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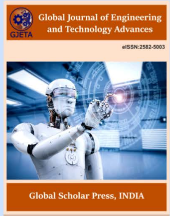

(Research Article)

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Heavy metal accumulation in marine water: An assessment of ONGC's blocks in Krishna-Godavari Basin, Bay of Bengal

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Abstract

Heavy metal pollution, in the aquatic ecosystem, has become an area of concern garnering increasing attention since the past few decades. These metals are introduced into the marine ecosystem mainly due to anthropogenic activities including offshore Oil and Gas exploration and production activities Though rich in aliphatic and aromatic hydrocarbons, crude oil also contains some trace element like vanadium, nickel, iron, aluminium, copper and some heavy metals like lead and cadmium. Poisonous or hazardous components of crude oil are mainly benzene and heavy metals which vary depending on the source of the crude oil. Elements like copper, mercury, lead, cadmium, zinc and chromium are very toxic. Except copper and zinc, others are nonessential and toxic. In fact, all metals are toxic at high concentrations. The heavy metal overload has inhibitory effects on the development of aquatic organisms such as phytoplankton, zooplankton, and fish. The metallic compounds could disturb the oxygen level and mollusc's development, byssus formation, as well as reproductive processes. Hence, monitoring the heavy metal concentrations in sea water over a period of time is of great help in checking the pollution level and identifying the trend, which in turn will be instrumental in formulating sustainable practices.

The paper mainly focuses on the study of the concentration of non-essential heavy metals in sea water around the operational areas of ONGC in western offshore area. The distribution of heavy metals in the seawater of ONGC's exploratory blocks in Krishna-Godavari Basin, Bay of Bengal was investigated. Fifty four sea water samples collected as per OSPAR guidelines from each blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1) of Krishna-Godavari Basin, Bay of Bengal and processed samples were analyzed by ICP-MS for Pb, Cr, As, and Cd. Comparison of average results in studied 6 blocks with various seawater quality guidelines is discussed to assess the present contamination. It reveals that seawater in study area are not contaminated with respect to perceived heavy metals. Generated data will assist in future for proactive measures and minimize the impact of anthropogenic sources.

Keywords: Heavy metal pollution; E&P activities; Krishna-Godavari Basin; Seawater Quality Guidelines

1. Introduction

Govt. of India started encouraging upstream hydrocarbon industry to surge the domestic oil and gas production to shrink import encumbrance. World-wide experiences with updating technology have proven that offshore regions have great potential for exploration and production (E&P) activities. These E&P activities, include exploration, development, production and transportation activities etc., may have adverse impact on marine environment. Oil and Natural Gas Corporation Limited (ONGC), accounts for two third of India's total oil and gas production, has an environment protection policy under which environmental monitoring study is carried out in its operational areas including exploratory blocks of the KG-PG Basin in Bay of Bengal. Present paper deals with the concentration of heavy metals in

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the seawater of six ONGC's blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1), of Krishna-Godavari Basin, Bay of Bengal.

Marine environmental pollution is a worldwide problem and heavy metals belonging to the important pollutants. They are intrinsic, natural constituents of aquatic environment in small concentrations.

Disposal of effluents and oil spills during process upsets during offshore Exploration and production activities contaminate the sea water and may adversely affect the marine environment. Though rich in aliphatic and aromatic hydrocarbons, crude oil also contains some trace element like vanadium, nickel, iron, aluminium, copper and some heavy metals like lead and cadmium. Poisonous or hazardous components of crude oil are mainly benzene and heavy metals which vary depending on the source of the crude oil. Elements like copper, mercury, lead, cadmium, zinc and chromium are very toxic. Except copper and zinc, others are nonessential and toxic. In fact, all metals are toxic at high concentrations. The heavy metal overload has inhibitory effects on the development of aquatic organisms such as phytoplankton, zooplankton, and fish. The metallic compounds could disturb the oxygen level and mollusks development, byssus formation, as well as reproductive processes. Hence, monitoring the heavy metal concentrations in sea water over a period of time is of great help in checking the pollution level and identifying the trend, which in turn will be instrumental in formulating sustainable practices.

The study of heavy metals in the aquatic environment has attracted more attention in comparison with other pollutants due to their non-biodegradable nature, accumulative properties and long biological half-lives. They also pose potential threats to ecosystems because they could be concentrated and biomagnified at sufficient high concentrations, and partly converted to more toxic organic compounds. Many of these metals tend to remain in the ecosystem and eventually move from one compartment to the other within the food chain.

