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Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India

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Abstract An attempt has been made to develop water quality index (WQI), using six water quality parameters Dissolved oxygen (DO), Biochemical oxygen Demand (BOD), Most Probable Number (MPN), Turbidity, Total Dissolved Solids (TDS) and pH measured at eight different stations along the river basin. Rating curves were drawn based on the tolerance limits of inland waters and health point of view. Bhargava WQI method and Harmonic Mean WQI method were used to find overall WQI along the stretch of the river basin. Five point rating scale was used to classify water quality in each of the study areas. It was found that the water quality of Netravathi varied from Excellent to Marginal range by Bhargava WQI method and Excellent to Poor range by Harmonic Mean WQI method. It was observed that the impact of human activity was severe on most of the parameters. The MPN values exceeded the tolerable limits at almost all the stations. It was observed that the main cause of deterioration in water quality was due to the lack of proper sanitation, unprotected river sites and high anthropogenic activities.

Keywords Water quality index · Bhargava's WQI · Harmonic mean WQI

Notations

BOD_5	biochemical oxygen demand
°C	degree Celsius
DO	dissolved oxygen
$F_i(P_i)$	sensitivity function of *i*th variable
MPN	most probable number
N	number of variables
N_p	number of parameters
NTU	nephlometric turbidity unit
Q	quality index value
TDS	total dissolved solids
wi	Weights
WQI	water quality index
xi	the element of the matrix of each row

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Introduction

River Netravathi is one of the major rivers flowing west into the Arabian Sea and has a length of 148 km (Jayaprakash 1988). The river Netravathi originates near Samse in Charmadi Ghats, which is part of the Western Ghats. After being joined by a number of small tributaries the river Netravathi joins into the Arabian Sea near Mangalore, South India (Ram and Anandh 1996). Several reports on river water quality assessment using physico–chemical and biological parameters have been published elsewhere (Madhyastha et al. 1999). Different water quality parameters are expressed in different units. For example temperature is expressed in degree Celsius, coliforms in numbers and most chemicals in milligram per litre etc. In other words different parameters occur in different ranges are expressed in different units, and have behaviour in terms of concentration–impact relationship. Before an index can be formulated all this has to be transformed into a single scale usually beginning with zero and ending at 1. Some index scales have the range 0–100. The water quality index is a unitless single dimensional numbers between 0 to 100. A higher index value represents good water quality (Pandey and Sundaram 2002; Cude 2001). Therefore a numerical index is used as a management tool in water quality assessment. Until now the River Netravathi has not been subjected to water quality evaluation using water quality indices. The water quality index (WQI) was determined according to Bhargava method [Bhargava 2006, Devpura, Haridwar, Uttaranchal (personal communication); Bhargava 1983] and Harmonic Mean WQI method (Shree Kumar 2006, Mangalore, Karnataka; personal communication).

Study methodology

Study area

The river Netravathi, is a major river of this district (Dakshina Kannada, Karnataka, India), having a drainage area of about 3,432 km^2. River Netravathi originates in the Western Ghats, runs for a distance of about 148 km, flowing westward (Jayaprakash 1988). Dakshina Kannada receives an average rainfall of 3,500–4,500 mm annually, and has an average temperature of 28°C (Gangadhara 1992). Its tributaries originate in the hilly tracts of Western Ghat region and flow downstream towards the Arabian Sea. The water of the river is used for irrigation and at certain places these rivulets are considered as “Holy” and the waters are using for “Holy Baths” by pilgrims. The people of Mangalore city and Uppinangady town use this water for drinking after it has been purified.

Description of sampling stations

Eight stations were chosen for sample collection in the study area along the stretch of the river to determine the water quality index, as described below (Fig. 1).

Station 1 Kudrya, this station is about 75 km from Mangalore City. The station is upstream of Dharmastala (A Pilgrimage Center). Dharmastala town is a unique example of communal harmony, famous for its Manjunatha Temple. The stagnant water pools in between rocks which looks green or bluish green due to recurrence of algal blooms.

Station 2 This station is upstream of the river, about 1.5 km before Dharmasthal. The average width of the river is about 80 m during rainy season and 20–25 m during the low water period. The river bed here consists of sand and pebbles and also some rocks protruding from the water. This site is also a pilgrimage center and hundreds of people take “Holy dip” and wash their clothes along the banks of this site everyday.

Station 3 Beltangadi Hole, this site is located 1 km away from the Beltangadi town, which is 60 km to the east of Mangalore. The average width of the river is about 50 m during rainy season and 10–15 m during the low water period (Jan–May; Madhyastha et al. 1999) the rivulet of river. Netravathi has a stream bed consisting of sand and pebbles and also some rocks protruding from the rocks. Human activities such as the cleaning of vehicles, washing of clothes, etc. as seen on the banks of these streams. It is surrounds by some temples, habitations and hospital.

Station 4 Safanagar is about 2.5 km upstream of Kumardhara and Netravathi river confluence point, and is about 50 km from Mangalore. The water is unclean (muddy) and suspended oil slicks can be observed. There are various fast food centers (Dhaba) that have come up along the NH 48. As a result of these human activities such as cleaning of vehicles, dumping of kitchen waste, which are seen on the banks of this stream.

