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Assessment of Water Quality Parameters of Lentic and Lotic Waterbodies in Narmada Canal Command Area in Saurashtra Region, Gujarat

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ABSTRACT

The objective of the present study was to assess the water quality of canal (man-made lotic waterbody) and ponds (man-made lentic waterbodies) present in Narmada Canal Command Area (NCCA) spread over four districts of Saurashtra region of Gujarat State, *viz.* Bhavnagar, Botad, Morbi, Surendranagar districts. Values of important physico-chemical parameters of water quality were determined through *in situ* and *ex situ* methods. Average values of parameters like pH (8.51), temperature (27.91 °C), electrical conductivity (6.32 ms/cm), TDS (559.18 ppm) turbidity (147.95 NTU), salinity (3.17 ppt) and phosphates (3.41mg/l) were found to be higher for pond waters, whereas the average values of DO (6.09 mg/l), total hardness (308.00 mg/l) and nitrates (2.37 mg/l) were found to be higher for the canal waters in the NCCA in the four districts. The study revealed that water quality of canals in the four districts was suitable for flora and fauna. For some ponds (n = 6) in Bhavnagar, Surendranagar and Morbi districts, the majority of water quality parameters, viz. pH, temperature, electrical conductivity, TDS, turbidity, salinity and phosphates had high values which might be undesirable from the view point of existence of some aquatic organisms. But as the values of these parameters for canal waters were lower and suitable for aquatic organisms, it is very likely that in the long run, the values of these water quality parameters of such ponds will become suitable for aquatic biota under the influence of long-term mixing of pond waters with canal waters having lower values of these parameters.

Keywords: Canal, Gujarat State, Physico-chemical parameters, NCCA, Pond, Water quality

I. INTRODUCTION

Water is a key component of the environment and it plays a variety of ecological and socio-economic roles in different ecosystems. To harness this precious resource, mankind has tried various strategies since ancient times. On one hand, man has been digging ponds or tanks and on the other hand, the modern man has been planning and implementing large water resources development projects. As a consequence,

there exists a situation in Gujarat, wherein on one hand, the rural landscape is dotted with numerous ponds of olden times and on the other hand, more and more villages have been coming under expanding network of canals under one or the other water resource development project. Such projects may have environmental impacts, which may vary with physiography, climate, soil, characteristics of canal flow and size of an irrigation project [1].

In India, the Sardar Sarovar Project (SSP) is one of the largest inter-state water resource projects covering four major states, viz. Maharashtra, Madhya Pradesh, Gujarat and Rajasthan [2]. A large number of people of Gujarat State are dependent on Narmada canal network in the modern times for domestic, agricultural and industrial purposes. The canal network supplies water of the river Narmada to various parts of Gujarat through main canal, branch canals and sub-canals as also pipelines [3]. From ecological/environmental view-point, the canals constitute artificial (man-made) lentic aquatic bodies which have slow moving waters, linear configuration, gently curved beds, uniform substrates and relatively steady water levels. They are characterized by relatively stable environment and meagre biota 0[4]. It is worthwhile to assess the extent of difference in quality of water of any canal introduced in an area and the water bodies (e.g. village ponds, countryside ponds, reservoirs, lakes etc.) that might be already existing in the area. It is also useful to understand or infer the ecological/environmental effects of such artificial lotic systems on existing wetlands of the area. An attempt has been made to assess water quality of Narmada canal segments and ponds (village ponds and countryside ponds) present in various villages in the command areas of Narmada canal in four districts of Saurashtra region of Gujarat (viz. Botad, Morbi, Bhavnagar, and Surendranagar).

II. STUDY AREA

The study was carried out in Saurashtra region (Gujarat State) with the focus on the select villages located in Narmada Canal Command Area (NCCA) of four districts, viz. Bhavnagar, Botad, Morbi, and Surendranagar (Fig 1).

Saurashtra region has a wide climatic variation. Agro-climatically, Gujarat state is divided into eight sub-zones. The major portion of Saurashtra region is covered by zone VI and zone VII which are known as south Saurashtra zone and north Saurashtra zone respectively [5]. The substrate of this region is predominantly rocky. Except some small pockets of Junagadh, Rajkot and Bhavnagar districts, the remaining parts of the region is deficient in rainfall. The mean annual rainfall varies between 400 mm and 800 mm [6]. Unevenly distributed rainfall is common in this region and consequently, drought occurs frequently in different parts. Because of the combined effect of scanty and erratic nature of rainfall and short courses of rivers (≤ 80 km), the surface water resource scenario is far from satisfactory.

