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Environmental Analysis of Sea Sediments around ONGC Installations of Mumbai High for Monitoring of E&P Impact on Marine Environment

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Abstract

The marine environment can be subject to contamination by organic pollutants from variety of sources such as discharge from industries, oil spillages, marine transportation and E&P activities of oil and gas. After discovery of Bombay High in 1974, ONGC has deployed several drilling rigs and process platforms and more than a hundred unmanned platforms in Western offshore. Besides stipulations made by MoEF, Govt. of India, to fulfil the commitment of ONGC for protecting environment, IPSHEM, ONGC has been carrying out regular monitoring of its oil fields and installations around Western Offshore areas. As water column is mobile in nature, contamination and accumulation of pollutants in sediments will guide us better to assess the environmental stress around the study area. Therefore, the paper focuses on analysis of petroleum hydrocarbon content, non-essential heavy metals like Lead, Chromium and Nickel along with biological study of bottom dwelling organisms i.e. macro benthos in the sea sediments around ONGC platforms like Neelam, Heera, Mumbai High Basin, ICP, SHP, NQ, NA(BHN), BHS and few reference point of Mumbai High(BHR). A long term analysis for the year 1995 to 2012 has been also made for petroleum hydrocarbon and heavy metals to observe the trend of behaviour of those environmental parameters. Although, PHC in sediments during last two surveys decreases, overall trend of PHC from 1995 to 2012 is found increasing. The trend analysis study of heavy metals in sediments reveals that the concentration of Lead observes to be decreasing trend whereas Chromium, Barium and Nickel found almost in parallel trend. Besides, abundance and biomass analysis of macro benthos in sea sediments shows that around almost all the installations, benthic fauna are moderately disturbed. Although all the above parameters are below the toxicity level for coastal environment, the trend behaviour of PHC and benthic study of sea sediments reflects some minor influence of ONGC activities on marine environment.

Introduction

The rapid population growth is accompanied with several human activities, notably the industrial exploitation of natural resources, as well as sewage and refuse dumping into the sea without any treatment. They are often conveyed to the marine environment along rivers and perennial stream. Heavy metals are at low concentrations in aquatic ecosystems where they tend to accumulate in marine sediments to reach toxic levels and can keep heavy metals among their layers and give an entire chronology of deposition mechanism. Even after deposition, trace metals may re-enter the water column under certain environmental conditions. Thus, the sediment acts as a buffer capable of keeping the metal concentration in water and biota above the background levels long after the input of the metal is stopped. Therefore, the analysis of heavy metal levels in sediment samples helps in the interpretation of water quality (Heiny and Tate, 1997) (Ref no.5)

Similarly hydrocarbon contamination into sediments brings adverse effects on benthic organisms. As benthic communities play an important role in the transfer of materials from primary production through the detrital pool into higher tropic levels, including commercially exploitable fish, the hydrocarbon pollution in sediment can affect the entire food web of marine organisms as well as it can affect even human being also. Moreover, in a benthic polluting environment, dominance of few opportunist species like polychaetes will impact on the biodiversity of marine ecosystem.

Again, assessment of the variations in marine ecosystem can be effectively monitored using benthic fauna because pollutants from any source will ultimately end in the seabed. The benthic communities play an important role in the transfer of materials from primary production through detrital pool into higher tropic levels, including commercially exploitable fish. Majority of the benthic fauna are sedentary and sessile in nature and cannot avoid any environmental perturbation, hence are considered sensitive indicator of change in the environment caused by natural and anthropogenic disturbances. ABC (Abundance Biomass Comparison) curves have a theoretical background in classical evolutionary theory of r- and k-selection. In undisturbed states, the community is supposed to be dominated by k-selected species (slow-growing, large, late maturing), and the biomass curve lies above the abundance curve. With increasing disturbance, slow-growing species cannot cope, and the system is increasingly dominated by r-selected species (fast-growing, small, opportunistic), and the biomass curve will be below the abundance curve. (Warwick and Clarke, 1994: Ref no.2)
In view the above, regular monitoring of the concentration of heavy metals, benthic fauna and hydrocarbon content in marine environment is very essential. In this paper, we are trying to analyse heavy metals and petroleum hydrocarbon in sediments over the years 1995-2012 around the ONGC offshore installations. Efforts have been made to observe variation of results over the years i.e. from 1995-2012.Also with the help of Abundance and Biomass of benthic fauna, effort has been made to find out the overall environmental status of the study area.