Station 5 Kumardhara Bridge is about 1.5 km from Uppinanagadi town and about 48 km from Mangalore. It represents the confluence point of Kumardhara river

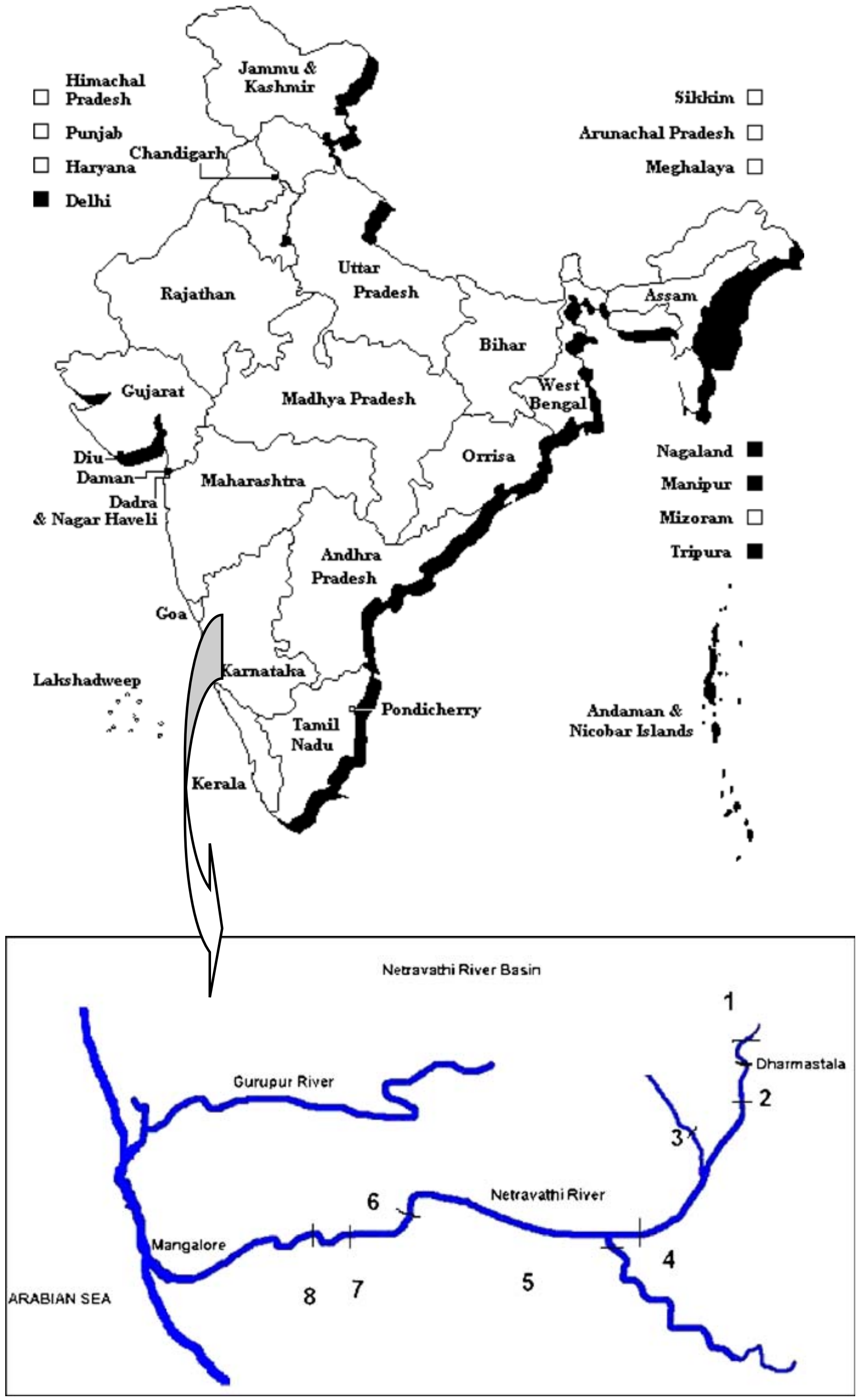

Fig. 1 A map of the study area showing the different sampling stations

and Netravathi river. Kumardhara river is one the major river that flows from Subramanya, an important pilgrimage center of this state. Hundreds of people take “Holy dip” and other activities at Subramanya. This river joins the river Netravathi river near the Uppinanagadi town. Road construction and vented dam work across the river is still in pending; NH 48 is under expansion, which results in lot of dust and silt.

Station 6 Pane Mangalore is about 33 km from Mangalore city. It is about 6 km from south Bantwal, situated on the bank of Netravathi river and is connected by road bridge across the river. It is a trading center of Dakshina Kannada. An attractive Laksha–Deepotsava fair is held here annually at Venkataramana Temple. The water is highly turbid in rainy season; looks brownish, muddy and various things such as clothes are thrown into the river, which causes lot of suspended floating material in the river water.