In this paper, analysis of distribution of four non-essential heavy metals, Pb, Cr, As and Cd, has been done in marine water of ONGC's six Blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1), in Krishna-Godavari Basin, Bay of Bengal, from the year of 2021.

The study is intended to determine the present level of four non-essential heavy metals, (Pb, Cr, As and Cd) concentrations in seawater of ONGC's six Blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1), in Krishna-Godavari Basin, Bay of Bengal. Pollution status of collected seawater was assessed by comparing average value of heavy metals, (Pb, Cr, As and Cd) with different quality guidelines of marine as well as drinking water. The results of this study, can be considered as base-line data, will help for proactive measurements to manage and control pollution in coastal region. Thus, study is vital so that any change caused by anthropogenic sources over a period of time can be monitored and managed.

2. Study Area

Krishna-Godavari Basin in Bay of Bengal is considered significant address for oil and gas reserves. Subsequently, offshore E&P activities have been started on Indian east coast nearly two decades ago by public and private operators as well. The study area extends from N16^{0}38'19.67" to N16°01'43.70" and E 82°28'58.06" to E 82°00'19.98". In the study area, the depth of water column varies from 20-1068 m. (Reference Table-1).

Table 1 The coordinates of each Blocks

Sr. No.	Sampling Stations /Block #	Depth(M)	Latitude	Longitude
1	Vasishta/G1-PML-65	681	N16°10'48.97"	E 82°11'27.59"
2	Yanam PML - 48	20	N16^{0}38'19.67"	E 82^{0}22'10. 86"
3	Godavari PML-46	368	N16°32'25.61"	E82°27'57.00"
4	DWN-M-3	450	N16°25'31.00"	E 82^{0}23'48. 10"
5	KG OS DW-III-62	818	N16°01'43.70"	E 82°00'19.98"
6	KG DWN 98/2-1	1068	N16°19'49.94"	E 82°28'58.06"

Figure 1 Location of sampling stations in the study area

3. Materials and Methods

3.1. Sample Collection and Pre-treatment

Niksin sampler was used to sample of heavy metals from the sub surface, middle and above bottom sample. These bottles are non-metallic, free-flushing sampler recommended for general purpose water sampling. During the sampling this plastic cylinder, was lowered to the desired depth with both ends open. Closure of the cylinder was usually triggered by a mechanical messenger. In Niksin sampler, top and bottom cap are held open by a clamp against the tension of a rubber string connecting the through the cylinder. The action of the messenger release clamp and caps are pulled into a position closing off top and bottom of the cylinder by retaining the water column in the cylinder from the depth and time of closure. This water can be retrieved without any contamination from the upper lying water column. As soon as the field work was finished, water samples were carefully shipped and preserved at laboratory.

3.2. Laboratory Analysis

Trace metal extraction is carried out following the standard method APHA- 23rd Ed. 3111B.

3.2.1. Preparation of sample for V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Cd, Ba, & Pb:

- Transfer 50.0 ml of well-mixed, acid-preserved sample appropriate for expected metals concentrations to a flask or beaker.
- In a hood, add 2.5 ml conc. Nitric acid .If beaker is used cover it with ribbed watch glass to minimize the contamination.
- Boiling chips or glass bead may be add to aid boiling and minimize spatter when high level (>10mg/L) concentrations are being determined.
- Bring to a slow boil and evaporate on a hot plate to the lowest volume possible (about 10to20ml) before precipitations occur.
- Continue heating and adding conc. HNO_3 as necessary until digestion is complete, as shown by a light colored clear solution.
- Do not let sample dry during digestion. Wash down flasks or beaker walls and watch glass cover (if used) with metal –free water and then filter with 42 filter paper.
- Transfer filtrate to 50 ml volumetric flask Cool, dilute to the mark and mix thoroughly. Take portion of this solution for metal determination.

3.2.2. Preparation of sample for Arsenic

- Add 50.0 ml sample to 250.0 ml in Kjeldahl flask.
- Add 7.0 ml 18 N H_2SO_4 and 5.0 ml conc. HNO_3.
- Add small boiling chips or glass beads if necessary. Evaporate to SO_3 fumes.
- Maintain oxidizing conditions at all times by adding small amountsofHNO_3 to prevent solution from darkening.

