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Evaluation of Environmental Pollution and Risk Assessment in Surface and Ground Waters around Oil Refinery at Bina, District Sagar, Madhya Pradesh

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Abstract: The study incorporates determination of physical parameters like pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Total Hardness (TH); cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}); anions (HCO_{3-} and Cl^{-}); trace elements (S, P, Zn and Al), hydrocarbons/organic compounds and other particulate matters in the surface and ground waters to study 'environmental pollution' and also to assess the risks posed by an oil refinery at Bina, district Sagar, after 6 years of continued production of oil and other products.

Keywords: Physical parameters, hydrocarbons, oil refinery, surface water and ground water.

Introduction

There is a strong relation between human activities and pollution in the environment! The oil refineries are major industries causing environmental degradation, if risk assessment based on analysis of water for physical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH) along with particulate matters and chemical parameters like hydrocarbons, acids etc. is not carried out regularly. Negligence in adopting standard waste disposal methods or unchecked leakages etc. may also cause pollution around such refineries.

Suleimanov (1995) noticed that the oil refineries may cause environmental degradation, due to release of crude oil products, polycyclic and aromatic hydrocarbons, phenols, metal-derivatives, surface-active substances, sulphides, naphthalene and other chemicals into the nearby water bodies.

Considerable pollution/contamination in surface and ground water bodies rendering the waters unsuitable for drinking/irrigation purposes was noted due to release of unwarranted total suspended solids (TSS, 20-93 mg/l), Cu (0-0.017 mg/l) and Cr (0.04-0.053 mg/l) in Ubeji and TSS (52-106 mg/l), Cu (0-0.04 mg/l) and Cr (0.05-0.08 mg/l) in Iffie rivers flowing on either side of an oil refinery at Warri, Nigeria (Atubi, 2011).

In India, oil refineries have caused heavy-metal concentration in Mithi river in basaltic terrain in Maharashtra (Singare *et al.,* 2012); and toxic oil contamination in ground water bodies releasing water into Chinnaeru river, Andhra Pradesh (Machender *et al.,* 2014) and in Balnagar region, Haryana (Dubey *et al.,* 2010 and Alexander *et al.,* 2012).

In Madhya Pradesh (Central India), high variation in pH (between 7.3 and 9.9), compared to the desirable

Fig.1: Refinery discharges (a) oil-patches in a dug-well near Kathai (b) dark, oily floats in a channel near Bhakri and (c) Dark tar-like float released from the refinery in a nala (seasonal stream) joining Betwa, a tributary of Yamuna in south Ganga basin

range (6.5–8.5, World Health Organisation, WHO, and high values of K^+, Cl^-, P, S, polycyclic and aromatic hydrocarbons, like- phenols, sulphides, naphthalene, acids besides other chemicals in surface water bodies have been recently reported from Bhakrai village, located at a distance of 8 km from the oil refinery at Bina, district Sagar, Madhya Pradesh and inhabited by over 1200 people (Khatik and Kathal, 2017); the cause of such 'hydrocarbon pollution' was attributed to the release of unmonitored/partially monitored wastes drained directly into the Betwa river through streams flowing close to the refinery (Fig.1).

The present study was carried out on the water samples collected from both surface and ground water bodies in the pre- and post monsoon seasons in 2016 in an area (700 km^2, E 78º 05' to E 78º 12' E longitudes and N 24º10' to N 24º 21' N latitudes, Fig. 1) around the oil refinery which is processing crude oil (120, 000 barrels per day since 2011. The area in the outskirts of the refinery is known for its 'quality wheat cultivation'.

The study aims at prepare a 'database' of pollutants and contaminants (based on the ion-chemistry and water-quality) of surface and ground waters, the refinery has been releasing for the last 6 years by draining unwarranted/unmonitored effluents directly into the water channels feeding Betwa river (a tributary of Yamuna, joining Ganga) besides, help monitoring in pollution/ contamination by the refinery in the area dominated by exposures of sandstones (Vindhyans) and basalts (Deccan Traps), with occasional calcareous Intertrappean beds.