Station 7 Bantval, this station is located on Netravathi river about 20 km away from the Arabian Sea and Mangalore city. The station is located 1 km away from Bantwal and B.C. Road Junction. The river bed here consists mostly of silt with pebbles. Nearer to this site, paddy field and arecanut gardens are located all round in the catchment. Various activities such as pujas, marriage ceremony etc., and attract devotees from locale; to Vitaal temple. The water is used for bathing and washing.

Station 8 Tumbe, station 17 km from Mangalore, has a vented dam. Water is collected, treated and supplied for domestic purpose to the whole of Mangalore region for various industries like MRPL, BASF, institutes like NITK, Surathkal and residential purposes. About 2 km downstream of the vented dam sea water intrusion takes places during high tides.

Materials and methods of analysis

Eight stations were selected; the water samples were collected from each station from representative sampling stations in each area was carried out as per standard sampling methods (IS: 2498, 1966–Part–I; APHA 1998). Samples for estimating dissolved oxygen (DO) and biochemical oxygen demand (BOD) were collected separately in BOD (glass) bottles. Water temperature was recorded on the spot. The parameter estimated and the methods used are given in Table 1.

Table 1 Parameters and methods used for the analysis of water samples

Parameter	Method
Temperature	Direct measurement
Electrical conductivity	EC method, Lovibond Con100 Model
Dissolved oxygen	Membrane electrode method, Lovibond Oxi200 Model
Biochemical oxygen demand	Membrane electrode method (5-day BOD test), Lovibond Oxi200Model
PH	Electronic method, Lovibond pH100 Model
Turbidity	Nephlometric method, Digital Nephelo-turbidity meter132 Model
MPN	Multiple-tube fermentation method

Results and discussion

Analysis of the Netravathi River for drinking purpose

A comparison of the physico–chemical and Biological characteristics of the analyzed water sample can be made with ISI (1991) drinking standards (Bhujangaiah and Vasudeva 2005; ISI 1991). For inland surface water and drinking water source, the tolerance limits according to IS: 10,500 – 1991, IS: 2,296 – 1982 and IS: 2,296 – 1982 (ISI 1991) have been adopted for the analysis (Table 2). Water quality Index for Netravathi water was analyzed from the month of October 2005 to February 2006 for drinking purposes. The results are given in the Tables 3, 4, 5, 6, 7.

Rating curves were drawn based on the Class A, B and C tolerance limits of inland waters (IS: 10,500 – 1982 and IS: 2,296 – 1982) as shown in the Fig. 2 (a–f). Water quality matrix based on Bhargava water quality method and Harmonic Mean water quality index methods are shown in the Tables 8 and 11 Rating scale for WQI based on Bhargava water quality method and Harmonic Mean water quality index methods are shown in the Tables 9 and 10.

Table 2 Classification of inland water into class A, B and C

Characteristic	Class A		Class B	Class C
	Desirable	Permissible		
PH	6.5–8.5	9.2	6.5–8.5	6.5–8.5
Turbidity, NTU	5.00	10.00	–	–
DO, mg/l	–	–	6.00	4.00
BOD_5 20°C, mg/l	–	–	2.00	3.00
Total coliform organism MPN/100 ml	1.00	–	50.00	5,000.00
TDS, mg/l	500	3,000	500	1,500

Table 3 Data (Oct 2005) of the Netravathi river water quality

Parameter	PH	DO (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)	MPN	TDS (mg/l)
Station 1	6.8	7.80	0.78	1.0	17	21
Station 2	6.8	7.87	0.98	1.0	79	21
Station 3	6.0	7.69	0.70	1.0	920	21
Station 4	6.1	7.89	0.53	1.2	79	21
Station 5	6.8	7.92	0.57	3.4	14	21
Station 6	6.7	7.45	1.40	4.7	33	21
Station 7	5.9	7.70	0.43	3.5	13	21
Station 8	6.0	7.45	0.45	6.1	17	21
Objective for Drinking Use Class B and C	6.5–8.5	>2.0–7.968	–	–	50 and 5,000	500

Rating curves

Effect of pH

Since most of the human body consists of (50–60%) water, the pH level has profound effect on all body chemistry, health and disease. All regulatory mechanism (including breathing, circulation, digestion, hormonal production) serves the purpose of balancing pH. The fluids in our body have to be in the range 7–7.2 level. If pH is less than 5.3, assimilation of vitamins or minerals is not possible; hence it should be above 6.4. When body pH drops below 6.4, enzymes are deactivated; digestion does not take place properly. An acid pH of range 1–4 can result from an acid forming diet, for example soft drinks (pH 1.5–3), can cause emotional stress, toxic overload or any process that deprive the cells of oxygen and other nutrients. The rainwater has a pH range 5.5–6, as such may not be harmful if it is consumed. The rainwater may not contain minerals for the growth of the body. pH greater than 8.5 causes the water taste as bitter or soda like taste. If pH is greater than 11 cause eye irritation and exacerbation of skin disorder. pH in the range of 10–12.5 cause hair fibers to swell. pH in the range 3.5–4.5 affects the fish reproduction [Adarsh and Mahantesh 2006, Bagalkot, Karnataka, India (personal communication); Leo and Dekkar 2000).