3. Materials and Methods

3.1 Study Area

The study area has covered oil and gas fields of ONGC in the Western continental shelf are shown in Fig. 1(a).

3.2 Field Sampling

Based on Paris Commission guidelines(1987) (Ref no.1) and keeping in view the pipeline network in the vicinity of the platforms in addition to sea state and maneuverability of the vessel around the installations, samples are collected at stations scattered in circles of 250m, 500m, 1000m and 2000m surrounding each installation. Reference samples were collected beyond 6 kms from the installations as shown in Fig. 1(b)
A Van Veen grab of 25 cms x 30 cms dimension and approximately 1.5 kg capacity having a penetration depth of 10 cm was used for collection of sediments. This medium version of the grab was used to prevent likely damage to pipelines etc. in case of any accidental strike on flow lines. Sea bottom dwelling organisms or benthos are also collected in the same way.

3.3 Laboratory Analysis

Sediment samples collected around installations from different stations are taken for further digestion. After making it dry, the samples are digested with hydrofluoric acid followed by per chloric acid, nitric acid and hydrochloric acid to get a clear liquid. Concentrations of Heavy metals were measured using Inductively Coupled Plasma-Optical Emission Spectrophotometer from this clear liquid sample. For PHC in sediment, the sediments collected from each station were digested with per chloric acid and PHC is being measured using Fluorescence spectrophotometer. All the macrofaunal samples were processed on board after 48 hrs of collection using 500 micron stainless steel mesh screen in filtered seawater and material retained on sieve mesh were fixed in 5% formalin Rose Bengal. In laboratory, all the fauna was stored, identified up to the lower possible level under the Microscope. Biomass (wet weight) was measured by blotting the sample on a blotting paper and weight was taken by direct weighing on balance. The biomass was calculated in g/m^2.

3.4 Data Analysis

3.4.1 Heavy Metals

The results of above analysis revealed the concentrations of metals like Nickel, Chromium, Lead and Barium. Considering data around entire study area, year wise concentration of each metal has been tabulated i.e. from 1995 to 2012 and accordingly plotted in scattered diagram of Microsoft Excell-2010 as shown in Fig 2 (a), 2(b), 2(c) and 2 (d). Latter on one trend line has been drawn for each metal to observe the change of behaviour.

3.4.2 Petroleum Hydrocarbon

From 1995 to 2012, year wise concentration of PHC has been tabulated considering the data around the whole study area and accordingly plotted in Scatter Diagram of Microsoft Excell-2010 as shown in Fig.3. After that, One trend line has been drawn over the graph to see the overall variation within the time period.

3.4.3 Abundance-Biomass Comparison Curve

Abundance i.e. mean density of different macro benthic species around each station of an installation are counted as numbers/ meter^2 and the total biomass of different stations are measured as gm/m^2 as listed tables. Now, the tables of abundance and biomass of different stations of a particular installation are incorporated in the software (primer V6). After running the software as “cumulative dominance curve” one ABC curve is formed where in y- axis we will get “cumulative dominance %” and in x-axis “species rank” will appear. The difference between the two curves is given by the W-statistic, which represents the area between them. Although, ABC curves of each installation are constructed separately but in this paper ABC curve of entire Mumbai High area has been constructed in a single curve.

