrometallurgical processes have been developed for extracting the metal content from the nodules. In a hydrometallurgical process—a leaching process—chemical additives and electrowinning are used to refine the mineral material. In a pyrometallurgical process—a smelting process—the mineral material is smelted to a crude alloy before the metal products are extracted by use of chemical additives. Environmental consequences will mainly be of two types. The first category is impacts caused during operation of the processing plant—primarily because of gas emissions from pyrometallurgical processes, the integrated power plant, and from the integrated sulphuric acid plant. Emissions of sulphur dioxide, nitrogen dioxide, hydrogen sulphide, and carbon monoxide will have effects on air quality. The second category comprises the environmental impacts caused during pre-treating, handling, and disposal of waste material. Main impacts here are caused by onshore disposal of waste material—slag, tailings, process water, and cooling water—from the processing operations.

To summarize: the effects of onshore processing are in many ways similar to those caused by land-based production. Mining deep seabed minerals thus represents no new source of environmental impacts, but rather an alternative source of supply of the same end-products. However, this does not apply to the effects on the seabed and the water column. Here deep seabed mining will create *new* types of environmental impact. Future exploitation of the nodules will represent the first large-scale activity ever attempted at such depths, and considerable uncertainty attends the environmental consequences. The greatest uncertainty concerns the deep seabed. Scientists describe themselves as cautious optimists, however, so there seems to be no reason to prohibit planned test mining. In fact, long-term pilot mining operations will probably be the most important source of knowledge about the environmental consequences of deep seabed mining.

The environmental consequences of the mining phase are presented in a schematic form in Table 1.[14]

Deep Seabed Mining Technology: Are the Concepts of Today the Technology of Tomorrow?

The environmental consequences will to a great extent depend on the technology selected. It is difficult to formulate detailed regulations protecting the environment unless we know what kind of technology will be used.

The basic technology for mining and processing of nodules has been developed. However, much development work remains before the stage is reached when it can be employed on a commercial scale. The 1996 Japanese test mining may prove important for further technological development. Only through integrated tests of the complete system can we learn which sub-systems to select for further development and which to reject.

Claims have been made that seven to ten years of further development work will be required subsequent to an integrated mining test in order to develop a technology that can be utilized in a commercial project. This is not necessarily correct, however, since others maintain that a government or company which has decided to exploit the resources and which has developed the basic technology and completed test mining will hardly need more than three or four years to have a technology that works. So, to what extent will the concepts of today be the technology of tomorrow?

Today's technology has two major characteristics. In the first place, we must realize that assumptions regarding reliability and efficiency are based upon theoretical analysis and testing on a minor scale. Secondly, the concepts are not only the result of research and development in deep seabed mining, but stem from other areas as well. The concepts of today show, in my opinion, that the deep seabed mining engineers can apply to their own area elements of the available technology and know-how in the offshore oil and gas sector, shipping, and land-based metal production. However, the question is: have they managed to free themselves from conventional lines of thought and to think afresh in order to develop technology precisely suited for the purpose?

No one can say to what extent tomorrow's technology will be different from that of today. There is reason to believe that we can expect to see radical changes in many areas—including a greater integration of the mining and processing phases. Complete or partial processing on the deep seabed in an environmentally safe manner would clearly not only be more efficient in technological terms, but also more rational from an economic angle.