Effect of dissolved oxygen

Natural waters in equilibrium with the atmosphere will contain dissolved oxygen concentrations ranging from about 5 to 14.5 mg O2 per liter depending on the water temperature, salinity, and altitude. The dissolved oxygen (DO) concentration present in water reflects atmospheric dissolution, as well as autotrophic and heterotrophic processes that respectively, produce and consume oxygen. DO is the factor that determines whether biological changes are brought by aerobic or anaerobic organisms. Thus, dissolved–oxygen measurement is vital for maintaining aerobic treatment processes intended to purify domestic and industrial wastewaters. The optimum value for good water quality is 4 to 6 mg/l of DO, which ensures healthy aquatic life in a water body. Taking the average temperature of Netravathi riverbasin as 28°C, and assuming the chloride concentration in the receiving stream to be negligible, DO saturation was fixed as 7.9 mg/l from the solubility table provided by G.C. Whipple and M.C.Whipple, 1911 (Sawyer et al. 1994; Leo and Dekkar 2000; Burden et al. 2002; De 2003).

Table 4 Data (Nov 2005) of the Netravathi river water quality

Parameter	PH	DO (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)	MPN	TDS (mg/l)
Station 1	6.4	6.20	0.59	2.6	900	31.073
Station 2	6.6	7.98	0.91	8.3	1,600	33.32
Station 3	6.7	7.69	0.95	8.3	>1,600	30.94
Station 4	6.7	6.76	0.51	7.5	188	33.208
Station 5	6.7	6.96	0.40	11.8	350	30.898
Station 6	6.7	6.60	0.48	20.1	1,600	39.291
Station 7	6.3	8.13	2.05	13.3	220	30.10
Station 8	6.6	8.45	1.70	16.4	1,600	31.29
Objective for Drinking Use Class B and C	6.5–8.5	>2.0–7.968	–	–	50 and 5,000	500

Table 5 Data (Dec 2005) of the Netravathi river water quality

Parameter	PH	DO (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)	MPN	TDS (mg/l)
Station 1	6.56	7.51	0.61	1.6	23	21
Station 2	6.22	7.31	1.43	2.9	40	28
Station 3	6.17	6.61	1.45	4.2	240	28
Station 4	6.38	7. 59	0.95	1.5	24	28
Station 5	6.62	7.65	0.57	2.5	12	21
Station 6	6.42	7.74	1.40	2.9	8.2	28
Station 7	6.52	7.63	0.43	1.6	130	21
Station 8	6.96	5.55	0.45	0.8	110	168
Objective for drinking use class B and C	6.5–8.5	>2.0–7.968	–	–	50 and 5,000	500

Effect of bio chemical oxygen demand (BOD)

Biochemical Oxygen Demand (BOD) determines the strength in terms of oxygen required to stabilize domestic and industrial wastes. For the degradation of oxidizable organic matter to take place minimum of 2 to 7 mg/l of DO level is to be maintained at laboratory experimentation or should be available in the natural waters (De 2003).

Effect of turbidity

Turbidity is more concern with aesthetic point of view. High turbid water shortens the filter runs. Many pathogenic organisms may be encased in the particles and protected from the disinfectant. For this and aesthetic reasons the IS has placed maximum contaminant level of 5 to 10 NTU, depending upon the treatment process used, as the maximum allowable in public water supplies (Sawyer et al. 1994; Burden et al. 2002; De 2003).

Effect of micro–organisms

In drinking water micro–organisms can cause sensory defects (odor, color, taste). Micro–organisms are an important cause of the corrosion of steel pipes. Various health related problems due to contaminated waters are diarrhea, abdominal cramps and vomiting due to salmonella, cholera is due to vibro cholerae, infection of lungs due to mycobacterium [Adarsh and Mahantesh 2006, Bagalkot, Karnataka, India (personal communication); Leo and Dekkar 2000].

Effect of total dissolved solids

The amount and nature of dissolved and undissolved matter occurring in liquid materials vary greatly. Waters

Table 6 Data (Jan 2006) of the Netravathi river water quality

Parameter	PH	DO (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)	MPN	TDS (mg/l)
Station 1	7.13	7.67	1.3	1.7	4	21
Station 2	6.85	6.95	3.47	3.1	14	35
Station 3	6.65	7.66	2.16	3.3	17	21
Station 4	7.25	7.64	1.73	2.3	17	28
Station 5	7.26	7.55	1.3	4.0	2	21
Station 6	7.39	7.58	2.24	1.8	9.2	28
Station 7	7.15	7.47	1.38	1.9	6.8	28
Station 8	7.5	7.5	1.29	2.0	5.5	35
Objective for Drinking Use Class B and C	6.5–8.5	>2.0–7.968	–	–	50 and 5000	500