- Maintain an excess of HNO3 until all organic matter is destroyed. Complete digestion is usually indicated by light color solution.
- Cool slightly, add 25 ml water and 1.0 ml HCLO4 and again evaporate to SO3 fumes to expel oxides of nitrogen.
- After final evaporation of SO3 fumes, filter with 42 filter paper and dilute to 50.0 ml with Distilled Water.

In order to obtain more accurate data, all the glassware and Teflon sample cups in this study were soaked with 5% nitric acid, rinsed with milli-Q water, and dried to eliminate potential contamination. An inductively coupled plasma mass spectrometer (ICP-MS; model Agilent 7700) was used for determination of trace metals concentration. Background correction and matrix interference were monitored throughout the analysis. The accuracy was examined by analysing all samples in duplicate. The analytical concentrations of the selected metals of our interest were listed in Table 2.

Table 2 Average metal concentration in ppb (µg/l) of each blocks

Station	Pb	Cr	Cd	As
Vasishta/G1-PML-65	1.48	3.75	0.20	2.55
Yanam PML - 48	0.99	13.88	0.21	1.64
Godavari PML-46	2.12	12.40	0.16	2.93
DWN-M-3	0.95	5.89	0.05	1.51
KG OS DW-III-62	1.31	9.07	0.11	1.83
KG DWN 98/2-1	4.84	25.59	0.91	4.46

OSPAR (Oslo and Paris) Commission Guidelines [3] have been followed, as shown in Figure 2.

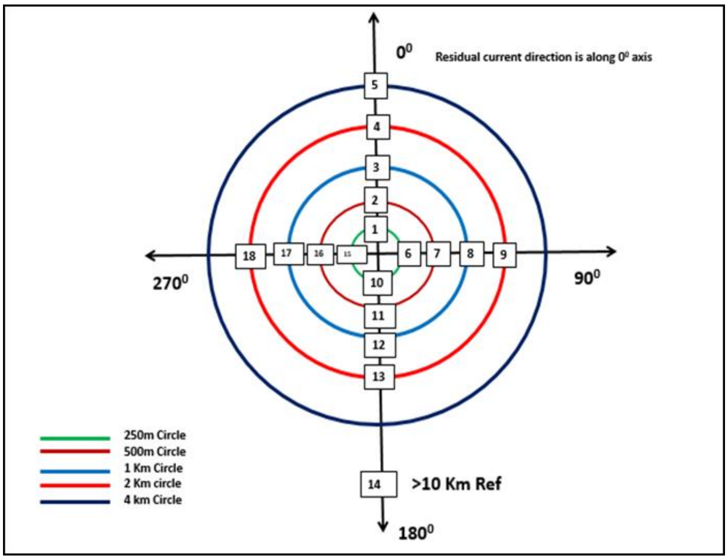

Figure 2 OSPAR Commission Sampling Strategy

4. Results and discussion

In this study, the concentrations of selected four heavy metals in seawater were measured (Table 2). These four heavy metals Lead (Pb), Chromium (Cr), Cadmium (Cd), and Arsenic (As) cause a serious threat to aqua system at higher concentration.

In the present investigation, average concentrations of heavy metals in seawater of different ONGC's six Blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1),varied from 0.95-4.84 µg/l for Lead, 3.75-25.59 µg/l for Chromium, 0.05-0.91µg/l for Cadmium, and 1.51-4.46 µg/l for Arsenic. It is noticed that the distribution of metal concentrations in the seawater of study area has not followed particular trend as concentration varied from one location to another but variation is found minimum when area, depth, and other oceanographic parameters are concerned. It was also documented that all measured metals were found nearly uniformly distributed across all the sampling sites.

These obtained metal concentrations were compared with water quality guidelines to assess present marine pollution status with respect to perceived metals and impact of industrial and economic activities in this area. Table 3 shows guidelines used in present study; water criteria proposed by USEPA, WHO, EU, BIS (ISO: 10500, 2012), ANZECC (*Australian and New Zealand Environment and Conservation Council*), and MMWQCS (*Malaysia Marine Water Quality Criteria and Standard (Class 3)* for heavy metals contents in marine seawater.