Table 1. Environmental consequences of deep seabed mining—mining phase

Impact	Impacted area	Duration	Near-field or far-field	Recovery	Significance
Physical impact to seabed material	Seabed	Long-term	Near-field	Slow	High
Mechanical damage at track edges	Seabed	Long-term	Near-field	Slow	Moderate
SPM from propulsion system	Water column	Short-term	Near-field	Slow	Moderate
SPM from mineral inlet	Water column	Short-term	Near-field	Slow	Moderate
Accumulated plume effect	Water column	Long-term	Near-field	Slow	High
Re-sedimentation	Seabed	Long-term	Near-and far-field	Slow	High
Nutrition hindrance	Seabed	Long-term	Near-field	Slow	Low
Pump motors	Water column	Short-term	Near-field	Rapid	Low
Thrusters	Water column	Short-term	Near-field	Rapid	Low
Expelling fish and marine mammals	Water column	Short-term	Near-field	Rapid	Low
Temperature decrease	Surface layer	Short-term	Near-field	Rapid	Low
Light reduction	Surface layer	Short-term	Near-field	Rapid	Low
Increase in particulate matter	Surface layer	Short-term	Near-field	Rapid	Moderate
Light intensity and quality reduction	Surface layer	Short-term	Near-field	Rapid	Low
Increase in trace-metal concentration	Surface layer	Short-term	Near-field	Rapid	Low
Exhaust	Surface layer, air	Short-term	Near-field	Rapid	Low
Noise	Air	Short-term	Near-field	Rapid	Low
Interference with commercial fishery	Water column	Short-term	Near-field	Rapid	Low
Collision	Surface	Short-term	Near-field	Rapid	Very low
Loss of mining ship	Seabed	Long-term	Near-field	Slow	Very low
Loss of subsea system	Seabed	Long-term	Near-field	Slow	Very low

Notes: Duration: *Short-term*: disturbance on a short-time scale, in the order of weeks; *Long-term*: disturbance over a longer period of time, in the order of years. Recovery: *Rapid*: impacted environment will recover within months; *Slow*: environment will recover more slowly, with recovery to normal state taking years. Significance: *Low*: not considered to cause any severe disturbance to the environment; *Moderate*: considered to cause a noticeable effect on the environment, but no major problem to the community in the environment in question; *High*: considered to cause severe harm to the environment; further studies needed prior to full-scale commercial mining.

Source: Berge, Stig, Jan Magne Markussen, and Gudmund Vigerust (1991), *Environmental Consequences of Deep Seabed Mining—Problem Areas and Regulations* (The Fridtjof Nansen Institute, Oslo).

Prospects For Commercial Exploitation

Is it true that commercial exploitation lies far in the future, and that there is still plenty of time to draw up rules and regulations for protection of the deep-sea environment?

The 1960s and the early 1970s were characterized by optimism, economic growth, and rapid technological development. It was during this period that interest in deep seabed minerals was seriously awakened. The introductory exploration of nodule deposits took place in the 1960s, while the 1970s saw private companies investing hundreds of millions of dollars in exploration and development of mining and processing technology, from which they expected quick profits. The early 1980s brought disappointment to private investors: metal prices had fallen due to a general decline in the world economy; the technological challenges had probably been underestimated; and there was strong dissatisfaction with Part XI of the United Nations Convention on the Law of the Sea. This resulted in a change of actors: private investments were replaced by national state programmes—actors able to think long-term, and whose motives were supply considerations and political factors. Japan and India started their own national programmes in 1981. Development programmes were under way in France and West Germany. The People's Republic of China and South Korea joined in earnest at the end of the decade. At present we find the highest level of activity in Asia. As mentioned, Japan is preparing an integrated test of a complete mining system. India, the leading developing country in this area, has progressed far, both in exploration and in development of processing and mining technology. Though China, starting later than India, has not come quite so far, its programme for exploration and technology development seems very well organized. South Korea has made a good start on the exploration of polymetallic nodules in the Pacific Ocean. Thus, what is new is the active role played by technologically and economically strong developing countries and newly industrialized countries.

Commercial exploitation of nodule resources will be determined on the basis of an interaction between economic, technological, environmental, political, legal, and to a certain extent also psychological and ideological factors. Thus, all the factors should be viewed in context; at the same time we need to differentiate between various actors, because they have different motives for involvement. The fact that we lack today an up-to-date techno-economic model for deep seabed mining is a major dilemma. Until such a model appears, one should be cautious about delivering weighty pronouncements on the economy or viability of such projects.