Table 7 Data (Feb 2006) of the Netravathi river water quality

Parameter	PH	DO (mg/l)	BOD_5 (mg/l)	Turbidity (NTU)	MPN	TDS (mg/l)
Station 1	7.41	6.89	1.29	11.9	59	18
Station 2	7.18	5.87	1.38	14.0	15	42
Station 3	7.12	6.63	2.16	15.0	15	42
Station 4	7.42	6.83	3.47	12.6	32	35
Station 5	7.39	6.96	1.73	13.5	13	28
Station 6	7.50	6.82	2.24	11.9	11	35
Station 7	7.60	6.92	1.30	12.5	15	35
Station 8	8.00	6.84	1.30	13.0	2	42
Objective for Drinking Use Class B and C	6.5–8.5	>2.0–7.968	–	–	50 and 5,000	500

with higher solids content have laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them. Total dissolved solid (TDS) consists of oxygen–demanding wastes, disease–causing agents, which can cause immense harm to public health. Organochlorinated pesticides such as DDT, is a very toxic compound. Exposure to high doses can affect the central nervous system, provoking paralysis of the tongue, lips, and, face, irritability, dizziness. The presence of synthetic organic chemicals (fuels, detergents, paints, solvents etc) imparts objectionable and offensive tastes, odors and colors to fish and aquatic plants even when they are present in low concentrations (Sawyer et al. 1994; Leo and Dekkar 2000).

If pH is less than or equal to 4.3 or greater than or equal to12.0, the quality index is equal to 2. If biochemical oxygen demand value is greater than or equal to 3 mg/l, the quality index equals to 2. If turbidity is greater than or equal to 100 NTU, the quality index is equal to 2. If the coliform per 100 ml is greater than 50, the quality index is equal to 2. The above assumption of retaining water quality index minimum at 2, not 0 is due to the reason that, if one of the quality index value is zero then Bhargava's and Harmonic Mean water quality index doesn't work. Rating curves were drawn based on the Class A, B and C tolerance limits of inland waters (IS: 10,500 – 1982 and IS: 2,296 – 1982) as shown in the Fig. 2(a–f).

Water quality of Netravathi River

In Netravathi basin, the temperature ranged from 26–30°C (Station 1–8). The pH varied from 5.9 to 6.8 in October (Table 3). Between November 2005 to February 2006, the variation of pH was from 6.17 to 8.00 (Tables 4, 5, 6 and 7). The lower values of pH were observed at station 3, 4, 7 and 8, which are near to the townships, temples along the river (Tables 4, 5, 6 and 7). The discharge of sewage from these townships may have contributed to the lower pH values. The pH values improved after December 2005 as most parts of the Western Ghats received rainfall.

Total Dissolved Solids (TDS) were also found to be within the desirable limit of 500 mg/l. In the month of December 2005, it was observed that the TDS at sampling station 8 was quite high (168 mg/l) compared to all the previous station readings. Sampling station 8 has a vented dam used for supplying water to Mangalore region. During the month of December 2005, the vented dam was kept open; this could have resulted in salt waters intrusion from the sea. The depth of water was in the range of 1–3 m. This may be due to the salt water intrusion.

The principal pollution indicator, DO didn't show any marked variation. There were slight variations at few stations. In the month of the January 2006 and February 2006, the width and depth of the Netravathi river was less compared to the previous months. In the month of February, the DO level dropped slightly compared to the previous months. DO was found to be in the range of 5.87–6.96 mg/l (Table 7). There are various check bunds built across the river, which resulted in less flow of water, and in turn resulted in higher demands and low DO. BOD was found to be minimum during these 5 months at all the stations of Netravathi and ranged from 0.43 to 3.47 mg/l (Tables 4, 5, 6, 7).