Table 3 Comparison of average concentration heavy metals obtained in this research with water Quality Guidelines

Heavy Metals			Cr	Pb	As	Cd
USEPA,2008* (µg/l)			100	15	10	5
WHO,2008* (µg/l)			50	10	10	3
EU,1998* *(µg/l)			50	10	10	5
BIS (ISO: 10500,2012)* (µg/l)			50	10	10	3
ANZECC	2000**	(µg/l)	20	7	30	5
MMWQCS***	(µg/l)		48	50	50	10
Gulf of Chabhar, Oman Sea****	(µg/l)		16.1	2.18	-	0.13
Present Study	(µg/l)		3.75-25.59	0.95-4.84	1.51-4.46	0.05-0.91

*Assessment of Heavy Metal Pollution in Water Resources and their Impacts: A Review by Priti Saha1 and Biswajit Paul2; ** Australian and New Zealand Environment and Conservation Council; *** Malaysia Marine Water Quality Criteria and Standard (Class 3); ****Heavy metals in sea water, sediments and marine organisms in the gulf of Chabhar, Oman Sea, Bazzi A.O

Table 4 Heavy Metals concentration in ppb (µg/l) in collected Seawater sample as per OSPAR guidelines of different blocks

	Vasihta G1 PML 65				Yaman PML				Godavari PML 46			
	Pb	Cr	Cd	As	Pb	Cr	Cd	As	Pb	Cr	Cd	As
Surface	16.34	6.88	1.05	2.42	0.00	6.92	0.22	1.50	0.00	6.36	0.00	1.33
	0.05	3.16	0.06	1.19	0.00	8.17	0.18	2.03	1.45	7.57	0.00	1.50
	0.00	3.56	0.09	4.95	0.00	10.24	0.16	1.99	3.96	14.93	0.14	2.06
	8.67	6.87	0.70	7.88	0.00	8.89	0.16	2.09	7.57	28.54	0.32	3.00
	7.60	10.76	0.56	1.32	0.00	7.03	0.16	1.84	0.00	5.95	0.00	1.51
	0.00	3.42	0.09	3.79	0.00	6.25	0.20	1.41	1.18	14.23	0.00	1.85
	3.47	4.61	0.38	1.99	0.00	5.58	0.19	1.33	0.21	15.69	0.00	1.21
	0.00	6.42	0.27	2.30	0.00	7.49	0.31	1.59	0.54	5.95	0.00	1.35
	1.36	5.57	0.25	2.06	0.00	6.55	0.16	1.75	3.12	16.65	0.20	2.08
	6.04	13.78	0.54	1.71	0.00	8.08	0.22	1.94	0.00	4.85	0.00	1.47
	1.41	8.05	0.35	1.58	0.00	6.00	0.17	1.31	0.32	10.18	0.00	1.82
	0.00	6.54	0.13	3.31	0.00	7.65	0.11	2.09	0.01	4.71	0.00	1.50
	0.96	4.88	0.22	1.40	0.00	7.00	0.12	1.94	2.93	9.31	0.00	2.30
	5.80	4.59	0.38	1.54	1.31	11.91	0.36	2.07	0.53	3.07	0.00	1.55
	5.36	4.66	0.52	3.21	0.00	7.60	0.19	2.05	0.41	4.03	0.00	1.67
	1.09	7.71	0.16	1.77	0.00	5.16	0.23	1.37	0.08	4.81	0.00	1.12
	0.00	3.20	0.04	1.38	0.00	7.38	0.14	2.01	0.00	3.56	0.00	0.88

