Supplementary Information

Estimation of physicochemical characteristics and associated metal contamination risk in river Narmada, India

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Table S1. Details of Sampling Locations in River Narmada, Madhya Pradesh

Sampling location code	Sampling location	Longitude	Latitude
R1	Udgam Sthal, Amarkantak	81°75′96.80″ E	22°67′24.70″N
R2	Bus stand Ghat, Dindori	81°07′69.90″ E	22°94′74.50″ N
R3	Rangrej Ghat, Mandela	80°37′38.50″ E	22°59′33.50″ N
R4	Gwari Ghat, Jabalpur	79°92′4.30″E	23°10′66.10″ N
R5	Saraswati Ghat, Jabalpur	79°79′95.10″ E	23°13′78.50″ N
R6	Jhansi Ghat, Nursinghpur	79°58′62.70″ E	23°10′97.60″ N
R7	Seedhi Ghat Shahganj, Sehore	77°79′16.01″ E	22°84′24.90″ N
R8	Bandrabhan Ghat, Hosangabad	77°78′03.50″ E	22°79′35.10″ N
R9	Sethani Ghat, Hosangabad	77°71′60.10″ E	22°76′31.10″ N
R10	Budani Ghat, Sehore	77°68′88.30″ E	22°76′61.80″ N
R11	Aavalighat, Sehore	77°48′79.01″ E	22°64′63.60″ N
R12	Nemawar Ghat, Devas	76°97′72.70″ E	22°49′27.00″ N
R13	Goumukh Ghat, Omkareshwar	76°15′03.70″ E	22°24′36.00″ N
R14	Nagar Ghat, Omkareshwar	76°14′51.80″ E	22°24′65.10″ N
R15	Nav Ghat Khedi, Khargoun	76°05′22.50″ E	22°22′89.80″ N
R16	Ramghat, Mandleshwar, Khargoun	75°65′94.90″ E	22°17′25.60″ N
R17	Siyaram Ghat, Bhattayan, Khargoun	75°76′20.90″ E	22°16′06.40″ N
R18	Shalivan Ghat Nawdatodi, Khargoun	75°58′46.40″ E	22°16′45.30″ N
R19	Khal Ghat, Dhar	75°15′41.90″ E	22°15′41.90″ N
R20	Brahamangaun Ghat, Badwani	75°28′54.50″ E	22°12′19.70″ N
R21	Rajghat, Kukra Badwani	74°88′79.50″ E	22°07′6.00″ N
R22	Koteshwar, Dhar	74°79′03.70″ E	22°08′08.40″ N
R23	Bada Barda Ghat, Dhar	75°15′14.01″E	22°10′74.40″ N

Table S2. Analyzed Physicochemical Water Quality Parameters with Their Standard Acceptable/Permissible Limit

S. No.	Parameters	Units	Analytical methods	Standard acceptable concentration limit (SAL) in drinking water	
				BIS 2012	WHO 2017
1.	Dissolve oxygen (DO)	mg/L	Electrometric DO meter	5	5
2.	pH	–	pH meter	6.5-7.5	6.5-7.5
3.	Surface water temperature (WT)	^{0}C	Thermometric	40	40
4.	Turbidity	NTU	Nephelometric	5	5
5.	Alkalinity	mg/L	Titrimetric	200	200
6.	Biochemical oxygen demand (BOD)	mg/L	5 days incubation, 20℃	5	5
7.	Chemical oxygen demand (COD)	mg/L	Open reflux	20	20
8.	Electrical conductivity (EC)	µS/cm	Electrometric conductivity meter	ND	600
9.	Total dissolved solids (TDS)	mg/L	Filtration and Gravimetric	500	500
10.	Total solid (TS)	mg/L	Filtration and Gravimetric	ND	ND
11.	Total hardness (TH)	mg/L	EDTA titrimetric	300	300
12.	Chloride	mg/L	Argentometric titration	250	250
13.	Faecal coliform	MPN/100 mL	Elevated temperature fermentation	Absent	Absent
14.	Manganese (Mn)	µg/L	ICP-MS	100	100
15.	Copper (Cu)	µg/L	ICP-MS	50	50
16.	Iron (Fe)	µg/L	ICP-MS	300	300
17.	Chromium (Cr)	µg/L	ICP-MS	50	50
18.	Zinc (Zn)	µg/L	ICP-MS	5000	5000
19.	Arsenic (As)	µg/L	ICP-MS	10	10
20.	Cadmium (Cd)	µg/L	ICP-MS	10	10
21.	Lead (Pb)	µg/L	ICP-MS	10	10
22.	Cobalt (Co)	µg/L	ICP-MS	ND	ND
23.	Nickel (Ni)	µg/L	ICP-MS	20	20

