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EIA OF ANTHROPOGENIC ACTIVITIES ON MARINE MACROBENTHOS

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Whenever probable implications of natural or manmade activities on coastal marine environment are assessed, it must be remembered that despite many changes such activities may cause in the physico-chemical properties of the marine ecosystem like water body, bed sediment etc., the ultimate concern is inevitably the biological resource. Hence, the status of flora and fauna of the concerned marine ecosystem should be evaluated, particularly those of high ecological importance such as zones of rich biological productivity, and feeding, breeding, spawning and fishing grounds of economically important organisms which can be degraded by these activities. Any man-made activities on coastal marine system should avoid areas of rich biological productivity of economic importance and endangered species. This has created an awareness of effective environmental monitoring measures. Marine organisms undergo natural stress, which varies in magnitude and frequency depending on changes in physico-chemical characteristics of the marine ecosystem. Though organisms have evolved to withstand the natural changes, they may not be well adapted of sudden and high artificial stress, which may even affect their adaptive capability to natural variations. Hence, from an ecological perspective, the purpose of an MEIA is to predict the ecological consequences of a planned development for providing a scientific basis to determine the acceptability of the perceived impacts relative to because these organisms reflect integrated effect of stress more effectively due to their sedentary habits, long life span, differential tolerance to stress etc.

Macrobenthos

The term marine benthos is widely designated to flora and fauna, which are intimately associated with marine sediments or hard substrates at the seabed. The organisms live within the sediment are known as 'infauna', which either use interstitial space or build burrows or tubes, whereas, the epifaunal organisms are either attached or move at or on the seabed. The larger metazoans over 0.5 mm in size will represent macrobenthos. Benthic macro-invertebrates are widely used in 'biomonitoring' programmes both as surveillance and compliance in order to assess the health of the environment. Species diversity, community structure, succession

and the abundance and distribution in space and time of macrobenthic organisms are mainly decided by the following environmental factors.

- a) Physico-chemical factors such as region, climate, temperature, light, salinity, water depth, currents and circulation, substratum and sediment texture and its oxidation-reduction state, pH, DO, organic content and trace metals.
- b) Biological factors like the food availability, feeding and competition, the prey predator relationship and species removal, the reproductive effects on breeding, spawning, dispersal and settlement, the behavioural effects which induce movement and aggregation and the growth, survival and mortality.

Impact identification

The increasing demand from urbanization and industrialization with indiscriminate use of the marine environment have brought considerable stress on the coastal ecosystems. Accordingly, the marine environment is widely used for various activities like the urban and industrial developments, sea transport, construction of port and harbours, different kind of wastes disposals, capture and culture fisheries, recreations, marine sports, minerals and oil explorations, ecotourism, marine archaeology and excavations, and military uses.

Any alterations in marine environment due to anthropogenic activities will have certain adverse or favourable impacts on marine ecology depending on the nature of activity. The major activities, which can bring marine environmental changes with special reference to benthic habitats are listed below:

- Reclamation
- Dredging/drilling
- Marine structures
- Waste disposals
- Vessel accidents
- Unplanned resource exploitation
- Military warfare testing

Impact on marine benthos

The above mentioned anthropogenic activities will cause disturbance to marine Benthic habitats as well as destruction of marine benthos. The extend of damage to Benthic habitats and the loss of macrobenthos due to such activities depends on various factors like the type and duration of activity, area covered, nature of habitat, climate, ecosensitivity of the area, ecosystem behaviour, biotic response and recovery phase and socio-economic phenomena. The impact assessment of various activities on marine macrobenthos is described below:

Reclamation

The coastal reclamation for various activities like urban and industrial development and usage, port and harbour constructions, recreation and tourism, aquaculture and coastal protection measures can cause wide spread damage to benthic habitats and macrobenthos. The reclamation of mudflats, productive beaches, sand dunes, and ecosystems like lagoon, creeks, estuaries, coral reefs, mangroves, saltmarsh, saltpans, algal beds etc can have serious impact on benthic habitats and macrobenthos including marine fishery since these habitats serve as an important feeding, spawning and nursery grounds for various marine organisms including commercially important fishes.

