Physical and geochemical parameters of surface-water bodies around the oil refinery at Bina, Sagar district, Central India

The physical and geochemical characterization of surface-water bodies (river, stream, pond) around an oil refinery at Bina, Sagar district, Madhya Pradesh, India was carried out to check plausible pollution/contamination caused by it during the pre- and post-monsoonal periods for risk-assessment and monitoring of environmental changes. The streams emerging from the refinery join Betwa river, a tributary of the Yamuna (south Ganga Basin). Various physical and chemical parameters were found to be above the acceptable standard international limits for drinking purposes.

The oil refineries may cause environmental degradation if risk assessment/ periodic monitoring of water samples is not carried out in time or periodically to study the physical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS) and total hardness (TH), and the impact of gases like SO_2, NO_2, CO, NH_4, along with hydrocarbons, particulate matter, etc. that refineries release in the atmosphere, surface and groundwater bodies due to waste disposal, leakages and unforeseen hazards.

Pollution by oil refineries due to high total suspended solids (TSS) and high concentration of H_2S, Cu and Cr in Ubeji and Iffi rivers in Nigeria[1] and a river in Iran[2] was noticed, which rendered the water unsuitable for drinking purposes. In India, the heavy metal concentration in Mithi river in the basaltic terrain of Maharashtra[3] and Chinnaeru river in Hyderabad, Andhra Pradesh[4], as well as toxic oil-contaminated groundwater in Panipat, Haryana[5] have been noticed.

The present study was carried out covering an area over 700 km^2 (in a radius of about 15 km) around the refinery at Bina (Figure 1), where sandstone (Vindhyans, Middle Proterozoic) and basalt (Deccan Trap, Upper Cretaceous to Eocene) with occasional calcareous sandstone (Intertrappeans) are exposed.

The characterization of physical and geochemical parameters in the surface waters, after 5 years of commencement of oil production was carried out to define and monitor plausible contamination/ pollution by the refinery. This was based on the analysis of 11 surface-water samples collected during the pre- and post-monsoon periods (2015) in Betwa river, streams and artificial ponds to study physical parameter like pH, EC and TDS using soil/water analyser kit; chemical parameters like calcium hardness (CaH), TH, Ca^{2+}, Mg^{2+}, HCO_3^- and Cl^- using titration (colourimetry); constituents like Na^+, K^+, P and S using inductively coupled plasma atomic emission spectroscopy, and hydrocarbons using gas chromatography high resolution mass spectroscopy at the Sophisticated Analytical Instruments Facility (SAIF), Indian Institute of Technology Bombay, Mumbai.

Tables 1 and 2 show the results with acceptable limits of various parameters and constituents according to the standards laid down by the World Health Organization[6] in 2006; Bureau Indian Standard[7], in 1983 and United States Environmental Protection Agency[8], in 1986, to understand the hydro-geochemistry and compare the levels of contamination/pollution in the surface-water bodies around the refinery.

The pH in some surface-water bodies ranges between 7.3 and 9.9 (against the desirable limits of 6.5–8.5), in pre- and post-monsoon months rendering it useless for drinking purposes (Table 1). The values of TDS, EC and TH, however, are within acceptable limits. Upper limits for drinking purposes are crossed in all/most of the samples for K^+ (above 12 ppm); Cl^- (above 250 ppm); P (above 3 ppm) and S (above 0.5 ppm) (Table 2).

It has been noticed that the oil refineries release crude oil products, polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface-active