III. METHODS AND MATERIAL

Selection of sampling sites

The villages and respective sampling sites were selected with the help of maps prepared through analysis of remotely sensed satellite data. For each of the select villages, water samples were collected from a village pond and a portion of Narmada canal passing through it (Table 1). The villages selected for water quality assessment were located in total 10 km belt on both sides of canal segment in any district. Number of sampling villages selected for water quality assessment for each district depended on total number of villages in the respective districts and number of such benefited villages varied from district to district. It may be noted that for each district, 10% of all the canal benefited villages were selected for sampling.

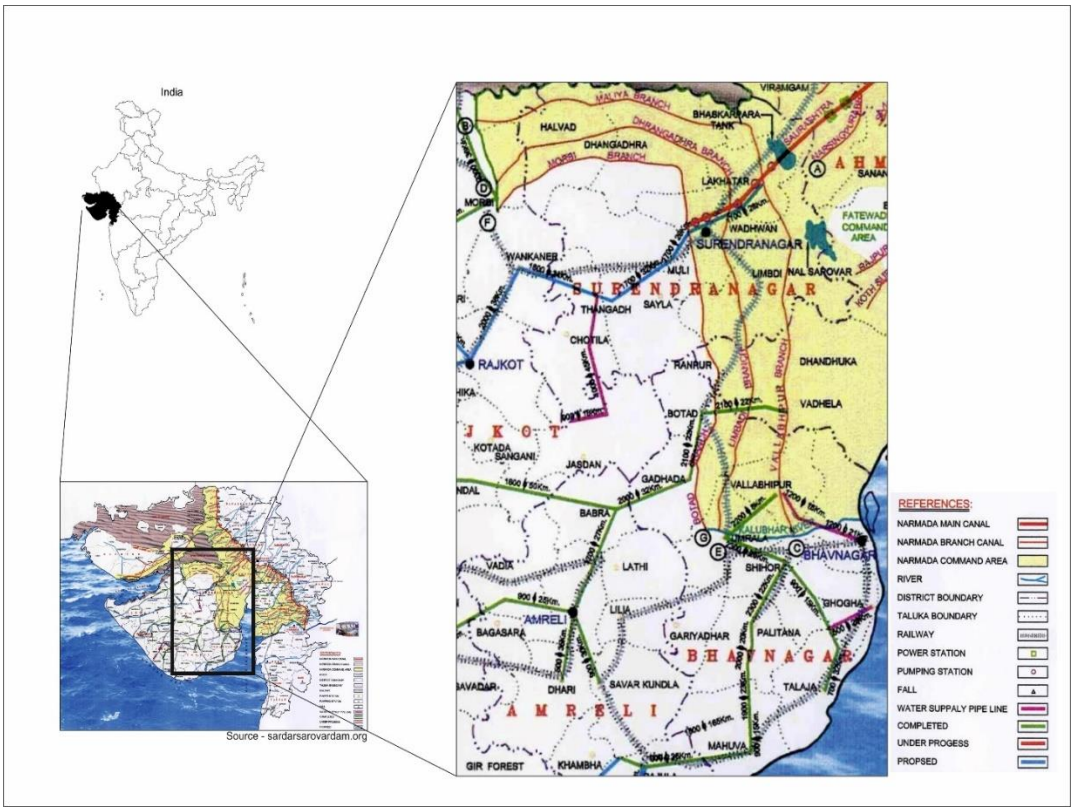

Figure 1: Study area – Narmada Canal Command Area (NCCA) in four districts of Saurashtra

TABLE I
SELECT VILLAGES IN NCCA IN FOUR DISTRICTS OF SAURASHTRA, GUJARAT

SN	District	No. of village selected for sampling	Village name	Total number of water samples (Canal, Pond)	
				Canal	Pond
1.	Bhavnagar	4	Rajgadh, Juna Ratanpur, Ramanka, Alampar	4	4
2.	Botad	5	Ranpur, Pati, Ningala, Sarangpur, Jalila	5	5
3.	Surendranagar	26	Hebatpur, Hathipura, Sushiya, Savda, Vachharajpura, Odu, Malvan, Rajsitapur, Rajcharadi, Bharada, Wadhwan, Baldana, Katuda, Kankavati, Nana ankewaliya, Lakhtar, Lilapur, Talsana, Bavli, Panshina, Rojasar, Gedi, Limbdi, Borana, Chuda, Darod	26	26
4.	Morbi	10	Jodhpur nadi, Kerala, Jetpar, Dhulkot, Malaniyad, Palasan, Charadva, Nichimandal, Maliya, Halvad	10	10