The reclamation of sand dunes, mangroves, saltmarsh can prompt severe coastal erosion and changes in coastal geomorphology due to increase in wave and tidal forces. The loss of marine macrobenthos of these habitats can also cause adverse impact on fishery, birds, marine and terrestrial mammals, reptiles which use them as an important source of food etc. The benthic macrofauna will be totally eliminated at the reclamation site. The large-scale reclamation will have serious impact on marine ecology of the region depending on the ecosensitivity of the reclamation site. However, at the sea front of the reclaimed site the structures like wall, revertment or other protection measures can provide fresh surface areas for hard bottom macrobenthos to colonize the region. The recovery of benthos at such sites may take 2 to 3 y. Depending on the response of macrofauna and the available surface area, the faunal loss due to reclamation may be compensated adequately. An improvement in the benthic ecosystem during post reclamation period is likely to occur in selected cases. However, damage to highly ecosensitive benthic habitats is rarely compensated.

Dredging

The capital and subsequent maintenance dredging to accommodate seagoing vessels during the port and harbour development can have severe adverse impact on benthic habitats, destruction of macrobenthos, impairment of water quality and direct or indirect impacts on the marine food chain. The impact will depend on the location and extend of dredging, substrate condition and type of organisms inhabiting the area. It can have adverse impact on the fishery of the region if the dredged site happens to be the commercially important fish breeding, spawning or nursery grounds. Mass mortality of benthic organisms including macrofauna at the dredged site cannot be avoided. The recovery of sensitive organisms will take several years. However, the impact on benthos will be temporary and localized. A change in community structure of macrofauna may result during recovery phase depending on the habitat condition. If the maintenance dredging is needed within the recovery phase, the fresh damage and delay in recovery of benthos will result. In general, the navigational channels and berthing places of port and harbours will sustain low macrobenthic faunal standing stock. During the capital and maintenance dredging, a large quantity of dredge spoil will be generated which needs a safe and eco-friendly disposal. Usually, a suitable dump site for the dredge spoil is identified in deep waters based on environmental feasibility studies. The dump site with low ecological significance is generally considered for such dredge disposals. The dredge dumping will increase turbidity. The benthos will get buried and totally destroyed at the dump site. Depending on the frequency of dumping operations and sediment feature, benthos having short life span can appear at these dump sites. A change in community structure of benthos at these dump sites is expected. Overall impact will be temporary and reversible. Beneficial effects are

- (a) increased nutrients that can enhance productivity of the region
- (b) improved circulation
- (c) increased recreational or commercial use of the water body, and
- (d) increased sediment supply for beach nourishment, land fill projects and soil improvement.

Marine structures

Construction of marine structures like jetties, warfs, piled structures, subsea pipelines, offshore platform, SBMS, shore protection groynes etc will have adverse

impact on benthic ecosystem and benthos especially at the foot print of these structures. The impact on macrobenthos will be permanent at the plinth area of these structures. However, these structures will provide new surface areas for hard bottom benthos. In many cases the surface area provided by these structure would be highly significant as compared to that of actual benthic faunal loss. As a result, a change in community structure of benthos can result depending on the nature of substrate during the pre-development phase to that of post-development phase.

Oil exploration

Base line marine ecology of the drilling site should be established before drilling in order to assess the ecological impact of oil drilling on macrobenthos. At the drilling site, a wide variety of liquid, solid and gaseous wastes are produced in the rig some of which are discharged to the sea. These include, drilling fluid, rock cuttings, formation or produced water, deck drainage, sewage, ballast and bilge. Major discharges, however, are the drilling fluids and drill cuttings. Several metals, in the forms in which they occur is used in drilling fluids, apparently, have low toxicities to marine benthos. High aromatic diesel fluids, sometimes added to drilling fluids, are the major among the most toxic petroleum products to marine benthos. Because of the low availability of sediment adsorbed hydrocarbons, most benthic macrofauna are able to tolerate relatively high concentrations of sediment hydrocarbons. Based on the toxicity grading (IMO/FAO/UNESCO/WMO) 90% of the 72 drilling fluids tested on 62 species of marine organisms including benthos can be considered practically nontoxic. However, there could be localized effects (100-500 m radius) on benthic macrofaunal communities where drilling mud and cuttings settle down and accumulate on the seabed. Damage to macrobenthos due to chemical toxicity, change in sediment texture or outright burial is likely to occur in a small area of a few hundred meters around the rig. The rate of recovery of impacted area will depend on the extent of damage and the rate of removal of drilling mud and cuttings by the bed transport associated with currents. Sandy bottom communities in high energy environment usually are tolerant to sedimentation and may recover faster than others.