At the end of the 1990s we will probably be entering a phase characterized by a stronger degree of international collaboration in this area. There are many indications that we could achieve an international collaborative project in the Pacific, with the aim of further developing technology for use on a commercial scale, with the participation of private as well as state interests from Asia, Europe, and North America. Various factors point to the advisability of such co-operation: first, purely national initiatives mean costly development programmes, and many countries have no doubt carried out parallel research and development in this area. Secondly, the majority of the potential co-operative partners have a sound technological base; actors who feel strong are often more interested in co-operating. Thirdly, there is an increasing general willingness to co-operate with others. Fourthly, it is worth recalling that back in the 1970s the initial development of deep seabed technology was characterized by positive co-operation between companies and research institutions in the USA, Europe, and Japan.[15]

It is difficult to say anything certain about the time prospects for commercial exploitation of nodule resources. However, from an environmental point of view we should assume a worst-case scenario—and this would imply that mining could start some ten to fifteen years from now.

Regulations—Environmental Consequences

The Status

As mentioned, the 1982 United Nations Convention on the Law of the Sea consists of eighteen parts, and environmental aspects are dealt with in each of them.[16] However, neither Part XI dealing with 'the Area' (deep seabed part) nor Part XII on 'Protection and Preservation of the Marine Environment' includes any detailed rules for protection of the environment in connection with deep seabed mining. In 1991 the Preparatory Commission for the International Sea-Bed Authority and for the International Tribunal for the Law of the Sea dealt with 'Draft Regulations on Prospecting, Exploration and Exploitation of Polymetallic Nodules in the Area'.[17] UN under-secretary-general at that time, Satya Nandan, stated that the Draft Regulations 'attempt to balance interest in developing seabed mineral resources with marine environmental protection'.[18] The Draft Regulations are otherwise based upon national deep seabed mining regimes—largely on US legislation—and on other multilateral conventions, in particular the 1988 Convention on the Regulation of Antarctic Mineral Resource Activities. US legislation has also had a strong influence upon other nations' legislation in this field. The United Nations Draft Regulations cannot be regarded as legislation, however. They constitute a framework—or rather guide-lines—for subsequent legislation in this area.

Most of the regulations intended to protect the environment can be grouped into one of three categories:[19] first, rules dealing directly with harmful impacts on the environments;

secondly, a control system to ensure that set standards are complied with; and thirdly, rules to promote compliance with standards, that is sanctions and compulsory means. These are covered by the common expression 'enforcement'.

Let us look at some of the important concepts in the first category. 'Standards' means all rules of direct significance in protecting the environment from harmful effects of deep seabed mining through requiring or prohibiting certain actions, procedures, or effects. The definition of an acceptance criterion—establishing an acceptable level of environmental consequences—is an important concept in this connection. Both the United Nations Draft Regulations and US legislation contain rules that can be regarded as acceptance criteria. According to US law,[20] activities must not involve a 'significant adverse effect on the quality of the environment'. 'Significant adverse effect' is defined in three ways:[21] first, as 'important adverse changes in ecosystem diversity, productivity, or stability of the biological communities within the environment'; secondly, as 'threat to human health through direct exposure to pollutants or through consumption of exposed aquatic organisms'; and thirdly, as 'important loss of aesthetic, recreational, scientific or economic values'. As we see, a rather precise yet comprehensive notion. Together with the establishment of the acceptance criterion, the required consequence analysis forms the foundation for the remainder of the regulatory system. The acceptance criterion expresses what is generally acceptable. The consequence analysis indicates whether the activity in question will remain within acceptable limits, as well as providing a basis for standards by clarifying what measures ought to be enforced to minimize any harmful environmental effects. Thirdly, the analysis is important for the control function: for instance, it may reveal that particular aspects of the activities require special supervision. And fourthly, the analysis can be important for compliance: an operator may be assumed to be more willing to comply with regulations if he can understand what harmful effects his activities may involve. 'Preventive safety standards' is another important concept. Operators are obliged under US legislation[22] to employ 'the best available technologies'—which will reduce the risk of negative environmental consequences.

The Draft Regulations From the Preparatory Commission

The Draft Regulations are not based on any principle of preventive caution. The key provision is slightly ambiguous in this respect:[23] 'Activities shall only take place if they *do not cause* serious harm to the environment' (our emphasis). This might suggest that deep seabed mining could be started only if it were proven that the activity would not involve undesirable effects on the environment. In that case, we would be dealing with a precautionary principle. Other provisions in the Draft Regulations reveal, however, that this has not been the intention. For instance, Article 110 (1) establishes that 'the Legal and Technical Commission . . . shall determine . . . whether the exploration or exploitation can reasonably be expected to result in serious harm to the marine environment'. Nor are there any rules establishing how operators should have fulfilled any burden of proof.