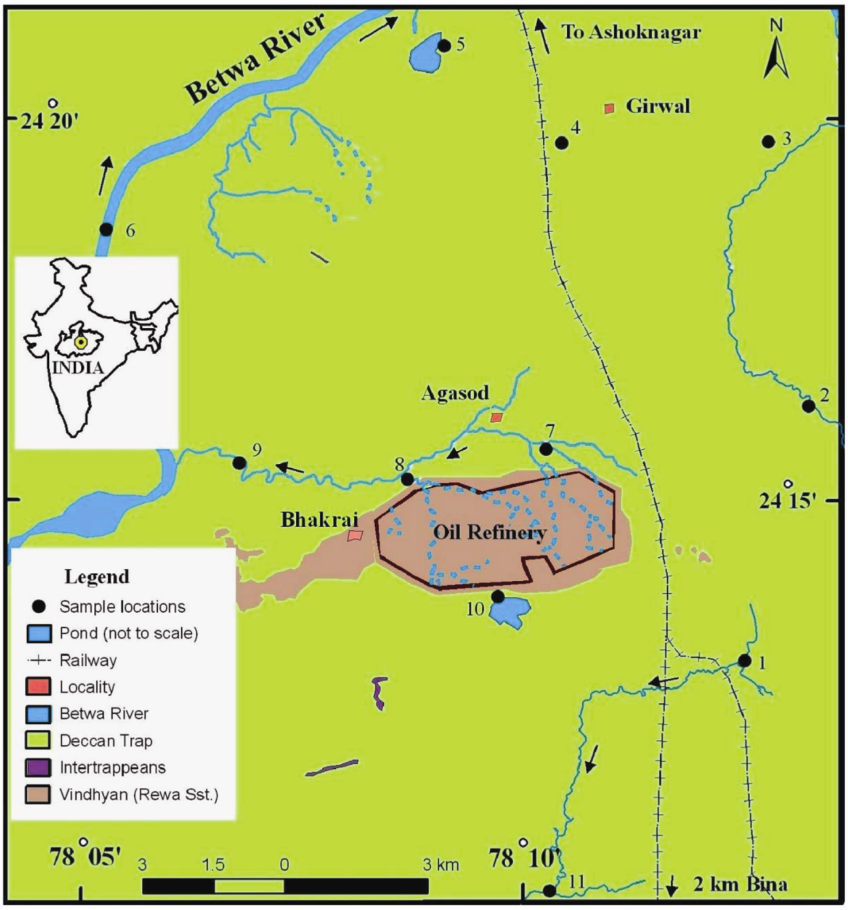

Figure 1. Geological map of the area showing location of samples (after Central Ground 2013). 1, Kalrauni–Belai; 2, Semarkheri; 3, Rusalla; 4, Girwal-Jodh; 5, Dam; 6, Betwa river; 7, Agasod; 8, Bhakrai–Agasod; 9, Hansiya; 10, Artificial Pond; 11, Bhilwali.

Table 1. Physico-chemical parameters of surface-water samples around the oil refinery during pre- and post-monsoon periods

Physical parameters	Surface-water samples: Pre-monsoon period Minimum	Maximum	Average	Post-monsoon period Minimum	Maximum	Average	International permissible standards: WHO (2006) Acceptable level	WHO (2006) Maximum permissible level	BIS (1983) Acceptable level	BIS (1983) Maximum permissible level	USEPA (1986) Standard for oil refinery
pH	7.3	**9.9**	8.4	7.3	**9.3**	8.27	7–8.5	6.5–9.2	6.5–9.2	9.2	6.5–8.5
EC (µS/cm)	308	1346	706.18	220	1082	567.78	–	1600	800	4800	–
TDS	153.2	676	363.69	109.7	540	284.34	500	1500	500	3000	–
CaH	28	148	61.09	20	220	79.27	–	–	–	–	–
TH	16	228	102.90	44	240	125.09	100	500	300	600	–

All values are in ppm, except pH and EC. Values above permissible limits are shown in bold letters.

Table 2. Constituents of cations, anions and trace elements of surface-water samples around the oil refinery during pre- and post-monsoon periods

Constituents (ppm)		Surface-water samples: Pre-monsoon period Minimum	Maximum	Average	Post-monsoon period Minimum	Maximum	Average	International permissible standards: WHO (2006) Acceptable level	WHO (2006) Maximum permissible level	BIS (1983) Acceptable level	BIS (1983) Maximum permissible level	USEPA (1986) Standard for oil refinery
Cations	Ca^{2+}	11.2	59.2	24.4	8	88	31.65	75	200	75	200	–
	Mg^{2+}	0.96	19.2	10.03	14.8	24.96	10.99	<30	150	30	100	–
	Na^{+}	33.77	177.14	78.80	14.86	122.02	57.86	–	200	–	–	–
	K^{+}	1.09	**24.13**	8.13	1.08	**14.93**	3.82	–	12	–	–	–
Anions	Cl^{-}	35.07	**304.59**	125.02	11.08	123.69	47.325	200	250	250	1000	–
	HCO_3^{-}	79.3	689.3	325.52	115.9	439.2	265.68	–	–	–	–	–
Trace elements	S	**0.99**	**186**	28.69	**1.83**	**170.8**	38.98	–	–	–	–	0.5
	P	0.09	**3.70**	0.55	0.023	0.53	0.19	–	–	–	–	3.0

Values above permissible limits are shown in bold letters.