4. Results and Discussions: Heavy Metals

4.(a) Nickel

Concentration of Nickel found higher during 2010 and overall trend of variation during the time period 1995 to 2012 observed almost constant line as shown in Fig. 2(a).

4.(b) Chromium

Contamination of Chromium observed minimum during 2005 and found maximum during 2010. Overall trend of variation of Cr during 1995 to 2012 found almost line. Fig. 2(b).

4.(c) Lead

Considering concentration of Lead from all the stations around the overall study areas, it has been observed that during the year 1998, sediments of the study areas were more contaminated with lead and after 2008, it starts decreasing during subsequent years. The overall trend of Pb is decreasing as shown in Fig. 2(c).

4.(d) Barium

Considering the study area as entire western offshore area, sediments were more contaminated with Barium during the year 2001 and concentration was minimum during 1995. The overall trend of behaviour from 1995 to 2012 is almost parallel as shown in Fig. 2(d).

4.1 Petroleum Hydrocarbon

Petroleum Hydrocarbon in sea sediments around Western Offshore area found increasing from 2007 to 2009 and decreases from 2010 onwards. During the period of 2007 to 2009, sea sediments around the study area were contaminated severely and overall trend of variation found increasing as shown in Fig. 3.

4.2 ABC Analysis

Fig.4 describes the ABC curve of Mumbai High area indicating the study area is moderately disturbed.

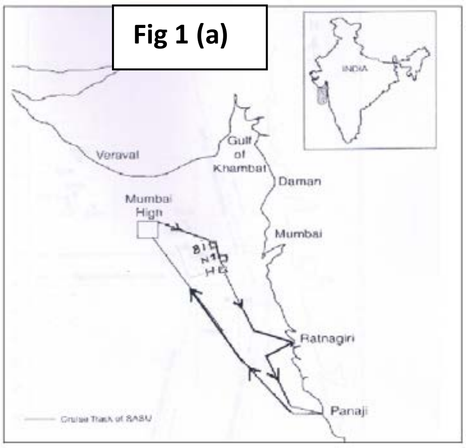
5. Conclusions

1. The trend analysis (1994-2012) of contamination of sea sediments around the study area reveals that concentration of Lead is decreasing whereas Chromium, Nickel and Barium maintain almost a constant trend.
2. Whatever the international findings are available, concentration of the metals around the study area is well comparable.(Table no.1)
3. As such no permissible limits for the hydrocarbon content in sediments are documented, but the PHC content in most of the sediments of the study area are comparable to the literature values of other oceans.(Table no.2)
4. The increasing trend of hydrocarbon content in sediments around most of the installations give a signal to adopt better discharge practices.
5. Again, the behaviour of ABC curve for entire Mumbai High area, the area is moderately disturbed for benthic community.

6. References

1. Paris commission (1989) Guidelines for monitoring methods to be used in the vicinity of platforms in the North Sea, Paris Commission.
2. WARWICK RM, CLARKE KR (1994) Relearning the ABC: taxonomic changes and abundance/biomass relationships in disturbed benthic communities. Mar Biol 118, 739-744.
3. Offshore Environment Monitoring around ONGC installations in Western Offshore Region reports from 1994 to 2012.
4. Marine pollution bulletins.
5. Concentration, distribution and comparison of selected trace elements in bed sediment and fish tissue1 Sep 1998. Heiny, J.S., and Tate, C.M., 1997.

Fig 1 (a)



Platform	Depth (m)
N-1	56
B-1	51
H	53
S	70
B-2	78
I	75
N-2	73
N-3	65

Fig 1(b)

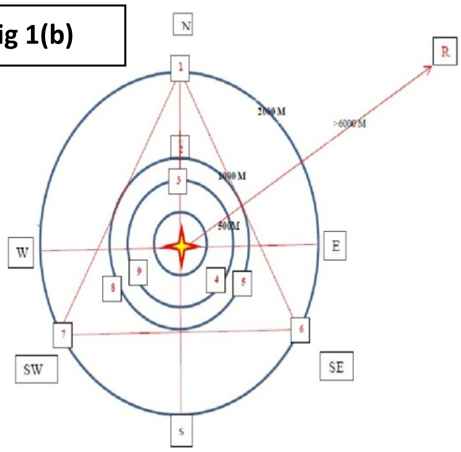


Fig.2(a)