Regarding the material content of the standards, we assume with the preventive safety standards that each contract shall contain a 'requirement to avoid serious harm to the marine environment that may arise from activities in the Area carried out by the contractor and to minimize to the fullest possible extent the risk of serious harm to the marine environment'.[24] No comment can yet be offered on this provision, as it remains to be seen what the individual contracts will contain. Emergency preparedness rules have been given consideration in the Draft Regulations.[25] However, the stipulated preparedness duty appears to be too comprehensive compared to the actual need. In practice this will depend on the stipulations included in the various 'contingency plans'.

As to the provisions that regulate conditions for halting activities in cases of contingency, the basic condition here is 'an incident causing serious harm to the marine environment arising from a contractor's activities in the Area'. However, the need to halt activities may be present also in cases where 'serious harm' is not due to any 'incident', but to regular operations. This will be especially clear if the legislation is based on a precautionary principle. Whenever there are indications that the environmental effects may be different from those anticipated, the natural consequence of a precautionary principle should be that activities must cease forthwith, until such time as knowledge emerges that can render it probable that the unexpected effects do not involve 'serious harm' to the environment. This point should be emphasized in the provisions. Another objection is that a complicated procedure has been stipulated before a halt can be implemented. Even in cases where the secretary-general takes 'immediate measures', some time will inevitably elapse from the moment the serious harm is detected until the operator is ordered to halt activities. However, certain circumstances may make it necessary to halt activities forthwith, where there are indications that serious harm may be caused to the environment. Thus, inspectors should be given the authority to do this in such special cases.

Control

A comprehensive preliminary control has been established, for ensuring that an operator's plans comply with the requirements and obligations stipulated. Furthermore, considerable attention has been paid to the inspectors.[26]

Two other forms of control are lacking. First, it should be possible to include third parties, for purposes of controlling, for example, the vessels to be employed. Considerable expertise is available within the existing classification societies. Secondly, consideration should be given to imposing on the operator a formal obligation to exercise internal control of the regular operation of his activities.[27]

Enforcement

Three different sanctions have been established: two concern the rights of the contractor according to the contract—suspension and termination—while the third is fines. The following comments refer exclusively to fines. The main objection here is the lengthy time-lag from the point at which a breach of standard is revealed until the appropriate fine is applied with final effect. A more flexible system would have been desirable. First, it ought to be explicitly stated that the contractor can be required to accept the fine with immediate effect. Secondly, advance stipulation of standardized fines should be seriously considered; this would mean that as soon as a breach occurred, the size of the fine would be clear. This would remove one potential appeal ground which the contractor could claim, thereby shortening the time from breach occurrence to final establishment of the fine. If such fines are to have the necessary preventive effect they will, of course, have to be sufficiently high to act as a deterrent.

Future Prospects

The United Nations cannot boast a record of being particularly active on the issue of 'environment and the deep seabed', though it would not be fair to call it a laggard in this field either. It is thought-provoking, though, that the USA started work in this area before the UN and has also worked more systematically.

The United States has clearly played a leading role in dealing with these questions. The country's authorities should be given credit for having followed up the technological and industrial progress of the 1970s with extensive environmental studies, while also drafting new regulations. It may come as a surprise that the USA has remained in the forefront also during the last decade. US authorities and private companies have stressed that commercial exploitation will take place in the distant future—perhaps thirty, forty, or fifty years from now. Why this great interest for something that is not supposed to be commercially interesting for several decades? Could it be that the country's involvement in a 'safe' domain will make it less vulnerable to criticism in other, more 'critical' areas? I do not think there are grounds for such a conclusion, though there may, of course, often be a political side to the priorities set in environmental research. The comprehensive German commitment probably has a political dimension—in addition to a very important scientific one.[28]

Like the United States, Germany has not signed the UN Convention on the Law of the Sea. Even so, the German government had been working hard to get the International Tribunal for the Law of the Sea established in Hamburg. Here it should also be noted that Germany has long been a major advocate of a universally acceptable Convention. The government has also been active at the informal consultation rounds, and has acted as an important mediator and link with the United States, in order to get the latter involved in the consultations.