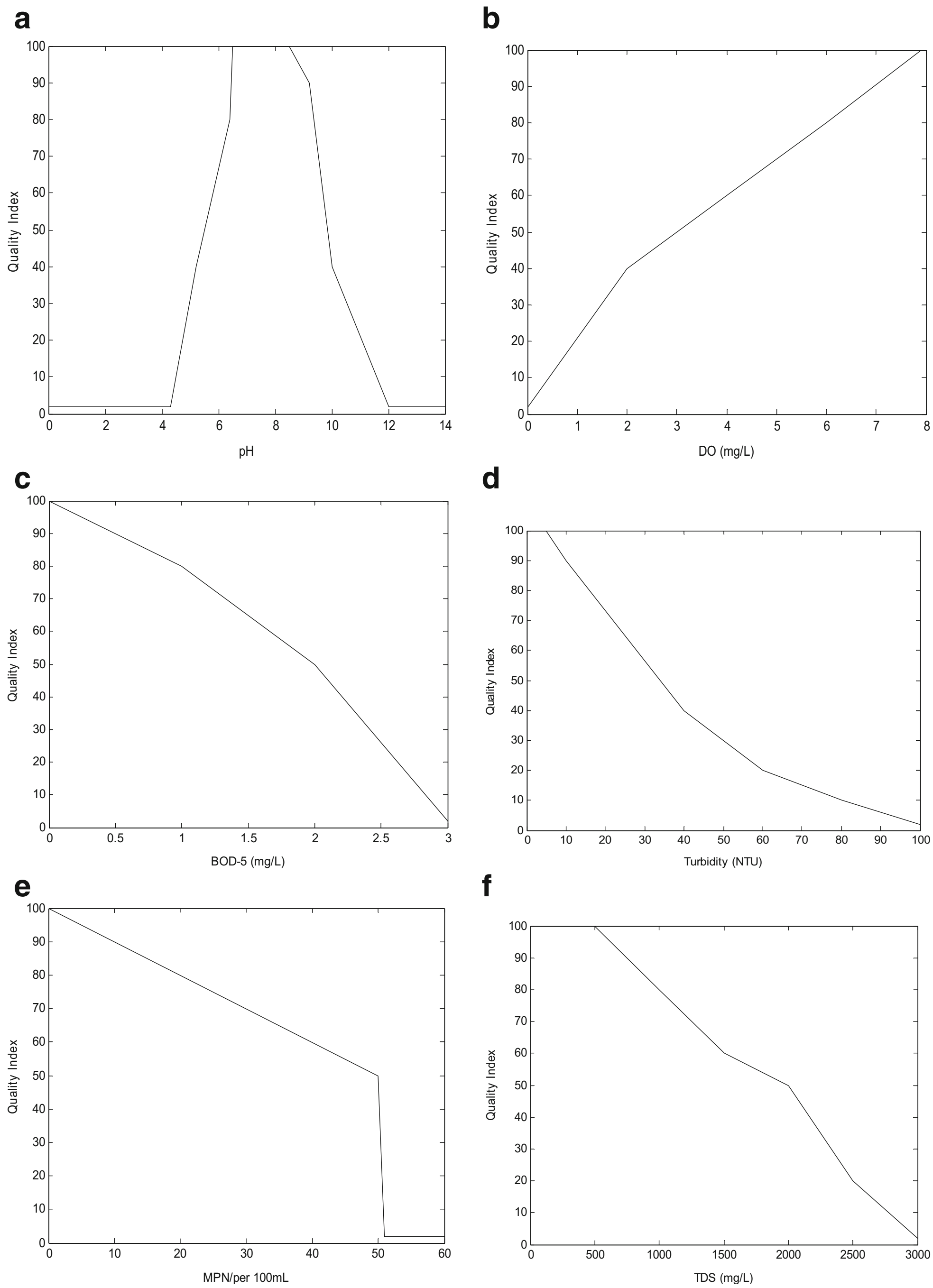

Fig. 2 Rating curve for water quality index versus various parameters based on Class A, B and C tolerance limits of inland waters (**a**–**f**)

Turbidity was also found to be less at most of sampling station and ranged from 1.0–20.1 NTU. Only in the month of November 2005, which is the festival season, the turbidity at all the stations were higher. In the month of February 2006, the turbidity was found be much higher than the previous months. Turbidity was found to be in the range of 11.9–15.00 NTU (Table 7). This may be due to the lean flow and increase in number of fast food centers come up along the river basin.

Table 8 Water quality matrix (Bhargava WQI method)

Time (Month)	Sampling stations							
	1	2	3	4	5	6	7	8
October	94.06	50.21	47.29	48.14	95.51	87.57	88.80	88.15
November	47.54	49.85	49.59	49.68	49.21	47.02	42.71	45.97
December	92.99	81.41	45.32	84.85	95.46	90.13	51.04	48.88
January	93.92	49.92	83.73	88.77	94.04	83.50	92.69	93.44
February	47.36	85.38	79.31	46.55	85.54	79.98	88.25	90.03

Most probable number (MPN) was found to be very high during the second set of data (Table 3) as the samples were collected at certain depth at few stations or due to the confluence of various numbers of polluted streams. Various activities such as washing of clothes, bathing, cleaning of vehicles etc. are carried along the riverbank.

Water quality indices

There are various water quality indices (WQI) to compare various physico–chemical and biological parameters such as Bhargava Method, Hortons Method, Ambient water quality, Delphi Method etc (Pandey and Sundaram 2002; Chetana and Somashekar 1997; Ram and Anandh 1996). Brown, et al. presented a WQI, which varied from zero to 100. The arithmetic mean method of WQI does not permit sufficient lowering of the index if any one significant relevant parameter exceeded the permissible limit. Brown, et al. also proposed multiplicative from of the index. In the multiplicative index, weights to individual parameters are assigned based on a subjective opinion as they are based on the judgement of the author and a few of his associates. The weight reflects a parameter's significance for a use and has considerable impact on the index [Bhargava et al. 1998; Dwivedi et al. 1997; Bhargava 2006, Devpura, Haridwar, Uttaranchal (personal communication)].

Among them the Bhargava Method was adopted because of the simplicity involved in handling small to large data for various beneficial uses. The water quality index (WQI) was determined according to Bhargava method.

