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Suitability of Water for Drinking and Irrigation Use Using Water Quality Index and GIS

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Abstract: The present study highlights techniques to identify suitability of water for drinking and irrigation uses. Twenty water samples from Dang district of Gujarat state were collected in pre-monsoon (PRM) and post-monsoon (POM) seasons and analyzed for different physico-chemical properties. The Water Quality Index varied from 37.83 to 121.68 in PRM season and from 40.09 to 152.83 in POM season. Surface water quality in the Dang district was good for drinking in 58.43 % and 64.43 % area in PRM and POM season, respectively. The US Salinity diagram showed that most of the water samples belong to the categories C2S1 and C2S2 (suitable class for irrigation) in both the seasons. Some samples falling in the category C3S2 are also acceptable for irrigation use in both the seasons.

Key words: *Water quality, WQI, irrigation water quality, GIS*

Introduction

Water is a natural resource essential for human health, agriculture, and for life of any ecosystem (Dixon and Wood 2003). The fresh-water is of vital concern for mankind, since it is directly linked to human welfare. In India, a population of 63 million lives in rural areas without access to clean water. Access of safe drinking water was declared as a human right by the United Nations but remains a challenge for both rural and urban India. According to the World Water survey, 31 % of Indians had been in a situation where it was unsafe to drink water but had to consume it given no other choice and thereby suffered from water-borne diseases such as diarrhea and gastroenteritis. There are number of methods to analyze water quality that vary depending on informational goals, the type of samples, and the size of the sampling area. One of the most effective ways to communicate information on water quality trend is by establishing suitable indices (Shinde *et al.* 2013). Indices are based on the values of various physicochemical parameters in water samples. The quality of water is measured in terms of its physical, chemical and biological parameters. Ascertaining the quality is crucial before its use for various purposes such as drinking; agricultural, recreational and industrial

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uses, *etc.* (Khan ***et al.*** 2003; Sargaonkar and Deshpande 2003; Roy *et al*. 2012). In addition, surface water bodies are highly vulnerable to contamination due to natural alteration and anthropogenic interference. This makes them potentially not suitable for irrigation (Salifu ***et al.*** 2017). Water Quality Index (WQI) is a very useful and efficient method for assessing the suitability of water for drinking purpose. It is also very useful method of communicating the information on overall quality of water to the concerned person and policy makers (Asadi ***et al.*** 2007; Yogendra and Puttaiah 2008). The objective of this study was to assess chemical composition of surface water in Dang district and its suitability for drinking and irrigation use. The results of this study will be useful to decision makers for future actions, ensuring ecological sustainability.

Materials and Methods

Study area and collection of water samples

The study was carried out in Dang district (20°33' to 21°00' N; 73°25' to 73°58' E), Gujarat which lies between (Fig. 1). The geographical area of Dang district is 1764 km^2. In this study, Pre-monsoon (PRM) and Post-monsoon (POM) season surface water samples from 20 sampling sites (Figure 1) were collected in 2015 and 2016 following standard procedures. The samples were collected from the rivers, streams and nearby water bodies. All PRM samples were collected in month of June, and POM samples in the month of October. The water samples were analysed at the laboratory of Soil science and Agricultural Chemistry department, College of Agriculture, Waghai for physico-chemical parameters and to determine the concentration of metals.

In the laboratory, the water samples were filtered through 0.45 µm Millipore membrane filters to separate suspended sediment. The samples were analysed for pH, electrical conductivity (EC), Total Dissolved Solids (TDS), major cations (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}), major anions (NO_3^-, SO_4^{2-}, Cl^-) and metals (Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+}) following the standard analytical methods. Concentrations of Ca^{2+} and Mg^{2+} were determined in the sodium acetate leachate following versenate method while, Na^{+} and K^{+} were determined using direct reading on flame photometer. The concentrations of NO_3^- and SO_4^{2-} were determined using direct reading on spectrophotometer and Cl^- was determined by silver nitrate titration method. The concentrations of Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+} were