Materials and Methods

Total 36 water samples (11 surface- and 25 sub-surface waters) collected in the pre- and post monsoon periods in 2016 (Fig.2) to study physical parameters like pH (using pH meter), EC and TDS, (using soil/water analyzer kit) and chemical parameters like CaH, TH, Ca^{2+}, Mg^{2+}, HCO_3^- and Cl^-, (using colorimeter), constituents like Na^+, K^+ and trace elements P, S, Zn and Al (using Inductively Coupled Plasma Atomic Emission Spectroscope, ICP-AES) and hydrocarbons (using Gas Chromatography High Resolution Mass Spectroscope, GC-HRMS) were analyzed at the Sophisticated Analytical Instruments Facility (SAIF), Indian Institute of Technology (IIT) Bombay, Mumbai

Results and Discussions

Table 1 shows hydro-geochemistry (with comparative standard values of WHO, 2006; Bureau of Indian Standard, BIS, 1983 and United States Environmental Protection Agency, USEPA, 1986) to understand the levels of pollution/contamination in the samples. Table 1 also shows that the pH in water samples ranges from 7.3 - 9.9 (desirable limits, 6.5 - 8.5) in surface water and from 7.1 - 8.9 in ground water in the pre- and post monsoon seasons rendering it useless for drinking purposes. TDS, EC and TH in samples are within the desirable limit of 1600 µS/cm (except in sub-surface waters where it varies from 353-2740 µS/cm). Cations and anions that exceed above the standard desirable limits for drinking purposes are: above 12 ppm for K^+, 250 ppm for Cl^-, 3 ppm for P and 0.5 ppm for S in all the surface water samples and most of the sub-surface water samples. Na^+ in most of the sub-surface water samples, however, cross the permissible limit of 200 ppm in pre- as well as post monsoon periods.

Table-2 shows the results compared to the standard United States Geological Survey (USGS, 2008) limits of various parameters.High concentrations of organic matter/hydrocarbons lupeol (8.18 µg/l), stigmast-4-en-3-one (6.89 µg/l), stigmast-3,5-dien-7-one (6.83 µg/l), stigmasterol (6.15 µg/l), *β*-sitosterol (3.75 µg/l) and campesterol (7.18 µg/l) occur in the soils around the oil refinery and outlet of the waste-water emerging from it (Table 2).

Conclusion

It may be concluded that parameters/constituents (pH, Na^+, K^+, Cl^-, S and P) are above the desirable limits. The concentration of sulphide, i.e. 186 ppm, is around 350 times in surface waters as per the USEPA standards (0.5ppm) and is 95 ppm, i.e. 190 times, in sub-surface waters in pre- as well as post monsoon seasons.

The 'database' of the polluting and contaminating constituents, trace elements and hydrocarbons formulated for surface and ground waters around the oil refinery in the present study may help monitoring the environment for 'risk assessment' in future as the streams are draining into Betwa river, a tributary of Yamuna that forms the part of the south Ganga basin.

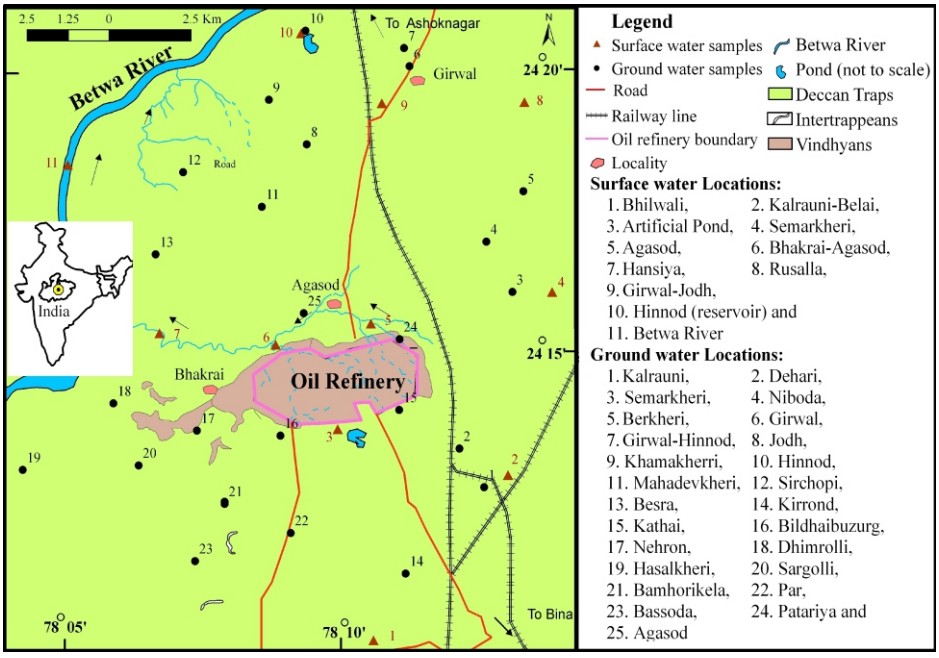

Fig.2: Geological map (after Central Ground Water Board, 2013)

Table 1- Statistical overview and comparison of physico-chemical parameters of surface and sub-surface water-samples around the oil refinery in pre- and post-monsoon periods.