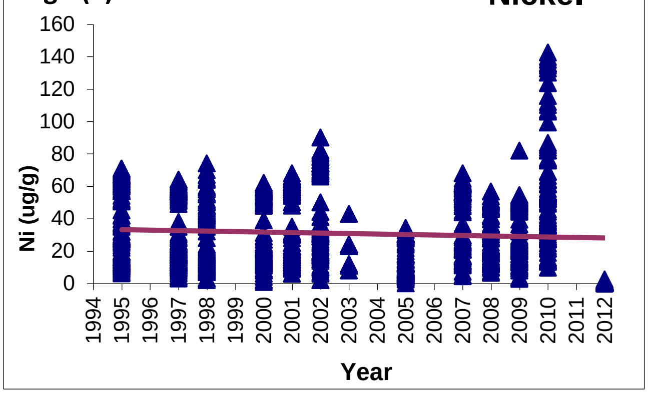
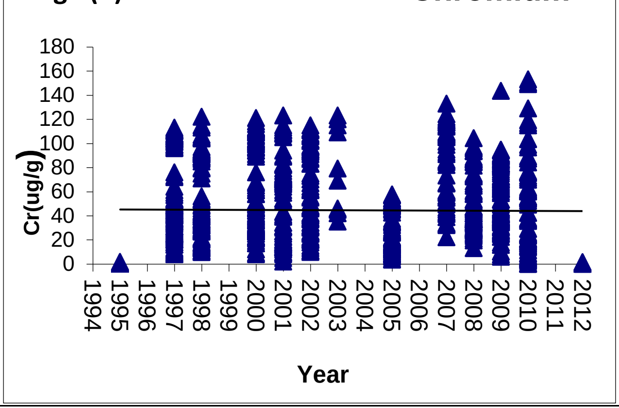


Fig 2(b)