The simplified model for WQI for a beneficial use is given by

$$WQI = [\eta^{n} i = 1 \quad f_i(P_i)]^{1/n} \times 100$$

where n is the number of variables considered more relevant to the use and $f_i(P_i)$ is the sensitivity function of the ith variable which includes the effect of weighting of the ith variable in the use.

The sensitivity function values for the different concentration of the variables quality are shown in the Fig. 2(a–f). Based on this Fig. 2 and the above model for the water quality index for the various beneficial uses of Netravathi can be calculated. For example, using the above WQI model, at some sampling station the WQI for drinking purposes would work out to [0.73 (the f value of BOD from Fig. 2)×0.58 (the f value of DO from Fig. 2)×1.0×(the f value of Turbidity from Fig. 2)×0.7 (the f value of MPN from Fig. 2)×0.9 (f value of pH from Fig. 2)×0.8 (the f value of TDS from Fig. 2)]=80 (say) and so on for

Table 9 Rating scale for WQI (Bhargava WQI method)

Usage-Drinking Purposes	<=40	41–50	51–70	71–90	91–100
Water Class	Poor	Marginal	Fair	Good	Excellent
October	–	2, 3, 4	–	6, 7, 8	1, 5
November	–	1, 2, 3, 4, 5, 6, 7, 8	–	–	–
December	–	3, 8	7	1, 2, 3, 4, 5, 6	–
January	–	2	–	3, 4, 6	–
February	–	1, 4	–	2, 3, 5, 6, 7, 8	–

Table 10 Rating scale for WQI (Harmonic mean WQI method)

Usage-drinking purposes	<=40	41–50	51–70	71–90	91–100
Water Class	Poor	Marginal	Fair	Good	Excellent
October	2, 3, 4	–	–	6, 7, 8	1, 5
November	1, 2, 3, 4, 5, 6, 7, 8	–	–	–	–
December	3, 7, 8	–	–	2, 4, 6	1, 5
January	2	–	–	3, 4, 6	1, 5, 7, 8
February	1, 4	–	–	2, 3, 5, 6, 7, 8	–

the other stations. Based on a classification system, wherein, classes I, II, III, IV and V respectively as shown in the Tables 9 and 10. Similarly harmonic mean water quality index can be calculated.

Harmonic Mean of water quality index method was used to determine the overall water quality index along the different sampling stations. Harmonic Mean was used because, if the quality index of the parameter is less, then the weightage to that parameter should be higher. To determine the water quality index following equation was used.

$$WQI = \frac{1}{\frac{1}{n_p}\sum_{i=1}^{n}\frac{1}{\phi_i}} \quad \text{Where } i = 1, 2, \ldots m$$

Where i=1, 2...*m*

X_I the element of the matrix of the each row
N_p number of water quality parameters

The water temperature followed a seasonal pattern and is varied from 23.5°C to 38.5°C (Madhyastha et al. 1999). Turbidity is a measure of cloudiness in water. The more turbid the water, the mukier it is. The water was found to be more turbid during the month of November 2005 and February 2006 at various sampling stations. This can be caused by soil erosion, waste discharge, urban runoff, algal growth etc. Abundance of algae was found along the sampling station 1 and 4. This may be due to, the number of fast food centers come up along the NH 48 highway. The DO level was the lowest at the station 2 in the month of February 2006 compared to the previous months. In general, DO level was low at all the sampling stations for February 2006. As the turbid water becomes warmer the suspended particles absorb heat from sunlight, causing oxygen level to fall. Photosynthesis decreases with lesser light, resulting in even lower oxygen level. Turbid streams are known to have a greater heating capacity than clear ones (Pandey and Sundaram 2002). Further, turbidity interferes with deeper penetration of light whereby surface water gets heated up.

The DO level found in all the stations is sufficient for the planktons to survive and various physiological activities. The poor flow during lean period (December 2005 and February 2006) coupled with deterioration of water quality with increased temperature resulted in the depletion of DO. Besides this, the mixing of organic wastes demanding oxygen might have induced drop in oxygen level (Jayaprakash 1988). The high organic load of wastewater affects the DO level of the receiving waters (Jayaprakash 1988). The time of sampling also might have had its role for variation of temperature at different times of collection. During Monsoon there was considerable increase in levels of DO leading to supersaturation which may be due to

Table 11 Water quality matrix (Bhargava WQI method)

Time (Month)	Sampling stations							
	1	2	3	4	5	6	7	8
October	93.73	10.86	10.77	10.80	95.30	86.24	87.59	87.25
November	10.79	10.85	10.84	10.85	10.84	10.77	10.59	10.73
December	92.54	79.84	10.72	83.39	95.30	89.40	10.88	10.82
January	93.29	10.85	79.16	87.17	93.41	77.67	91.97	92.85
February	10.78	84.73	75.51	10.76	84.24	74.94	87.73	89.49

lower temperature, increase turbulence, and rain fall. There should be adequate DO in all season.