In situ and *ex situ* water analysis

Water quality assessment was carried out through *in situ* water quality testing for certain parameters (viz. temperature, pH, turbidity, DO, TDS, EC and salinity) as also through collection of water samples for *ex situ* assessment of some other parameters (nitrates, phosphates and total hardness). For *ex situ* analysis, composite samples were collected to get representative samples from each pond and canal portion. For *ex situ* analysis, water samples were taken in sampling bottles (each of 1 litter), labeled carefully and brought to the GEER Foundation's, Ecological Monitoring Laboratory for further analysis. The methodologies followed for physico-chemical analyses were as per APHA and Maiti [7,8].

The results obtained for the above-mentioned parameters were compiled and the average values for each parameter were determined considering values for all the sites of canal and ponds in each district. Further, statistical correlation was also carried out in order to find correlation among the various physico-chemical parameters.

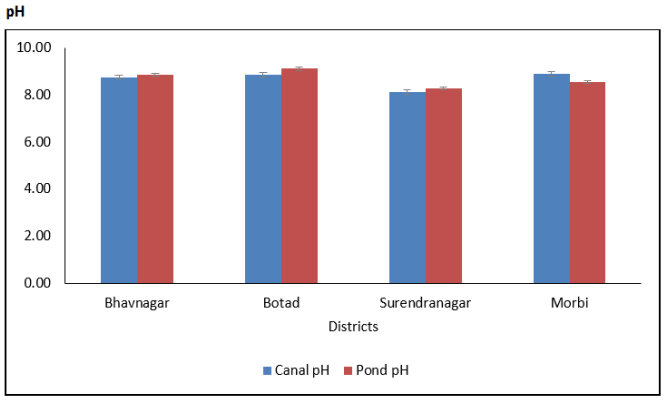

Figure 2: pH (average±SE) of water of canals and ponds in four districts

In the present study, the average value of pH of water at all the sampling sites (ponds and canal) was found to be alkaline in nature. The average of pH values for all the sites of canal varied from 8.13 (Surendranagar) and 8.90 (Morbi) (SE=0.09), whereas the values at all the pond sites varied from 8.27 (Surendranagar) to 9.11 (Botad) (SE=0.06) (Fig. 2). The actual values of pH at all the sites (considering canal and pond sites together) ranged between 7.01 and 9.71 indicating that pH values were in alkaline range in the NCCA in Saurashtra region. The permissible range of pH values for drinking water prescribed by Bureau of Indian Standards (BIS) is 6.5-8.5 and the values obtained in the present study fall near the upper limit of the pH standards. Hence, it is desirable using water for drinking purpose only after primary treatment. Considering all the four districts, there was a small difference (0.03) in average pH of pond water (8.69) and average pH of canal water (8.66). The minimum pH difference (0.10) was recorded for Bhavnagar district, whereas maximum pH difference (0.35) was recorded for Morbi district (Fig.2). The past studies on water quality of wetlands of Gujarat have indicated that, pH of wetlands of Gujarat usually remains in alkaline range [9,10,11,12,13,14] which corroborates with the findings of present study.