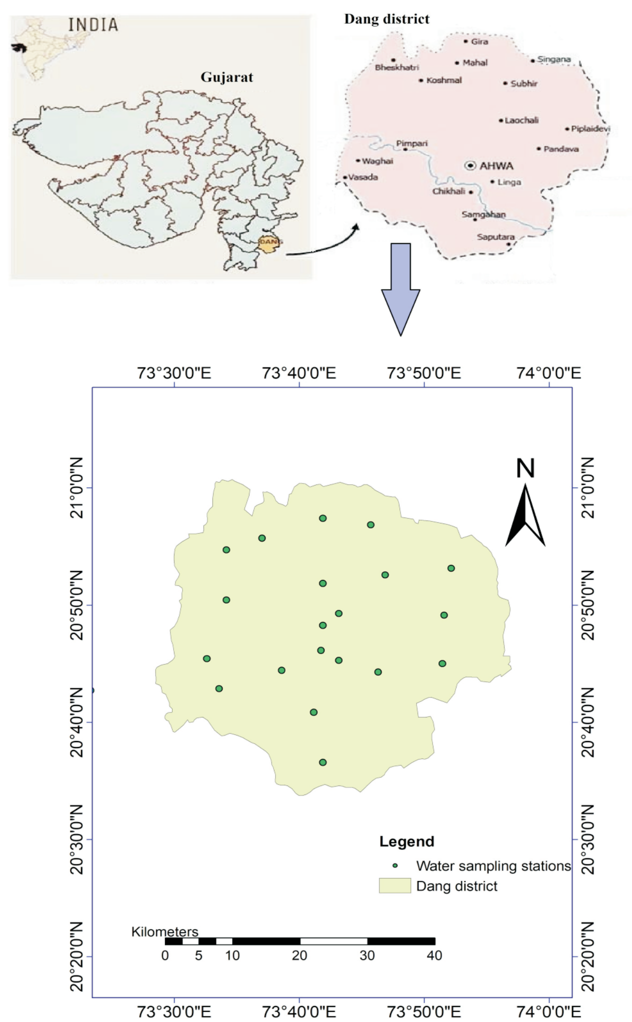


Fig. 1. Location map of Dang district

WQI is defined as a technique of rating that provides the composite influence of individual water quality parameter on the overall quality of water (Sarkar ***et al.*** 2006; Shinde ***et al.*** 2013**)**. For computing WQI, three steps were followed. In the first step, each parameter has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes or human consumption (Vasanthavigar ***et al.*** 2010; Rokbani ***et al.*** 2011). The maximum weight of 5 has been assigned to the parameters *viz.* TDS, nitrate, chloride and sulphate due to their importance in water quality assessment (Srinivasamoorthy ***et al.*** 2008). In the second step, the relative weight (W_i) is computed for each parameter using Equation 1:

$$W_i = w_i \Big/ \sum_{i=1}^{n} w_i \qquad (1)$$

Where, W_i is the relative weight; w_i is the weight of each parameter and n is the number of parameters. In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the BIS 10500 (1991) and the result is multiplied by 100 (Equation 2).

$$q_i = \left(C_i \big/ S_i \right) \times 100 \qquad (2)$$

Where, q_i is the quality rating; C_i is the concentration of each chemical parameter in each water sample in mg L^{-1} and S_i is the Indian drinking water standard for each chemical parameter in mg L^{-1} according to the guidelines of the BIS 10500 (1991).

For computing the WQI, the Sub-index (SI) is first determined for each chemical parameter, which is then used to determine the WQI as per the Equation 3.

$$SI_i = W_i \times q_i$$
$$WQI = \sum SI_i \qquad (3)$$

Where SI_i is the sub-index of i^{th} parameter; q_i is the quality rating based on concentration of i^{th} parameter and n is the number of parameters. The water samples in study area were classified into five different status categories (Table 3) varying from excellent to unsuitable for drinking, based on computed WQI values. In addition to this, SAR was also determined in order to ascertain the suitability of water for irrigation use. Classification and suitability of water for irrigation were done by plotting US Salinity Laboratory hazard diagram and by correlating SAR and electrical conductivity.