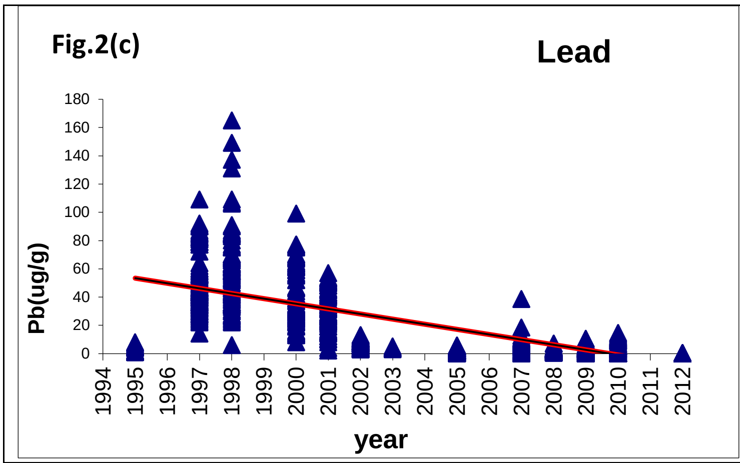


Fig.2(c)
Lead
Pb(ug/g)
year

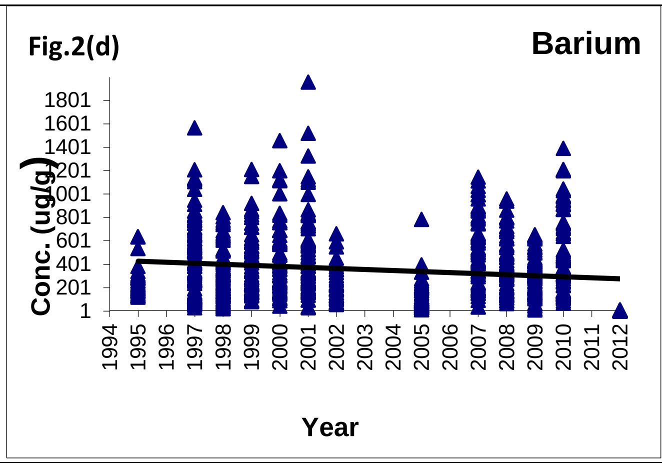


Fig.2(d)
Barium
Conc. (ug/g)
Year

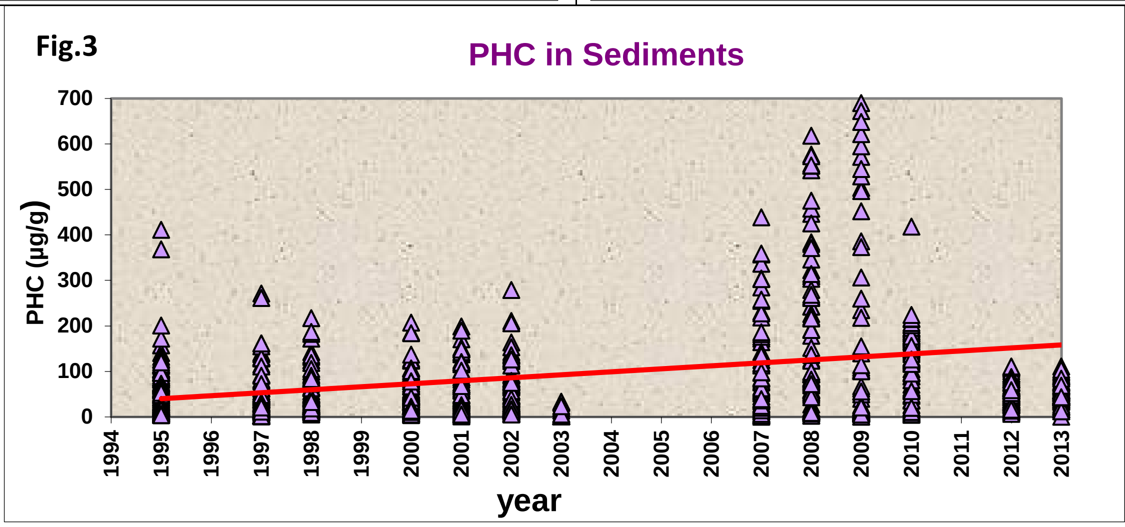
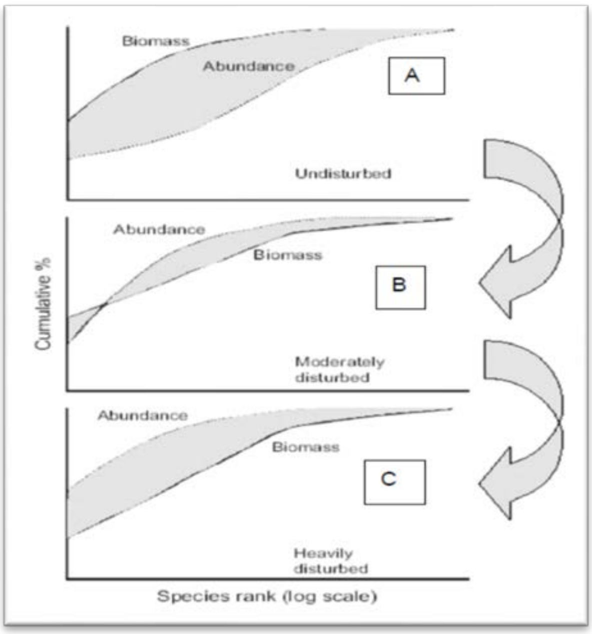