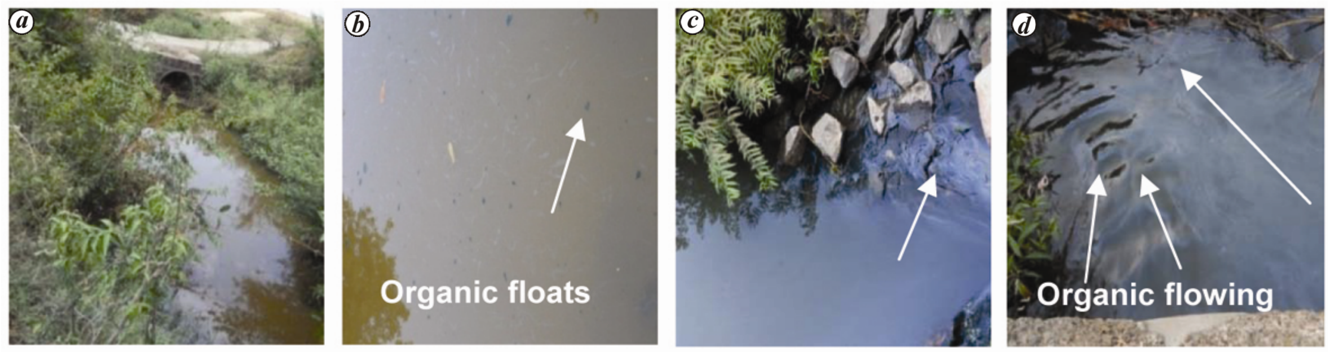

Figure 2. Refinery discharges in adjoining streams near Bhakhrai causing: ***a***, contamination and pungent smell; ***b***, dark, oily floats; ***c***, hydrocarbons during 2015; ***d***, thick hydrocarbon layer in the same stream in 2016.

substances, sulphides, naphthalene acid and other chemicals into the nearby water bodies[9].

The present study shows that hydrocarbons occur in the soil and water of Bhakrai village, 8 km away from the refinery, which is inhabited by over 1200 people (Figure 2). Table 3 shows the results with acceptable limits of various

Table 3. Hydrocarbons contamination in the water and soil

Location	Samples	Compounds	Molecular formula	MW	Maximum detected concentration (μg/l)	Safe desirable (SD) limit (μg/l) USGS Report[11]
Hansiya	Water	9,12,15-Octadecatrienoic acid, 2-{(trimethylsilyl)oxy}-1-[[(trimethylsilyl)-oxy]methyl] ethyl ester, (Z Z Z)	$C_{27}H_{52}O_4Si_2$	496	6.18	NA
		Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	2.77	NA
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
Bhakrai	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
		β-Sitosterol	$C_{29}H_{50}O$	414	3.75	NA
		Ethyl iso-allocholate	$C_{26}H_{44}O_5$	436	2.45	NA
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

MW, Molecular weight; NA, Not available. Highest concentrations of the common compounds are shown in bold letters.

parameters according to the standards laid down by the United State Geological Survey[10] in 2008.

Hydrocarbons such as 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) show their higher concentrations in the organic matter present in the soil around the oil refinery and outlet of the waste-water emerging from it (Table 3).

These values may be used for better environmental monitoring and risk assessment of the oil refinery. Data collected from May 2015 to May 2016 show that the pollution caused by trace elements and hydrocarbons is on the rise. Thus environmental monitoring is desirable even though the level of pollution at present is not that alarming.

1. Atubi, A. O., *Am. Rev. Pol. Econ*., 2011, 45–56.
2. Narimisa, M. R. and Basri, N. E. A., In Paper presented in the International Conference on Environmental Science and Technology, IPCBEE, IACSIT, Singapore, 2011, vol. 6, pp. 329–333.
3. Singare, P. U., Mishra, M. and Trivedi, P., *Adv. Anal. Chem*., 2012, **2**(3), 14–24.
4. Machender, G., Dhakate, R., Mallikharjuna Rao, S. T., Rao, B. M. and Prasanna, L., *Arab. J. Geosci*., 2014, **7**, 513–525.
5. Dubey, S. K., Yadav, R., Chaturvedi, R. K., Yadav, R. K., Sharma, V. K. and Minhas, P. S., *Bull. Environ. Contam. Toxicol*., 2010, **85**(3), 295–300.
6. WHO, Report, World Health Organization, Genava, 2006, p. 595.
7. BIS, Report, Indian standard specification for drinking water IS: 10500, Bureau of Indian Standard, New Delhi, 1983.
8. USEPA, Guidelines for the health risk assessment, United States Environmental Protection Agency, EPA/630/R-98/03, 1986.
9. Suleimanov, A. Y., *Med. Truda Promyswe Nnaia Ekol*., 1995, **12**, 31–36.
10. USGS, United States Geological Survey, Anthropogenic organic compounds in source water of nine community water system that withdraw from streams, 2002–05, 2008.

ACKNOWLEDGEMENTS. We thank P. O. Alexander for useful suggestions, R. K. Trivedi for holding discussion and Head, Department of Applied Geology, Dr Harisingh Gour Vishwavidyalaya, Sagar for providing infrastructural facilities to carry out this work. J.K. thanks the University Grants Commission, New Delhi for financial support under the Women Scientist Fellowship and the Sophisticated Analytical Instrumentation Faculty (SAIF), Indian Institute of Technology, Bombay, for analysis of soil and water samples.

Received 8 February 2017; revised accepted 9 July 2017

JEMINI KHATIK*
P. K. KATHAL

Centre of Advanced Study in Geology, Department of Applied Geology, Dr Harisingh Gour Vishwavidyalaya, Sagar 470 003, India
**For correspondence.*
e-mail: jemini_tomar2001@yahoo.com