Waste disposals

The effect of disposal of wastes on the marine environment depends on various factors and processes such as biota and their response, physico-chemical

characteristics of the environment, nature, composition and amount of wastes, its rate of discharge, physico-chemical properties of the wastes; the behaviour or interaction of waste with sea water, and its toxicity. Impact assessment involves two major features namely the biogeochemistry and marine ecotoxicology. The first one deals with the effect of geochemical and biological factors of the environment on the mobility, distribution and transformation of wastes viz., bioaccumulation, magnification, biodegradation, bioconversion etc. whereas the second one estimates the effect of toxic factors on biota viz. acute and chronic toxicities.

Sewage

High organic pollutant with low DO levels and trace metals like Pb, Cu etc. can have adverse impact on macrobenthos at the outfall location and will result in change in community structure of macrofauna. Tolerant groups like polychaetes (*Capitella capitata*) and ampeliscid amphipods (*Ampelisca agassizi*, *A. vadorum*) will dominate during organic pollution. The region will experience low diversity of macrofauna. The enrichment of nutrients and organic carbon in the marine environment results during organic pollution. Excessive nutrient input results in high carbon production which depletes DO levels in sluggish coastal waters especially at the sea bottom reaching to anoxia or hypoxia which can endanger macrobenthic communities. It can cause mass mortalities of benthic fauna. It can also cause health hazards either directly or indirectly through the contamination of commercially important macrobenthos by the bacterial and viral pathogens.

Industrial wastes

Industrial activities generate variety of wastes which are ultimately find their way to the marine environment. From the global perspective, five classes of contaminants are considered to be critical to the health of the marine environment.

1. Petroleum hydrocarbons (crude oil and refined products)
2. Halogenated hydrocarbons
3. Heavy metals (Hg, Cd, Pb)
4. Radionuclides (cesium¹³⁷, strontium⁹⁰ and plutonium^{239 & 240})
5. Solid wastes (dredge materials and fly ash etc.)

Petroleum hydrocarbons

The oil pollution in the sea is mostly caused by anthropogenic activities rather than natural incidents like seeps. More than 65% of the oil pollution in marine environment is designed by municipal and industrial wastes, urban and river run off, ocean dumping and atmospheric fall out. About 26% of the oil in the sea originates from transportation of the oil (e.g. deballasting, dry docking, tanker accidents) and the fixed oil installations (coastal refineries, offshore production facilities, marine terminals) represent 9% of the oil spill.

About 2.12 mt/y of oil reaches the marine environment due to various activities. The toxic components of oil are benzene, toluene, xylene and other low molecular weight aromatics, carboxylic acids, phenols and sulphur compounds. Oil is biodegraded in the marine environment by bacteria. The volatile components of oil quickly evaporates and the denser components get sedimented.

Saltmarshes, mangroves, seagrasses, mudflats and other low energy habitats tend to trap oil and the toxic components readily destroy the marine flora and fauna. Macrobenthos are impacted either directly or indirectly due to degradation of the habitats. In severe cases the oil pollution eliminate the entire benthic communities.

The response of benthic community to oil pollution is given in the table below:

Community	Expected degree of Initial impact	Expected Recovery
Microbenthos		
Rocky intertidal	Light	Moderate
Sandy or muddy intertidal	Moderate	Moderate
Subdial/offshore	Heavy	Slow

Polycyclic aromatic hydrocarbons (PAHs) are of concern because of their potential carcinogenicity, mutagenicity and teratogenicity to organisms. PAHs readily sorbs to particulate matter and sedimented. Benthic organisms are exposed to PAHs at the seafloor. These compounds undergo bioaccumulation; biotransformation and biodegradation in many benthic organisms.

Halogenated hydrocarbons represent greater threat to marine ecosystem. These compounds typically accumulate in the lipid-rich tissues of organisms and many of them are highly toxic. Compounds like DDT, PCBs, chlordane etc. resist breakdown in aquatic environments and are chemically stable, persistent, highly mobile and toxic and can cause acute or chronic pollution problems.

Heavy metals

Heavy metals like As, Cd, Pb, Hg, Se etc are known as metalloids and metals like Co, Cu, Fe, Mn etc. are the transitional metals. Municipal and industrial wastes are the major source of contamination of these metals to the sea. Metals readily absorb to particulate matter and get sedimented. Macrobenthos accumulate these metals from sea water, bottom sediment, interstitial water or other food supply. Bioaccumulation depends largely on metal speciation and bio-availability. Mussels and oysters accumulate heavy metals and therefore they are identified as bio-indicator of metal pollution.