	0.45	4.77	0.19	2.66	0.00	8.12	0.17	1.96	0.00	4.06	0.00	1.40
	0.31	4.35	0.14	9.22	4.68	18.03	0.36	2.49	3.54	13.29	0.26	2.59
	0.51	3.86	0.15	3.99	0.00	10.56	0.27	1.52	3.01	12.31	0.11	3.18
	1.99	5.14	0.38	4.43	4.28	24.17	0.62	1.75	4.52	36.33	0.11	4.23
Middle	2.03	12.37	0.46	7.81	1.65	38.37	0.47	2.76	2.41	14.27	0.38	4.23
	0.00	1.76	0.00	2.78	0.65	11.32	0.34	2.20	3.98	18.11	0.18	4.89
	0.16	3.82	0.16	3.61	1.91	13.82	0.31	2.38	6.01	14.56	0.49	5.38
	0.00	3.05	0.07	4.78	0.00	9.78	0.15	2.01	3.08	14.65	0.44	4.36
	1.36	5.63	0.17	3.82	5.79	141.71	0.85	2.12	2.34	11.73	0.29	3.95
	1.90	3.68	0.22	2.01	1.41	51.23	0.51	2.31	3.18	11.00	0.36	3.40
	1.11	5.20	0.25	1.78	2.83	17.87	0.63	3.07	1.63	12.16	0.18	5.06
	2.40	6.97	0.55	2.62	0.00	8.82	0.14	1.97	1.85	13.57	0.18	4.74
	0.00	3.92	0.09	2.68	1.48	13.62	0.30	2.05	1.79	12.50	0.26	4.94
	0.63	3.96	0.21	1.52	4.99	10.90	0.37	1.24	2.05	13.43	0.28	4.72
	0.05	2.55	0.04	4.92	0.00	1.56	0.01	1.10	4.42	15.40	0.23	4.68
	0.55	3.84	0.11	7.31	2.38	44.83	0.15	1.53	2.32	13.27	0.04	3.27
	0.00	3.99	0.05	4.06	1.47	33.05	0.00	1.45	1.46	12.87	0.81	6.05
	0.78	3.94	0.23	5.66	2.56	8.27	0.37	0.66	2.31	13.98	0.31	4.51
	0.00	2.43	0.00	3.20	6.69	102.53	0.78	1.14	2.70	13.55	0.04	4.23
	1.60	0.77	0.20	0.68	0.00	2.91	0.00	1.44	2.92	15.24	0.26	4.34
	0.06	0.25	0.09	0.54	0.42	5.29	0.19	1.33	1.95	16.15	0.14	5.21
	1.48	0.86	0.14	0.58	0.00	3.29	0.04	1.14	10.60	38.34	0.66	4.38
	1.35	0.88	0.15	0.54	0.00	0.85	0.00	1.12	7.69	17.56	0.41	6.00
	0.00	0.00	0.00	0.44	0.00	7.14	0.00	1.16	2.62	12.77	0.24	3.40
Bottom	1.47	1.74	0.21	1.91	0.00	2.94	0.00	1.36	1.98	15.42	0.16	4.89
	0.00	0.00	0.00	0.53	0.00	3.93	0.14	1.79	1.78	11.62	0.18	4.29
	0.00	0.00	0.00	0.66	0.00	1.34	0.24	0.90	1.08	9.59	0.12	1.70
	1.31	1.24	0.17	1.06	4.66	3.10	0.35	1.42	0.00	4.12	0.00	1.32
	0.00	1.22	0.12	0.86	0.16	1.73	0.00	0.67	0.85	14.99	0.00	1.85
	0.00	2.84	0.15	1.01	0.00	1.87	0.00	1.08	1.88	20.47	0.00	1.91
	0.00	0.00	0.00	0.83	0.70	2.66	0.15	0.87	2.06	13.70	0.34	2.40
	0.11	0.00	0.10	0.72	0.16	2.44	0.05	1.11	0.00	1.47	0.00	0.91
	0.00	1.06	0.04	0.94	0.00	0.86	0.00	0.85	0.00	2.72	0.00	0.89
	0.00	0.00	0.12	0.81	0.00	3.52	0.00	1.56	0.00	3.41	0.00	1.13
	0.00	0.47	0.11	1.74	0.00	2.45	0.00	1.67	0.00	3.93	0.00	1.49
	0.00	0.00	0.00	0.65	3.21	4.03	0.09	1.32	0.00	10.10	0.00	1.79
	0.17	1.48	0.09	0.64	0.00	2.94	0.00	1.62	4.41	26.65	0.29	2.19