Water temperature

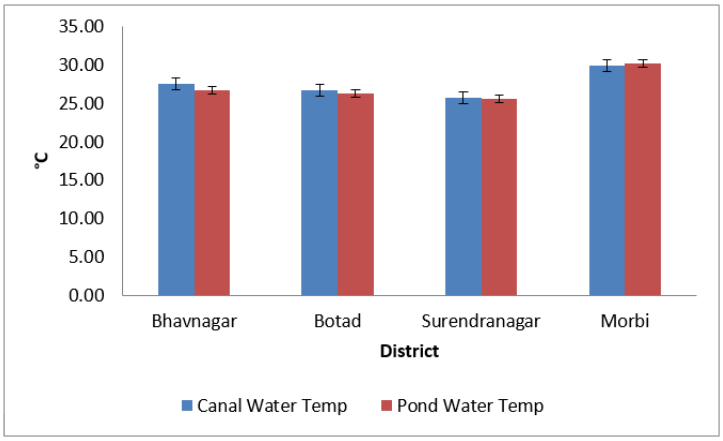

Figure 3: Water temperature (average±SE) of canals and ponds in four districts

The water temperature at all the sites on canal varied from 25.70˚C (Surendranagar) to 29.94˚C (Morbi) (SE=0.74), whereas average of water temperature at all the sites of ponds varied to 25.63˚C (Surendranagar) to 30.17˚C (Morbi) (SE=0.55) (Fig. 3). The actual values of water temperature at all the sites

(considering canal and pond sites together) ranged from 17.01˚C to 38.10˚C. Considering all the four districts, there was a small difference (0.29 ºC) in average water temperature of pond water (27.19 ºC) and average water temperature of canal water (27.48 ºC). The minimum difference(0.07ºC) between pond and canal water was recorded for Surendranagar district, whereas maximum difference (0.81ºC) was recorded for Bhavnagar district (Fig. 3).

Electrical Conductivity (EC)

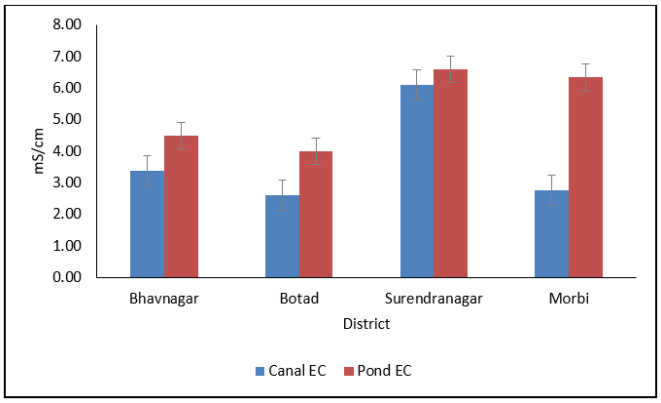

Figure 4: Electrical Conductivity (average±SE) of water of canals and ponds in four districts

In the present study, the average of electrical conductivity values at all the sites on canal varied from 2.61 mS/cm (Botad) and 6.10 mS/cm (Surendranagar) (SE=0.48). On the other hand, the average of electrical conductivity at all the sites of ponds varied from 3.98 mS/cm (Botad) to 6.60 mS/cm (Surendranagar) (SE=0.42) (Fig. 4). The actual values of EC at all the sampling sites (considering pond and canal sites together) ranged from 0.21 mS/cm to 17.23 mS/cm. Considering all the four districts, there was a small difference (1.64 mS/cm) in average Electrical Conductivity of pond water (5.35 mS/cm) and average Electrical Conductivity of canal water (3.71 mS/cm). The minimum difference (0.50 mS/cm) was recorded for Surendranagar district, whereas maximum difference (3.56 mS/cm) was recorded for Morbi district (Fig.4). The higher values of conductivity in village ponds can be attributed to the mixing of domestic sewage, run-off and anthropogenic activities (bathing, cloth washing, open defecation etc.) carried out at the pond [15]. BIS [16] has classified water quality for irrigation purpose based on EC values in four different classes and according to the classification, the average values of EC obtained in the present study for ponds falls in the range of 2.61 ms/cm to 6.60 ms/cm depicting medium to high range of salt concentration. It is likely that this value may go on reducing with constant mixing of Narmada canal water that was found to have lower EC values.

Total Dissolved Solids (TDS)

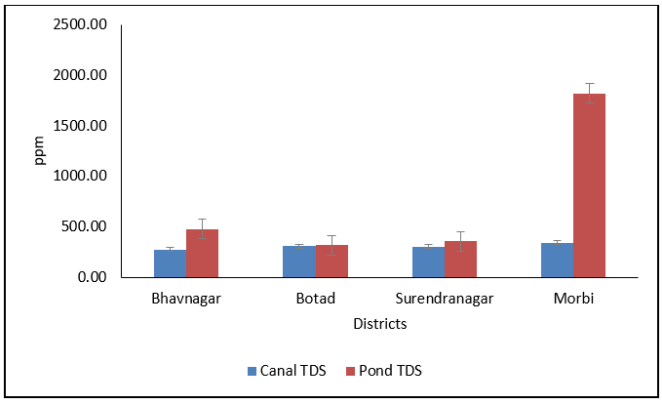

Figure 5: Total Dissolved Solids (average±SE) of water of canals and ponds in four districts