As mentioned, as of 13 October 1993, fifty-nine countries have ratified the Law of the Sea Convention. The secretary-general's informal consultations on outstanding issues have entered a new phase, with the United States as an active participant. The aim is to conclude these negotiations before sixty ratifications have been achieved. There seems to be a definite chance of obtaining consensus on Part XI, which should pave the way for a universally acceptable LOS Convention. The best means to achieve agreement on the remaining issues seem to be to establish limited institutional arrangements and formulate general principles that can be accepted by all. The Draft Regulations and the removal of environmental considerations from the list of hard-core issues signify to some extent that environmental effects have now been put on a 'waiting list', and one area of conflict has thus been 'frozen'. Here we may note obvious parallels with the Antarctic Treaty negotiations, where the decision was to 'freeze' the most difficult issues and formulate general guide-lines.[29] In this connection, it is perhaps worth noting that the road to possible agreement started, in a way, with the removal of 'environmental considerations' from the list of hard-core issues.

However, from the point of view of environmental protection of the deep seabed, this may turn out to be a sensible approach. Even though experts are cautious optimists about the environmental aspects of ocean mining, and the general attitude amongst participants at the informal consultations in August 1992 was that these problems would be manageable, there is also broad agreement within the scientific community on the need for more research about these aspects. Consequently, we do not know for sure what regulations will be required in order to promote precautionary environmental protection of the deep seabed under the LOS. The UN and the International Seabed Authority should thus draw up a concrete plan for keeping abreast of scientific progress, and so at regular intervals assess the need for revising the regulations. But by placing environmental considerations on the 'waiting list', there is a risk that they will remain there, and consequently that the need for regular revisions of the regulations will be forgotten. If this happens, the UN may fail to promote precautionary environmental protection of the deep seabed.

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23. Art. 105(1) is the relevant provision here: 'Activities in the area shall only take place if they do not cause serious harm to the environment.' The crucial concept is 'serious harm'. Art. 2(2) defines 'serious harm' as follows: 'Serious harm to the marine environment means any effect from activities in the area on the living or non-living components of the marine environment and associated ecosystem beyond that which is negligible or which has been assessed and judged to be acceptable by the Authority pursuant to these regulations and the relevant rules and regulations adopted by the Authority and which represent: (*a*) significant adverse changes in the living and non-living components of the marine and atmospheric environment; (*b*) significant adverse changes in the ecosystem diversity, productivity and stability of the biological communities within the environment; or (*c*) loss of scientific or economic values which is unreasonable in relation to the benefit derived from the activity in question.'
24. Art. 111(*b*).
25. Art. 112.
26. Art. 108 (Procedure for Submission of an Environmental Report or an Environmental Impact Statement); Art. 109 (Environmental Impact Statement); and Art. 110 (Consideration of an Environmental Report or an Environmental Impact Statement).
27. Art. 116 already establishes the obligations which in reality involve a form of internal control, for instance that 'each contractor shall take all necessary measures to ensure compliance . . . with the obligations with regard to the protection and preservation of the marine environment from activities in the Area'. This means that the contractor must implement various measures to ensure real compliance. Internal control requires only that these measures and procedures be systematized and formalized. Additionally, the systematic procedures should in turn be the subject of control.
28. In the preface of the information folder of the German programme, Bernd Neumann, parliamentary state secretary in the Federal Ministry for Research and Technology, writes the following: 'The Federal Republic of Germany has attained a position of international leadership in recognizing the worldwide linkage of ecosystems through its support of deep-sea ecology and deep-sea environmental protection . . . The research projects are to assist the development of environmentally benign techniques and international legal regulations for deep-sea environmental protection by the United Nations.' Thiel, Wilhelmsen, Beiersdorf, Halbach, and Schriever (1993), *TUSCH—Research for the Precautionary Environmental Protection of the Deep Sea*, 1.
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