(Note: not defined (ND))

Table S3. Input Parameters Used to Characterize the Average Daily Dose Value of Heavy Metals

S. No.	Risk Parameters	Symbols	Units	Values	References
1.	Ingestion rate	IR	L/day	2	EPA (2004)
2.	Exposure frequency	EF	Days/year	350	US EPA 1977
3.	Average time	AT	Years	68.13	Dalakoti et al. 2017
4.	Body weight	BW	Kg	51.9	Dalakoti et al. 2017
5.	Exposure duration	ED	Years	30	US EPA 1977
6.	Reference chronic dose	RFD	mg/kg-day	Fe (0.7), Mn (0.024), Zn (0.3), Cu (0.04), Cr (0.003), As (0.0003), Cd (0.0005), Co (0.0003), Ni (0.02).	RAIS database
7.	Slope factor	SF	mg/kg-day	Cr (0.5), As (1.5), Pb (0.0085)	RAIS database

Table S4. Physicochemical and Biological Characteristics of Water Quality Parameter (mean ± standard deviation) in River Narmada

Sampling location	WT (°C)	pH	EC (µS/cm)	TS (mg/l)	TDS (mg/L)	Alkalinity (mg/L)	DO (mg/L)	COD (mg/L)	BOD (mg/L)	TH (mg/L)	Chloride (mg/l)	Turbidity (NTU)	Faecal coliform (MPN/100 mL)
R1	21±0.1	8.0±0.1	845±0.02	96±0.01	52±0.02	25±0.03	5.7±0.01	310±0.03	210±0.03	156±0.02	49±0.01	12.7±0.01	3.6±0.1
R2	23±0.1	8.2±0.1	629±0.01	68±0.01	24±0.02	15±0.01	7.4±0.01	82±0.02	35±0.01	200±0.02	100±0.01	10.5±0.01	2.1±0.1
R3	20±0.1	8.4±0.1	627±0.01	40±0.02	36±0.01	25±0.02	7.6±0.01	92±0.02	40±0.02	177±0.02	40±0.01	11.0±0.01	8.1±0.1
R4	26±0.1	8.3±0.1	550±0.01	54±0.02	24±0.01	200±0.02	7.8±0.01	86±0.02	40±0.01	160±0.02	50±0.01	10.0±0.01	3.1±0.1
R5	22±0.1	7.7±0.1	299±0.02	106±0.03	70±0.02	20±0.02	8.1±0.01	46±0.01	15±0.01	200±0.02	70±0.01	5.0±0.01	2.4±0.1
R6	22±0.1	8.2±0.1	237±0.02	130±0.02	66±0.01	25±0.02	8.2±0.02	50±0.02	20±0.01	260±0.02	97±0.01	10.0±0.01	2.6±0.1
R7	23±0.1	8.8±0.1	226±0.01	92±0.01	48±0.01	35±0.02	8.5±0.02	33±0.01	10±0.01	124±0.02	45±0.01	1.6±0.01	3.6±0.1
R8	22±0.1	8.7±0.1	264±0.02	178±0.01	76±0.02	20±0.01	8.1±0.01	22±0.01	8±0.01	284±0.04	80±0.02	12.0±0.01	2.3±0.1