Suitability of water for irrigation based on US Salinity diagram

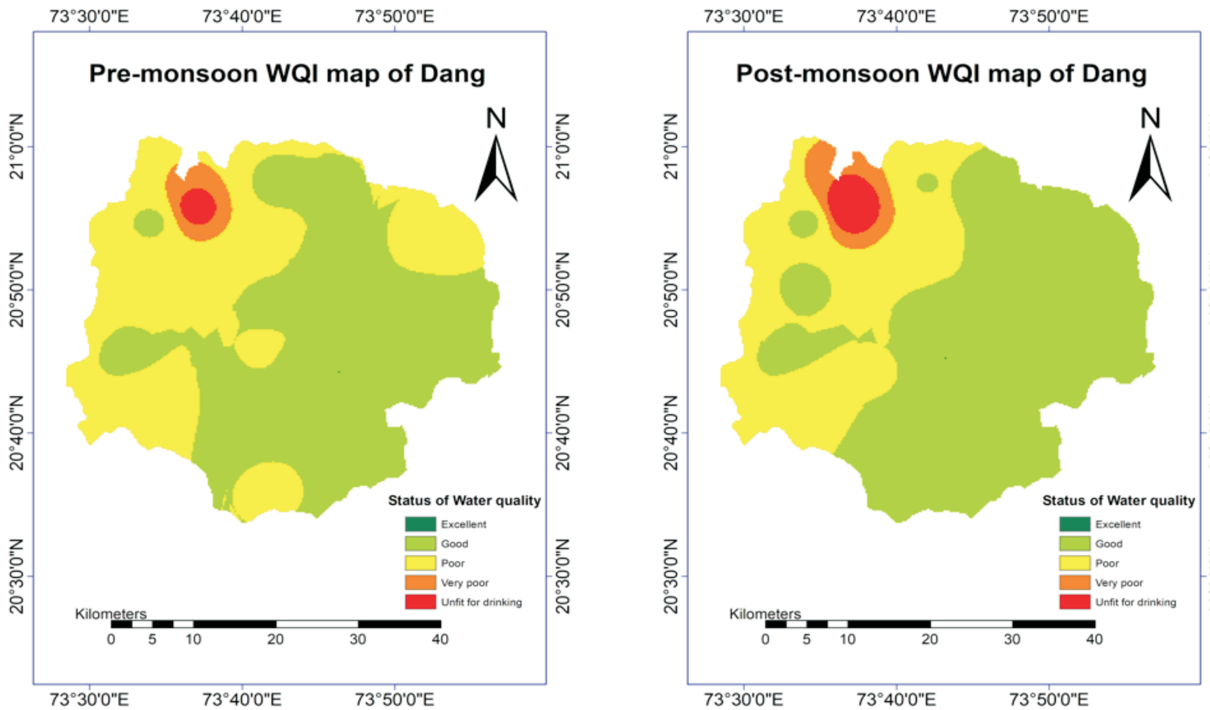
The suitability of water for irrigation depends on the effect of mineral constituents in water on both plants and soil. Saline condition on irrigated lands is the major cause for low production and is one of the most prolific adverse environmental impacts associated with irrigation. US Salinity Laboratory Staff (1954) proposed irrigational specifications based on hydro-chemical properties for evaluating the suitability of water for irrigation use. The diagram for the classification of irrigation water is based on the electrical conductivity in micromhos per centimetre and the sodium-adsorption-ratio. There is a significant relationship between SAR values and the extent to which sodium is adsorbed by the soils. The higher the SAR, the less suitable the water is for irrigation. SAR was computed using the following equation, where all the concentrations are expressed in mg L^{-1}:

$$SAR = \frac{Na^+}{\sqrt{(Ca^{2+} + Mg^{2+})/2}}$$

Results and Discussion

Suitability of water for drinking

WQI for all 20 sampling stations in Dang district is presented in table 4 based on status categories of WQI (Brown *et al*. 1970). The spatial distribution map of the WQI in PRM and POM seasons is shown in figure 2.



The statistics of water quality parameters of samples from Dang districts are shown in table 1.