	DWN M3				KG OS DW III 62				KG DWN 98/2-1			
	Pb	**Cr**	**Cd**	**As**	**Pb**	**Cr**	**Cd**	**As**	**Pb**	**Cr**	**Cd**	**As**
	0.17	7.76	0.00	1.18	0.00	3.37	0.00	1.20	1.50	28.95	0.29	2.12
	0.00	0.10	0.00	0.82	0.00	7.01	0.00	1.17	1.17	19.54	0.55	1.97
	0.00	3.51	0.00	1.28	0.75	7.54	0.03	1.50	1.99	26.48	0.22	2.01
	8.85	12.98	0.09	1.33	0.00	4.62	0.00	1.46	15.12	17.26	1.22	6.29
	1.51	15.44	0.03	1.81	1.58	10.67	0.14	1.79	1.96	21.28	3.43	3.62
	0.28	3.26	0.00	1.16	0.00	6.66	0.09	1.53	4.03	24.01	0.32	2.52
	2.02	14.28	0.21	2.33	0.58	8.41	0.06	1.38	6.96	21.39	0.93	2.05
	7.60	5.68	0.00	1.34	3.68	10.22	0.34	2.02	1.51	22.32	1.28	1.76
Surface	0.00	1.38	0.00	0.95	0.05	4.99	0.12	1.42	3.05	24.98	0.74	2.16
	0.00	1.51	0.00	1.14	0.00	4.41	0.00	1.57	20.61	24.97	3.94	9.44
	0.00	1.55	0.00	1.15	0.00	6.27	0.01	1.63	13.74	21.90	1.96	6.95
	1.71	12.26	0.07	2.38	0.00	10.74	0.08	1.63	31.30	28.33	1.86	3.80
	1.39	18.50	0.00	1.76	0.93	5.81	0.11	1.35	8.42	26.67	0.55	2.85
	0.00	0.76	0.00	0.77	0.05	5.98	0.09	1.65	21.20	44.94	1.83	2.93
	0.00	4.50	0.00	1.62	0.60	4.19	0.00	1.48	9.98	23.36	0.93	3.77
	0.00	8.59	0.00	0.77	0.16	5.30	0.09	1.29	11.21	28.14	1.54	2.34
	0.00	3.64	0.00	1.99	0.00	5.50	0.00	1.37	2.31	27.91	0.38	3.04
	0.00	1.49	0.00	1.09	0.74	15.79	0.00	0.88	13.45	46.32	2.21	2.38
	0.00	4.00	0.00	0.41	0.87	16.65	0.14	1.29	0.86	29.75	0.45	2.45
	0.43	4.44	0.13	0.72	0.00	2.57	0.00	0.77	5.70	33.74	1.31	3.25
	0.56	2.58	0.00	0.78	1.80	13.41	0.17	1.62	2.84	30.16	0.83	6.47
	0.71	13.63	0.10	1.76	0.92	12.55	0.21	1.48	2.99	28.55	0.58	10.86
	0.00	6.72	0.04	0.86	0.00	6.53	0.00	1.20	2.82	35.00	0.03	5.01
Middle	5.31	12.60	0.00	1.62	8.58	9.25	0.08	1.27	0.29	30.78	0.29	2.12
	0.00	4.40	0.00	0.79	0.00	16.92	0.00	1.20	7.39	38.29	0.99	6.77
	0.00	4.05	0.00	1.02	2.88	12.08	0.30	0.95	4.85	22.99	0.61	3.47
	1.91	12.65	0.10	1.75	6.19	22.45	0.63	2.47	1.87	37.34	0.32	6.62
	0.00	5.33	0.00	1.16	0.37	5.09	0.16	0.94	3.24	36.31	0.38	11.63
	5.64	9.26	0.00	1.39	0.20	6.63	0.04	1.23	3.51	37.15	0.90	10.75
	3.85	3.35	0.77	1.50	0.49	7.46	0.04	1.40	3.96	36.18	0.80	4.61
	3.34	6.24	0.70	1.45	0.45	4.78	0.13	1.47	1.37	34.56	0.45	4.90
	2.89	1.68	0.56	1.12	0.00	12.59	0.00	1.21	1.01	33.46	0.61	5.27
	0.35	17.24	0.00	1.81	0.00	7.86	0.00	1.21	3.54	46.96	0.96	19.02
	0.00	3.62	0.00	1.73	3.90	21.54	0.28	1.71	1.04	32.63	0.67	2.82
	2.34	17.27	0.00	2.30	4.26	16.45	0.24	2.09	12.03	38.76	4.30	11.34
	0.62	9.81	0.01	1.57	0.00	14.14	0.01	1.53	6.78	34.47	0.77	6.03