Constituents (ppm)		Surface water samples				Sub-surface water samples				WHO (2006)		BIS (1983)		USEPA (1986)
		Pre-monsoon period		Post-monsoon period		Pre-monsoon period		Post-monsoon period		Acceptable level	Max. Permissible level	Acceptable level	Max. Permissible level	Standard for oil refinery
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.					
Physical parameter	pH	7.3	**9.9**	7.3	**9.3**	7.1	**8.9**	7	**8.8**	7-8.5	6.5-9.2	6.5-9.2	9.2	6.5-8.5
	EC	308	1346	220	1082	355	**2740**	333	**2710**	-	1600	800	4800	-
	TDS	153	676	110	540	178	1419	167	1361	500	1500	500	3000	-
	CaH	28	148	20	220	16	164	28	256	-	-	-	-	-
	TH	44	228	44	240	36	288	56	300	100	500	300	600	-
Cations	Ca^{2+}	11	59.2	8	88	6.4	65.6	11.2	102.4	75	200	75	200	-
	Mg^{2+}	0.96	19.2	1.9	25	1.92	29.76	1.9	17.28	<30	150	30	100	-
	Na^{+}	33.8	177.1	14.9	122.0	20.2	**554.2**	32.15	**560.4**	-	200	-	-	-
	K^{+}	1.02	**24.1**	1.1	**14.9**	0.9	**83.53**	0.88	**60.8**	-	12	-	-	-
Anions	Cl^{-}	35.1	**304.6**	11.1	123.7	22.1	**548.3**	12.92	**559.3**	200	250	250	1000	-
	HCO_3^{-}	79.3	689.3	115.9	439.2	196.4	1098	183	597.8	-	-	-	-	-
Trace Elements	S	**0.899**	**186**	**1.834**	**170.8**	**0.77**	**72.43**	**1.681**	**95.1**	-	-	-	-	0.5
	P	0.093	**3.723**	0.023	0.528	0.059	2.352	0.014	1.2	-	-	-	-	3
	Zn	0.01	0.035	0.002	0.029	0.01	0.073	BD	0.688	-	-	-	5	1
	Al	**0.07**	**0.07**	0.002	0.15	0.019	0.129	BD	0.068	-	0.02	-	0.03	-

Note: All values in ppm (except pH and EC), values above the permissible limits in **bold** letters and (-) shows values not specified by WHO, BIS and USEPA

Table - 2 : Hydrocarbons contamination in the water and soil.

S. No.	Location	Samples	Name of the compounds	Molecular formula	MW	Maximum detected Concentration (µg/l)	Safe Desirable
1	Hansiya	water	9, 12, 15-Octadecatrienoic acid, 2-{(trimethylsilyl) oxy]-1-[[(trimethylsilyl)oxy]methyl] ethyl ester, (Z Z Z)	$C_{27}H_{52}O4Si_2$	496	6.18	NA
			Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	2.77	NA
2	Bhakrai	water	Benzophenone	$C_{13}H_{10}O$	182	**7.38**	**0.5**
			Pentadecanoic acid, methyl ester	$C_{16}H_{32}O_2$	256	3.11	NA
			Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	1.35	NA
			Hexadecanoic acid, methyl ester	$C_{17}H_{34}O_2$	270	5.95	NA
		soil	Stigmastenol	$C_{29}H_{52}O$	416	6.51	NA
			Lupeol	$C_{30}H_{50}O$	426	8.18	NA
			Stigmasta-3, 5-dien-7-one	$C_{29}H_{46}O$	410	6.83	NA
			4, 22-Stigmastadiene-3-one	$C_{29}H_{46}O$	410	1.8	NA
			Stigmast-4 en-3-one	$C_{29}H_{48}O$	412	6.89	NA
			Stigmasterol	$C_{29}H_{48}O$	412	1.21	NA
			ß-Sitosterol	$C_{29}H_{50}O$	414	3.75	NA
			Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	2.45	NA
4	Bildhaibuzurg	soil	Cholesterol	$C_{27}H_{46}O$	386	**5.58**	**1.3**
			Campesterol	$C_{28}H_{48}O$	400	7.18	NA
			Stigmasterol	$C_{29}H_{48}O$	412	6.15	NA
			y-Sitosterol	$C_{29}H_{50}O$	414	6.01	NA

Note: MW-Molecular weight**,** NA-not available and highest concentration of common compounds in **bold** letter

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