Response of benthic organisms to metal pollution is given in the table below:

Level	Types of responses	Effects at next level
Biochemical/cellular	Impairment of metabolic pathways Detoxication	Disruption in energetics and reduction in energy stores. Adaptation of organism
Organismal	Metabolic changes Behavioral changes Increased incidence of disease Reduction in growth and reproduction	Reduction in performance of populations
	Adjustment in rate functions Disease defence	Regulation and adaptation of population
Population	Changes in population dynamics	Effects on coexisting organisms and community
	Adaptation of populations of stress	No change at community level
Community	Changes in species composition	Deterioration of community
	Reduced energy flow	Reduced secondary production
	Ecosystem adaptation	No change in community stability

Radioactive wastes

There are six categories of radioactive wastes:

1. High level wastes
2. Transuranic wastes
3. Low level wastes
4. Uranium and mill trailings
5. Decontamination and decommissioning wastes from nuclear reactors, and
6. Gaseous effluents

The entry of these wastes to marine environment is through the nuclear fuel cycle, wastes from various agricultural, industrial, medical, military and scientific applications. Marine benthos take up radio-nuclides from water, sediments and fresh food chain. This will impact in physiological and genetic changes, aberrant growth and development, disease and death on marine benthos. The impact depend on total dose, dose rate, type of radiation and exposure period.

Thermal effluents

The heated effluent adversely affect marine benthos by increase in heat and the toxicity due to release of chemical substances. The intake of coolant water can cause impingement of organisms on intake screens and the entrainment of various larval forms of macrobenthos in the cooling water system.

Thermal discharges can alter the water quality especially at the seabed and the benthic communities in the near field areas. It can affect physiological and behavioural responses of organisms carrying growth retardation and either avoidance or attraction to the heated waters. Thermal isolation or gradient may occur in certain species due to heat and O₂ depletion. Sub-lethal levels which can retard reproduction or hatching and inhibition in development of larvae. The biocides may kill selected sensitive organisms.

Vessel accidents

The release of various toxic pollutants like chemicals, fertilizers, oil, etc can result due to ship accidents during transport and also improper handling at the port. This can cause mass mortality of benthic organisms at the accidental site. If the

pollutants are transported to sensitive coastal ecosystem like coral reef, mangroves, salt marsh, intertidal areas etc. it will cause serious damage to benthic ecosystem and macrobenthos. Recovery of contaminated sites will take several years depending on the geophysical and biotic response. Recovery of subtidal ecosystem will take more time as compared to intertidal regions.

Resource exploitation

A large quantum of flora and fauna including the fishery is periodically removed from the marine environment. This can cause serious depletion of the marine resource and also can alter the benthic faunal assemblage and community structure in the affected area. A selective removal of flora and fauna may cause alterations in the benthic community structure of the area. Even unplanned coastal aquaculture also can cause serious impact on benthic ecology of the region through waste disposals from the culture ponds.

Military uses

The sea bed is used for testing various military warfares which can also destroy the benthic habitats and macrobenthos of the test sites. However, such impacts are purely localized and reversible.

Mitigation and Environment Management Plan (EMP)

Advance impacts due to various anthropogenic activities on macrobenthos would occur. Hence, standard mitigation measures and subsequent EMP to minimize the adverse impacts are necessary and are as follows.

- ◆ The key factor in minimizing the adverse impacts would be the reduction in construction period at the site and avoidance of activities beyond the specified geographical area.
- ◆ The ecology of the development site and its surroundings should be carefully assessed for environmental feasibility. Unplanned waste disposals to the marine environment should be disposed off after critical evaluation, planning and proper model studies.

- ◆ Accidents and spillages of materials in the marine environment should be avoided by strictly following well planned traffic management using modern navigation aids.
- ◆ Reduction in marine construction time, and all fabrications sufficiently away from CRZ should be considered.
- ◆ Better coordination of various activities to complete the job in time should be considered.
- ◆ The intertidal and subtidal segments are to be restored to the original contours after the construction phase.
- ◆ General clean up of the used marine area should be undertaken for aesthetic purpose.
- ◆ Dredging, spoil dumping and coastal reclamation should be planned based on adequate model studies.
- ◆ Domestic, industrial and ship generated wastes should be adequately treated before release into marine environment.
- ◆ No waste should be allowed to release into highly ecosensitive marine environment. Similarly, any new development in ecosensitive region should be totally prohibited.
- ◆ Ecosensitive and biodiversity zones should be identified for the future development.
- ◆ Mangrove afforestation or biomass enhancement activities should be supported to balance the carbon flux in the environment for a sustainable development.
- ◆ Baseline ecology of the project site should be established for future periodic monitoring of the marine environment.
- ◆ Post project monitoring should be considered.
- ◆ Risk assessment, contingency plan and emergency response plan should be formulated for effective management.