	0.00	6.11	0.00	2.60	1.44	11.64	0.23	2.11	0.00	0.00	0.08	1.34
	0.00	2.41	0.00	1.90	2.33	7.55	0.27	1.76	0.91	9.51	0.34	2.93
	0.00	1.98	0.00	1.66	4.83	13.23	0.66	3.00	2.08	15.70	0.37	3.42
	0.00	3.14	0.00	2.47	0.00	4.44	0.00	1.59	0.53	9.15	0.24	3.11
	0.00	2.47	0.00	1.87	0.35	4.82	0.13	1.16	0.12	2.63	0.29	1.43
	0.00	1.36	0.00	1.99	0.00	7.08	0.00	1.91	0.91	18.54	0.89	4.01
	0.00	4.79	0.00	1.46	1.56	12.46	0.22	2.33	0.00	11.90	0.19	2.11
Bottom	0.00	2.13	0.00	1.82	2.33	8.44	0.34	2.21	0.00	13.70	0.19	1.65
	0.00	4.10	0.00	1.78	2.20	8.70	0.05	3.21	5.10	22.62	2.53	6.76
	0.00	1.60	0.00	1.70	2.18	9.76	0.00	4.24	2.23	19.56	0.71	3.13
	0.00	7.47	0.00	2.20	0.41	8.60	0.00	2.93	0.88	22.02	0.49	2.93
	0.00	0.64	0.00	1.40	1.67	9.69	0.02	3.60	4.86	23.92	0.82	3.24
	0.00	4.00	0.00	1.76	1.35	4.47	0.11	2.25	1.85	26.75	0.58	4.23
	0.00	6.42	0.00	1.73	1.11	6.19	0.00	2.72	5.29	24.48	0.78	3.34
	0.00	2.32	0.00	1.78	3.00	11.09	0.05	3.47	1.17	21.14	0.40	2.94
	0.00	4.68	0.00	2.09	1.10	10.82	0.02	3.28	0.00	9.51	0.34	2.38
	0.00	0.62	0.00	1.20	2.37	5.93	0.20	2.59	0.00	22.34	0.33	3.28
	0.00	5.55	0.00	1.61	2.44	8.33	0.04	3.13	0.00	12.31	0.27	3.13

Toxicity of Heavy Metals In biological systems, heavy metals have been reported to affect cellular organelles and components such as cell membrane, mitochondrial, lysosome, endoplasmic reticulum, nuclei, and some enzymes involved in metabolism, detoxification, and damage repair. Metal ions have been found to interact with cell components such as DNA and nuclear proteins, causing DNA damage and conformational changes that may lead to cell cycle modulation, carcinogenesis or apoptosis. Several studies have demonstrated that reactive oxygen species (ROS) production and oxidative stress play a key role in the toxicity and carcinogenicity of metals such as arsenic, cadmium, chromium, lead, and mercury. Because of their high degree of toxicity, these five elements rank among the priority metals that are of great public health significance. They are all systemic toxicants that are known to induce multiple organ damage, even at lower levels of exposure.

The heavy metal overload has inhibitory effects on the development of aquatic organisms (phytoplankton, zooplankton, and fish). The metallic compounds could disturb the oxygen level and mollusks development, byssus formation, as well as reproductive processes.

It is observed that metal contents in seawater are fall under non-polluted category with respect to perceived metals but the concentration of Lead, Chromium and Arsenic in few samples is nearing to threshold limit. This may be considered as a serious threat for aquatic organism and human being health. Present relative lower values could be great turbulence which basically restrict the accumulation of trace metals into the seawater. Therefore, it may be concluded that studied seawater are not contaminated in terms of studied heavy metals. Though the precise source of current metal inputs in the study area is accurately unknown and, hence requires further research. However, observed concentrations are believed to have perhaps been enriched through natural processes, industrial activities around the study area and polluted river water influx.

The results of this study supply valuable information about the metal contents in seawater from different ONGC's blocks in Krishna-Godavari Basin, Bay of Bengal. This can be considered as a bio-indicator of the environmental contamination in this zone by estimating the bioavailability of metals to the marine biota.

5. Conclusion

The results of present study emphasise that heavy metal concentrations in seawater of 6 different ONGC's blocks (Vasihta G1 PML-65, Yaman PML, Godavari PML-46, DWN M-3, KG OS DW III 62, and KG DWN 98/2-1), of Krishna-Godavari Basin, Bay of Bengal were on absolutely lower side and well comparable with the reported values of available oceanographic scientific literature. This can be thought to have resulted from absence of significant anthropogenic influence around the study area.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

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