R9	23±0.1	8.2±0.1	267±0.01	154±0.03	58±0.01	15±0.01	7.9±0.01	35±0.01	7±0.01	150±0.02	39±0.01	2.6±0.01	1.8±0.1
R10	21±0.1	8.2±0.1	407±0.02	78±0.02	60±0.02	20±0.02	8.2±0.01	18±0.01	5±0.01	220±0.02	86±0.02	10.5±0.01	3.1±0.1
R11	23±0.1	8.5±0.1	275±0.01	166±0.02	146±0.01	30±0.02	7.8±0.01	40±0.02	12±0.01	240±0.02	150±0.02	3.7±0.01	1.8±0.1
R12	22±0.1	8.1±0.1	286±0.01	296±0.01	196±0.01	125±0.02	7.4±0.01	70±0.02	14±0.01	310±0.02	120±0.02	5.5±0.01	1.9±0.1
R13	22±0.1	7.9±0.1	650±0.02	388±0.03	333±0.02	120±0.03	7.2±0.01	80±0.03	10±0.01	400±0.04	22±0.01	13.5±0.01	2.1±0.1
R14	23±0.1	7.1±0.1	537±0.01	400±0.02	250±0.01	75±0.02	7.4±0.01	65±0.02	6±0.01	280±0.04	70±0.01	15.0±0.01	2.3±0.1
R15	23±0.1	7.4±0.1	326±0.01	278±0.02	258±0.01	180±0.03	7.5±0.01	40±0.02	4±0.01	160±0.02	140±0.02	10.0±0.01	1.9±0.1
R16	24±0.1	7.3±0.1	580±0.01	615±0.01	442±0.01	227±0.03	7.1±0.01	70±0.02	12±0.01	340±0.04	106±0.02	3.5±0.01	2.5±0.1
R17	21±0.1	7.5±0.1	264±0.01	244±0.01	221±0.02	190±0.01	7.6±0.01	20±0.01	15±0.01	400±0.04	140±0.02	7.5±0.01	3.1±0.1
R18	22±0.1	7.6±0.1	342±0.02	320±0.02	235±0.02	200±0.03	7.4±0.01	30±0.01	5±0.01	126±0.02	75±0.02	6.0±0.01	2.9±0.1
R19	23±0.1	7.9±0.1	101±0.02	169±0.02	63±0.02	125±0.03	7.9±0.01	10±0.01	3±0.01	270±0.02	25±0.01	1.3±0.01	1.7±0.1
R20	22±0.1	7.8±0.1	188±0.02	172±0.02	165±0.03	130±0.02	7.8±0.01	12±0.01	2±0.01	124±0.02	13±0.01	1.1±0.01	1.8±0.1
R21	21±0.1	7.8±0.1	340±0.01	245±0.01	235±0.01	109±0.02	8.3±0.02	9±0.01	2.5±0.01	128±0.02	112±0.02	8.5±0.01	1.6±0.1
R22	22±0.1	7.2±0.1	250±0.01	247±0.02	240±0.02	100±0.02	7.8±0.01	24±0.01	8±0.01	154±0.02	48±0.01	1.1±0.01	1.2±0.1
R23	23±0.1	7.3±0.1	273±0.02	271±0.02	263±0.01	57±0.01	7.8±0.01	13±0.01	5±0.01	132±0.02	244±0.03	5.0±0.01	1.9±0.1

Table S5. Heavy Metals Concentration (mean ± standard deviation) at Different Sampling Locations in River Narmada