Total Dissolved solids or filterable residue includes salts and organic residue. Sampling station 1 and 7 marked the least fluctuations in the present study. This may be due to the forest, semigreen catchments area thereby less soil erosion of the top soil. It is noticed that the stations of downstream region have higher TDS values compared to the upstream ones (Jayapraksah 1988). A sudden rise TDS values is seen in the month of November 2005 and December 2005 of the study. This may be correlated with festival period. The number of pilgrims is much more in this season and they use this water for various purposes. This also may be due to addition of sewage at non–point source and also the anthropogenic activities along the banks at different stretches of downstream.

Hydrogen ion concentration (pH) of water is an important indicator of the chemical condition of the environment. In the present study at different sampling stations of Netravathi river, the pH marked the variation from 6–8. Narrow annual fluctuation in pH observed in all the sampling stations is due to the low annual variation in free CO2 (Jayaprakash 1988). During monsoon season, water shows an acidic character, whereas, during most of the other months it shows slightly alkaline or neutral pH. High concentration of free CO2 during monsoon, may explain the decrease of pH towards acidic side. During this season rain water is charged with CO2 as it falls towards earth. Water trickling through organic soil may become further charged with products of decomposition and later enter a stream, introducing gaseous CO2 in water. When CO2 enters pure water, a small proportion of it is hydrated to form carbonic acid, some of this carbonic acid dissociates into bicarbonate and hydrogen ions bringing about a lowering of the pH. So increase in CO2 decreases pH and vice–versa thus, they are interrelated. The pH of water body indicates degree of deterioration of water quality (Deepa 2004).

MPN index values from the Tables 3, 4, 5, 6, which shows that the stations along the temple vicinities are much affected by anthropogenic indulgence and defecation on the banks. A little upstream to the temple areas of the river waters are clean and transparent at sampling station 2 and 5. As these are holy places devotees take a dip before entering the temple. They also use it for washing clothes and vehicle cleaning. The local people use these waters as sources for drinking, bathing and for agricultural purposes. Increased inflow of pilgrims decreased hygienic conditions and poorly maintained sanitation results in the deterioration of environmental health of the aquatic system (Madhyastha et al. 1999). With respect to the WHO and IS standards the MPN of coliforms/100 ml in samples collected from all the stations exceeded the prescribed limit. The load of coliform bacterial contamination is found to be heavy. Higher coliform counts clearly indicate lack of sanitation facilities on these stretches.

The inflow of pilgrims to the temple towns brings enormous pressure on the basic requirement fulfillments like food, shelter and waste disposal. Naturally the immediate environment near the river banks is being utilized and also the river water for bathing and washing. Many a times primary sanitary requirements are also not available. Even if there are some provisions, the influx is far greater than the basic facilities available, and the carrying capacity of these temple towns are limited. Ultimately the receiving ecosystem is affected during most part of the year, probably expect during the rainy season (Madhyastha et al. 1999)

The water quality of Netravathi is in the Excellent to Marginal range by using Bhargava water quality index method mainly due to lower input of municipal wastes and /or various activities carried at the bank of the river. Only in the month of November 2005 (Tables 7 and 8), the WQI at all the work stations was seen to be Fair. In the month of December 2005 and February 2006, the WQI was in the range of Good to Marginal. In the month of October 2005 and January 2006, the WQI was in the range of Excellent to Fair.

The water quality of Netravathi is in the Excellent to Poor range by using Harmonic Mean water quality index method. Only in the month of November 2005 (Tables 9 and 11), the WQI at all the work stations was seen to be Poor. In the month of January 2006 and February 2006, the WQI was good at most of the stations. The polluted waters of the small stream joining the river are diluted to a greater extent by Netravathi as the inflow from them comparatively less and variable. Based on the WQI values for various beneficial uses of the Netravathi river may be identified for purposes of quality improvement with respect to any beneficial uses. A general decline in WQI value at all sampling stations in November 2005 and sampling station 2 at most of the months indicated an increase in the Netravathi river's pollution status. As large number of people bathe in the river at Dharmasthal and many drink its water while bathing all the year–round for religious rites, as well as for recreation.

Hence this station is critical and poses a serious threat to public health. The lowest river WQI at Dharmasthal suggests that serious efforts are needed for improving the river water quality. High coliform counts at all sampling points further emphasizes then need for protecting the health of the villagers living downstream of the river. They should be trained to disinfect the water by boiling or using bleaching powder before drinking. Water can be used for bathing, recreational purposes and drinking after treatment.

Conclusions

All of these physico–chemical and biological parameters have shown temporal and spatial variations. The water is colorless in almost all the sampling stations. Water temperature shows almost dependence on atmospheric temperature. Water is slightly acidic having an average pH of less than 7 in most of the stations. MPN was found to be high during the month of November 2005 as this was the festival season. Turbidity was recorded more for the month of February 2006; this may be due to lean flow and increased number of fast food centers along the river basin.

Human settlement and urbanization along the banks are also increased rapidly demanding more and more water for their activities. Absence of industrial pollution is responsible for the total neglect or extensive treatment of these waters from the hygienic point of view. Even though the parameters analysed are all within the safe limits, it would be better to treat the sewage before discharging into the rivers from the human settlement areas.

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