Table 1. Statistics of water quality parameters of samples from Dang district

	WHO		BIS:10500		PRM			POM		
	Max. desirable	**Highest permissible**	**Max. desirable**	**Highest permissible**	**Min**	**Max**	**Mean**	**Min**	**Max**	**Mean**
pH	7.0-8.5		6.5	8.5-9.2	7.2	8.5	7.9	7.1	8.4	7.6
EC	750	1500	300	-	318	972	465	322	845	522
TDS	500	1500	500	2000	213	651	311	195	675	290
Ca^{2+}	75	200	75	200	27.4	88.0	52.4	23.0	92.5	57.8
Mg^{2+}	30	150	30	100	7.0	39.0	19.4	7.5	28.5	15.5
Na^{+}	50	200	200	-	5.0	67.0	29.8	7.5	81.4	34.5
K^{+}	100	200	50	-	0.1	11.0	1.1	0.1	16.1	0.9
Cl^{-}	250	600	250	1000	14.0	121.0	35.6	12.4	143.5	40.5
SO_4^{2-}	200	600	150	400	3.7	52.5	19.5	7.0	99.0	25.5
NO_3^{-}	45	50	45	100	1.0	32.4	9.2	1.7	27.5	9.4
Fe^{2+}	0.3	3	0.3	-	0.01	0.65	0.19	0.01	0.60	0.21
Cu^{2+}	-	1	0.05	1.5	0.01	0.18	0.03	0.01	0.15	0.02
Zn^{2+}	5	-	5	15	0.01	0.67	0.17	0.04	0.90	0.26
Mn^{2-}	0.5	-	0.1	-	0.01	0.30	0.07	0.01	0.96	0.06

Calculated W_i values of each parameter are given in table 2.

Table 2. Relative weight and drinking water standard values of chemical parameters

S. No.	Parameter	Concentration as per BIS 10500 (S_i)	Weight (w_i)	Relative Weight (W_i)
1	**pH**	6.5	4	0.082
2	**EC**	300	3	0.061
3	**TDS**	500	5	0.102
4	**Ca^{2+}**	75	3	0.061
5	**Mg^{2+}**	30	3	0.061
6	**Na^{+}**	200	4	0.082
7	**K^{+}**	50	2	0.041
8	**Cl^{-}**	250	5	0.102
9	**SO_4^{2-}**	150	5	0.102
10	**NO_3^{-}**	45	5	0.102
11	**Fe^{2+}**	0.3	3	0.061
12	**Cu^{2+}**	0.05	2	0.041
13	**Zn^{2+}**	5	2	0.041
14	**Mn^{2-}**	0.1	3	0.061

(EC was measured in µS cm-1; all other parameters were measured in mg L-1, except pH)

The data indicates that most of the parameters exceed the desirable limits of WHO (1997) and BIS (1991), though it is within the maximum permissible limits in PRM and POM seasons. The concentration of TDS is more than the desirable limit but within the permissible limit in some of the samples. The higher EC and TDS may cause gastrointestinal irritation in the consumers.

Table 3. Station-wise location, WQI and status of water quality in PRM and POM seasons

Station	**Location**		**Pre-monsoon WQI**	**Status of WQ**	**Post-monsoon WQI**	**Status of WQ**
	Longitude (X)	**Latitude (Y)**				
1	73.57	20.91	43.28	Good	41.62	Good
2	73.62	20.93	121.68	Unfit for drinking	152.83	Unfit for drinking
3	73.70	20.96	43.65	Good	48.70	Good
4	73.76	20.95	47.66	Good	43.17	Good
5	73.87	20.89	58.90	Poor	45.26	Good
6	73.78	20.88	46.36	Good	44.73	Good
7	73.57	20.84	54.80	Poor	42.75	Good
8	73.54	20.76	40.55	Good	41.89	Good
9	73.56	20.71	63.52	Poor	60.66	Poor
10	73.69	20.68	41.21	Good	45.20	Good
11	73.70	20.61	52.58	Poor	42.99	Good
12	73.70	20.77	60.57	Poor	48.63	Good
13	73.72	20.75	42.12	Good	40.09	Good
14	73.64	20.74	48.79	Good	54.57	Poor
15	73.77	20.74	37.83	Good	45.25	Good
16	73.70	20.86	50.71	Poor	53.81	Poor
17	73.86	20.82	42.87	Good	40.92	Good
18	73.86	20.75	47.27	Good	43.86	Good
19	73.70	20.80	43.10	Good	45.41	Good
20	73.72	20.82	44.33	Good	46.96	Good

The concentration of sodium was within the prescribed limit of 200 mg L^{-1} in all samples of in both the seasons. Higher sodium intake may cause hypertension, congenial heart diseases and kidney problems. The concentrations of Ca^{2+}, Mg^{2+} and K^{+} were also within the highest permissible limits in all the samples of both seasons. The analytical data shows that Cl^{-} was within the safe limit (250 mg L^{-1}) in all water samples. Higher concentration of Cl^{-} in drinking water causes a salty taste and has a laxative effect in people not accustomed to it.