In the present study, the average of TDS values at all the sites on canal varied from 272.94 ppm (Bhavnagar) to 342.23 ppm (Morbi) (SE=20.35). On the other hand, the average of TDS at all the sites of ponds varied from 318.80 ppm (Botad) to 1822.51 ppm (Morbi) (SE=97.26) (Fig. 5). Considering all the four districts, there was a large difference (437.92 ppm) in average TDS of pond water (744.15 ppm) and average TDS of canal water (306.23 ppm). The minimum difference (11.89 ppm) was recorded for Botad district, whereas maximum difference (1480.28 ppm) was recorded for Morbi district. The permissible values of TDS for drinking water are 1000 ppm as per WHO Standards [17] and 500-2000 ppm as per Indian standards [18], whereas for irrigation purpose the permissible value of TDS is 2100 ppm. The average TDS values recorded during the present study for villages of Suarashtra

region were found to be within the recommended permissible values. However, high values of TDS (i.e. from 318.80 ppm to 1822.51 ppm) were recorded for waters of certain village ponds and therefore, the water of such ponds may be used for drinking purpose only after proper water treatment. As TDS of canal water in the NCCA of Morbi and Bhavnagar districts were found to be considerably lower than that of certain ponds in the respective districts, it is likely that in the long run, due to continuous mixing of canal water (having low TDS). the TDS of certain village ponds (with high TDS) would reduce (Fig.5).

Turbidity

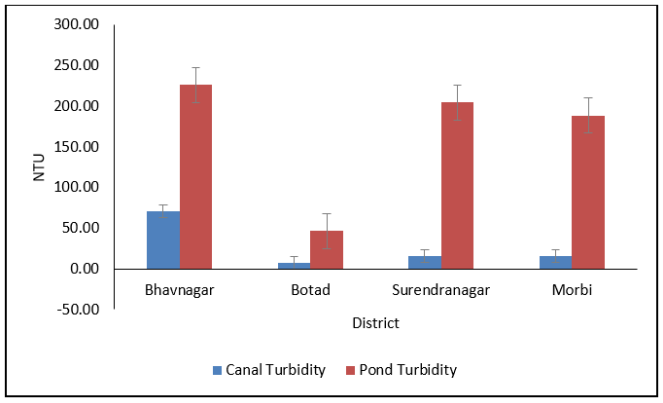

Figure 6: Turbidity (average±SE) of water of canals and ponds in four districts

In the present study, the average of turbidity values at all the sites on canal varied from 7.01 NTU (Botad) to 70.38 NTU (Bhavnagar) (SE=7.66), whereas the average of turbidity values at all the sites of ponds varied from 46.41 NTU (Botad) and 225.91 NTU (Bhavnagar) (SE=21.95) (Fig. 6). Altogether (i.e. considering pond and canal sites together) the values of turbidity ranged from 0.01 NTU to 1090.00 NTU. Considering all the four districts, there was a large difference (139.09 NTU) in average turbidity of pond water (166.29 NTU) and average Turbidity of canal water (27.20 NTU) (Fig.6). The minimum turbidity difference (39.40 NTU) between pond and canal waters was recorded for Botad district, whereas maximum turbidity difference (172.94 NTU) was recorded for Morbi district. The increase in turbidity might be due to waste discharge and excessive growth of aquatic vegetation and algae (Verma et al., 2012). Higher turbidity affects aquatic biota indirectly as it cuts off light to be utilized by plants for photosynthesis there by lowering the rate of primary productivity. Furthermore, drinking water permissible range of turbidity as specified by WHO and Indian Standards are 5 NTU and 1 NTU- 5 NTU respectively. The values recorded in the present study were higher than these permissible values. Therefore, it is recommended to use it for consumption only after primary treatment. Fortunately, as turbidity of canal water in the NCCA of Botad and Morbi districts was found to be considerably lower than that of water of certain ponds having high turbidity, it is likely that in the long run, under the effect of canal water (having low turbidity) turbidity of certain village pond (with high turbidity) would reduce.