Sampling location	Cr (µg/L)	Mn (µg/L)	Fe (µg/L)	Cu (µg/L)	Zn (µg/L)	As (µg/L)	Cd (µg/L)	Pb (µg/L)	Co (µg/L)	Ni (µg/L)
R1	0.11±0.01	1.94±0.01	7.22±0.01	347.23±0.02	121.78±0.03	0.26±0.01	0.09±0.005	38.49±0.03	0.06±0.005	NA
R2	0.13±0.01	1.76±0.01	9.21±0.01	381.23±0.03	96.30±0.02	0.23±0.01	0.06±0.005	45.70±0.03	0.06±0.005	NA
R3	0.27±0.01	2.73±0.01	8.00±0.01	367.34±0.03	105.01±0.03	0.44±0.01	0.23±0.005	42.47±0.03	0.12±0.01	NA
R4	0.11±0.01	1.63±0.01	5.68±0.01	258.15±0.02	64.87±0.01	0.27±0.01	0.06±0.005	30.60±0.02	0.05±0.005	NA
R5	0.20±0.01	0.94±0.01	0.78±0.01	75.15±0.01	18.22±0.01	0.23±0.01	0.02±0.005	5.96±0.01	0.03±0.005	NA
R6	0.10±0.01	1.24±0.01	1.56±0.01	88.29±0.01	25.46±0.01	0.25±0.01	0.05±0.005	9.21±0.01	0.03±0.005	NA
R7	0.03±0.01	1.06±0.01	1.30±0.01	76.57±0.01	17.24±0.01	0.25±0.01	0.03±0.005	7.53±0.01	0.03±0.005	NA
R8	0.20±0.01	0.68±0.01	1.10±0.01	65.87±0.01	15.13±0.01	0.22±0.01	0.04±0.005	6.08±0.01	0.04±0.005	NA
R9	0.05±0.01	1.21±0.01	0.24±0.01	49.53±0.01	9.87±0.01	0.27±0.01	0.02±0.005	3.79±0.01	0.03±0.005	NA
R10	0.11±0.01	1.74±0.01	1.45±0.01	72.87±0.01	17.54±0.01	0.20±0.01	0.04±0.005	7.59±0.01	0.03±0.005	NA
R11	0.14±0.01	4.00±0.01	0.25±0.01	48.40±0.01	11.57±0.01	0.27±0.01	0.04±0.005	4.09±0.01	0.05±0.005	NA
R12	7.32±0.01	1.22±0.01	114.91±0.02	3.19±0.01	2.23±0.01	1.78±0.01	0.30±0.005	0.24±0.01	NA	2.07±0.01
R13	7.34±0.01	0.86±0.01	124.14±0.02	2.35±0.01	2.20±0.01	1.18±0.01	0.12±0.005	0.17±0.01	NA	1.87±0.01
R14	7.22±0.01	0.90±0.01	101.70±0.02	3.01±0.01	2.13±0.01	1.14±0.01	0.05±0.005	0.08±0.01	NA	1.68±0.01
R15	6.80±0.01	0.60±0.01	111.03±0.02	3.32±0.01	2.46±0.01	1.03±0.01	0.04±0.005	0.10±0.01	NA	1.83±0.01
R16	5.07±0.01	0.30±0.01	111.51±0.02	1.74±0.01	1.14±0.01	0.87±0.01	0.03±0.005	0.08±0.01	NA	1.58±0.01
R17	4.66±0.01	2.29±0.01	102.73±0.02	2.52±0.01	2.20±0.01	0.84±0.01	0.03±0.005	0.05±0.01	NA	2.05±0.01
R18	3.53±0.01	3.89±0.01	51.88±0.01	2.00±0.01	2.43±0.01	0.55±0.01	0.03±0.005	0.07±0.01	NA	1.53±0.01
R19	3.74±0.01	0.59±0.01	83.41±0.01	1.98±0.01	0.93±0.01	0.55±0.01	0.03±0.005	0.07±0.01	NA	1.17±0.01
R20	3.27±0.01	0.62±0.01	75.98±0.01	2.88±0.01	1.62±0.01	0.56±0.01	0.01±0.005	0.08±0.01	NA	1.27±0.01
R21	3.15±0.01	0.30±0.01	125.63±0.02	2.04±0.01	1.67±0.01	0.77±0.01	0.02±0.005	0.05±0.01	NA	2.08±0.01
R22	3.21±0.01	0.98±0.01	88.65±0.01	2.36±0.01	1.26±0.01	0.74±0.01	0.02±0.005	0.08±0.01	NA	1.35±0.01
R23	3.49±0.01	283.22±0.02	158.48±0.02	0.48±0.01	0.39±0.01	0.92±0.01	0.02±0.005	0.02±0.005	NA	1.70±0.01

(Note: not assessed (NA))