Concentration of sulphate was within the desirable limit of 150 mg L^{-1} in both the seasons. Higher concentration of sulphate in drinking water is associated with respiratory problems (Maiti 1982; Subba 1993). All samples have NO_3^- concentration within recommended level of 45 mg l^{-1} (BIS 1991). High concentrations of nitrates can cause methemoglobinemia, gastric cancer, goiter, birth malformations, and hypertension. Concentration of Fe^{2+}, Mn^{2+}, Zn^{2+} and Cu^{2+} was found within desirable limits in all the samples.

The WQI varied from 37.83 to 121.68 in PRM season and from 40.09 to 152.83 in POM season. The area under various status categories of water quality is presented in table 5.

Table 4. Area under various status categories based on WQI in Dang district

Status of water quality	**Area (%)**	
	PRM	**POM**
Excellent	0.00	0.00
Good	58.43	64.43
Poor	38.37	30.25
Very poor	2.37	3.32
Unfit for drinking	0.83	2.00
Total	100.00	100.00

Suitability of water for irrigation

EC is an indication of the salinity hazard and it is the most important water quality guideline required for crop productivity. The value of SAR ranged from 0.89 to 10.49 in PRM season and it ranged from 1.25 to 10.67 in POM. The total concentration of soluble salts in irrigation water can be categorized as low, medium, high and very high with EC values of <250 µScm^{-1}, 250–750 µS cm^{-1}, 750–2,250 µS cm^{-1} and 2,250–5,000 µScm^{-1}, respectively. The electrical conductivity and SAR values were plotted on a US Salinity diagram in Grapher15 software for classification of irrigation waters, in which the EC is taken as salinity hazard and SAR as alkalinity hazard.

It showed that the water samples were classified into C2S1 and C2S2 in both the seasons which are suitable class for irrigation purposes. Some samples falling in the category C3S2 are also acceptable for irrigation use in both the seasons. The spatial distribution map of the status of irrigation water quality in PRM and POM seasons is shown in figure 3.

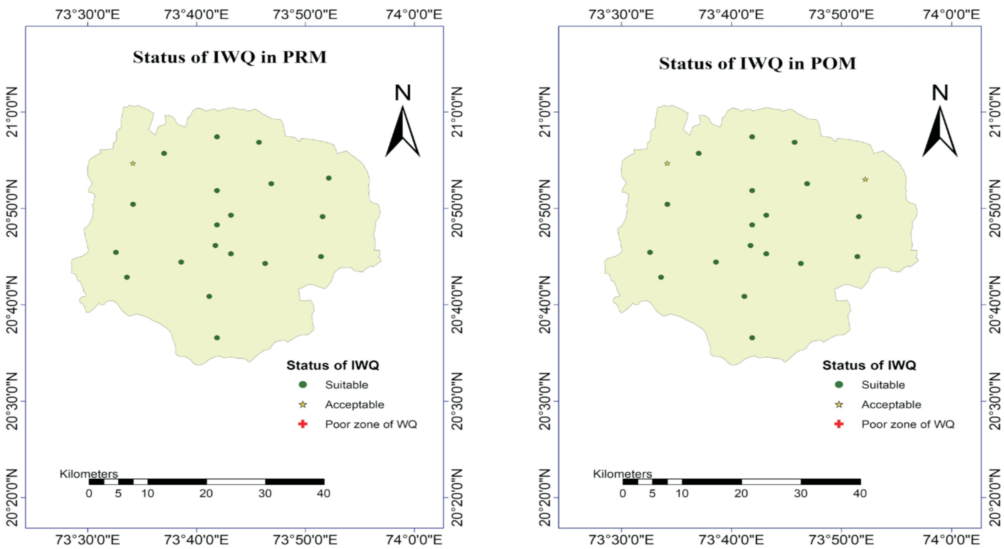


Fig. 3. Spatial distribution map of the status of irrigation water in PRM and POM seasons

Conclusion

The value of WQI was found to vary from 37.83 to 121.68 in PRM season and from 40.09 to 152.83 in POM season for Dang district. Surface water exhibits 'Good' quality in 58.43 % and 64.43 % area in PRM and POM season respectively. It showed that most of the water samples belong to the categories C2S1 and C2S2 (suitable class for irrigation) in both seasons. Some samples falling in category C3S2 are also acceptable for irrigation use in both the seasons.