Fig.3
PHC in Sediments
PHC (µg/g)
year


Biomass
Abundance
A
Undisturbed
Abundance
Biomass
B
Moderately disturbed
Abundance
Biomass
C
Heavily disturbed
Cumulative %
Species rank (log scale)

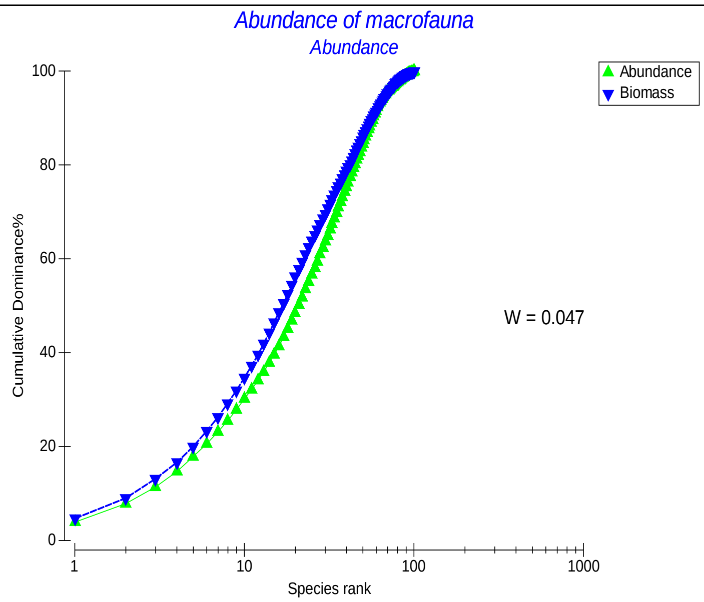

Abundance of macrofauna
Abundance
Abundance
Biomass
W = 0.047
Cumulative Dominance%
Species rank

Fig.4

Table 1:Heavy Metal concentration (µg/g)in the sediments from various parts of the world

Area	Pb	Ni	Cr	Reference
Hong Kong Coast	9-260	5-220	5-560	F Zhou *et al (*2007)
Gulf Saudi Arabia	60-402	3.7-116.1	2.0-87	Sadiq. M(1985)
Gulf Kuwait Bay	17-48	149.5-209.1	148.9-204.3	Anderlini *et al* (1982)
North Sea , UK	17-238	6.5-220	0.4-41	Shiber *et al* (1979)
Narangansett Bay, USA	17-81	53-168	13-81	Eisler *et al* (1977)

Table 2: values of PHC in various sea sediments

Area	Survey year	Total Petroleum hydrocarbons(µg/g)	Reference
Saudi Arabia, Gulf	1991–1993	11-6900	Readman et al. (1996)
Kuwait, Gulf	1992–1993	40–240	Readman et al. (1996)
Xiamen Harbour, China	1993	3.1–33a	Hong et al. (1995)
Victoria Harbour, Hong Kong	1992	60–646a	Hong et al. (1995)
Western Coast, Taiwan	1990	869–10300a	Jeng and Han (1994)
Rhone River, France, Mediterranean Sea	1985–1986	25–170	Bouloubassi and Saliot (1993)
Kuwait, Gulf	1991	28	Fowler et al. (1993)
Saudi Arabia, Gulf	1991	19–671	Fowler et al. (1993)
Great Barrier Reef, Australia	1984	0.5–2	Volkman et al. (1992)
New York Bight, USA	1971–1975	35–2900	Farrington and Tripp (1977)
Black Sea	1988–1990	7–153a	Wakeham (1996)
Bosphorus, Black Sea, Turkey	1995	12–76	J W Readman and G Fillmann
Sochi, Black Sea, Russia	1995	7.6–170	J W Readman and G Fillmann (1995)
Odessa, Black Sea, Ukraine	1995	110–310	J W Readman and G Fillmann (1995)
Danube Coastline, Black Sea, Ukraine	1995	49–220	J W Readman and G Fillmann (1995)