References

Asadi, S.S., Vuppal, P. and Reddy, A.M. (2007). Remote sensing and GIS techniques for evaluation of groundwater quality in municipal corporation of Hyderabad Zone-V, India. *International Journal of Environmental Research and Public Health* **4,** 45–52.

BIS. (1991). Bureau of Indian Standards—Indian standard specification for drinking water IS: 10500

Brown, R. M., McClelland, N.I., Deininger, R.A. and Tozer, R.G. (1970). A water quality index—Do we dare? *Water Sewage Works* **117**, 339-343.

Dixon, A.B. and Wood, A.P. (2003). Wetland cultivation and hydrological management in Eastern Africa: Matching community and hydrological needs through sustainable wetland use. *Natural Resources Forum* **27**, 117-129.

Khan, F., Husain, T. and Lumb, A. (2003). Water quality evaluation and trend analysis in selected watersheds of the Atlantic region of Canada. *Environmental Monitoring and Assessment* **88**, 221-242.

Maiti, T.C. (1982). The dangerous acid rain. *Scientific Reports* **9**, 360–363

Rokbani, M.K., Gueddari, M. and Bouhlila, R. (2011). Use of geographical information system and water quality index to assess groundwater quality in El Khairat deep aquifer Enfidha, Tunisian Sahel. *Iranian Journal of Energy and Environment* **2**, 133-144.

Roy, Ratna, P., Jagdish Prasad and Gupta Rashmi (2012) Assessment of well-water quality for drinking purpose-A case study in Nari area, Nagpur district Maharashtra. *Journal of Environmental Science and Engineering* **54**, 11420-423.

Salifu, M., Aidoo, F., Hayford, M.S., Adomako, D. and Asare, E. (2017). Evaluating the suitability of groundwater for irrigational purposes in some selected districts of the Upper West region of Ghana. *Applied Water Science* **7**, 653–662.

Sargaonkar, A. and Deshpande, V. (2003). Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environmental Monitoring and Assessment* **89**, 43-67.

Sarkar, B.C., Mahanta, B.N., Saikia, K., Paul, P.R. and Singh, G. (2006). Geo environmental quality assessment in Jharia coalfield, India, using multivariate statistics and geographic information system. *Environmental Geology* **51**, 1177-1196.

Shinde, V., Nandgude, S.B. and Singh, M. (2013). Assessment of water quality around surface coal mine in India. *Nature Environment and Pollution Technology* **12,** 215-224.

Srinivasamoorthy, K., Chidambaram, M., Prasanna, M.V., Vasanthavigar, M., John Peter, A. and Anandhan, P. (2008). Identification of major sources controlling groundwater chemistry from a hard rock terrain— A case study from Mettur taluk, Salem district, Tamilnadu, India. *Journal of Earth System Science* **117**, 49–58.

Subba Rao, N. (1993). Environmental impact of industrial effluents in ground water regions of Visakhapatnam industrial complex. *Indian Journal of Geology* **65**, 35–43

U. S. Salinity Laboratory Staff. (1954). Diagnosis and improvement of saline and alkaline soils. USDA hand book 60, USDA, Washington.

Vasanthavigar, M., Srinivasamoorthy, K., Vijayaragavan, K., Ganthi, R.R., Chidambaram, S., Anandhan, P., Manivannan, R. and Vasudevan, S. (2010). Application of water quality index for groundwater quality assessment: Thirumanimuttar sub-basin, Tamilnadu, India. *Environmental Monitoring and Assessment* **171**, 595–609.

WHO. (1997). Guidelines for drinking-water quality, recommendations-V.1, World Health Organisation, Geneva.

Yogendra, K. and Puttaiah, E.T. (2008). Determination of water Quality Index and suitability of urban water body in Shimoga Town, Karnataka. *In* 'The 12th World Lake Conference'. pp. 342-346.

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