Salinity

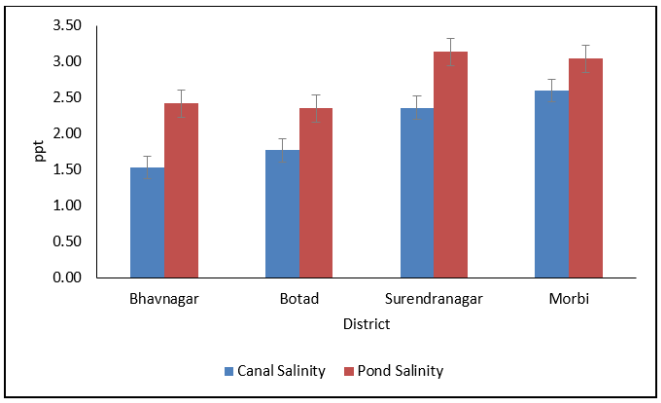

Figure 7: Salinity (average±SE) of water of canals and ponds in four districts

In the present study, average of salinity values at all the sites on canal varied between 1.53 ppt and 2.60 ppt (SE=0.16), whereas average of salinity values at the sites of ponds varied between 2.35 ppt and 3.14 ppt (SE=0.19) (Fig. 7). The actual values of salinity at all the sampling sites representing ponds and canal ranged between 1.01 ppt and 8.68 ppt. Chlorides represent one of the important anions which determine total salinity of water. High chloride concentration in water indicates presence of organic waste, primarily of animal origin (Solanki et al., 2012). Fig. 7 clearly indicates that for each district, salinity

values were relatively higher for village ponds as compared to the salinity values of canal waters. Considering all the four districts, there was a small difference (0.67 ppt) in average salinity of pond water (2.73 ppt) and average salinity of canal water (2.06 ppt). The minimum salinity difference (0.44 ppt) between pond and canal water was recorded for Morbi district, whereas maximum difference (0.89 ppt) was recorded for Bhavnagar district (Fig.7). As the canal water was found to have lower salinity, it is likely that in the long run, due to long term mixing of canal water (having low salinity), salinity of waters of village ponds may drop and it will benefit livelihood of local communities, mesophytic flora and freshwater aquatic fauna.

Dissolved Oxygen (DO)

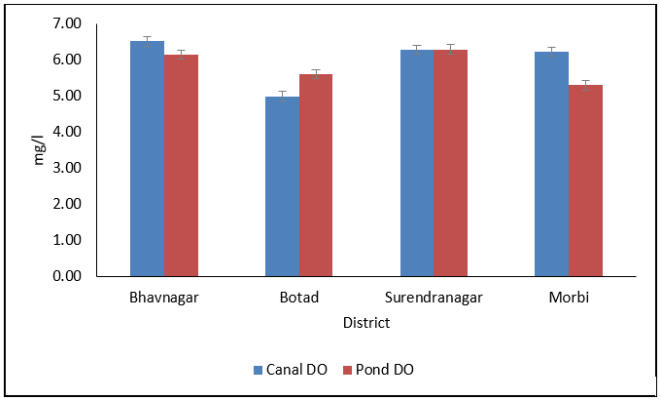

Figure 8: Dissolved Oxygen (average±SE) of water of canals and ponds in four districts

The average of DO concentration at the sites on the canal ranged from the 4.99 mg/l (Botad) to 6.52 mg/l (Bhavnagar) (SE=0.13). On the other hand, average of DO values at sites of ponds varied between 5.30 mg/l (Morbi) and 6.29 mg/l (Surendranagar) (SE=0.13) (Fig. 8). The actual values of DO of all the sites (considering pond and canal sites together) ranged between 3.15 mg/l and 9.42 mg/l. Considering all the four districts, there was a small difference (0.17 mg/l) in average Dissolved Oxygen of pond water (5.83 mg/l) and average Dissolved Oxygen of canal water (6.00 mg/l) (Fig.8). The minimum DO difference (0.01 mg/l) between pond and canal water was recorded for Surendranagar district, whereas maximum difference (0.93 mg/l) was recorded for Morbi district. As per Central Pollution Control Board (CPCB)'s water quality criteria for propagation of wildlife and fisheries, the DO of wetlands should be 4 mg/l or more [19]. All the sites of four districts were found to have DO concentration more than 4 mg/l, which is good for the survival of aquatic life.

Total Hardness

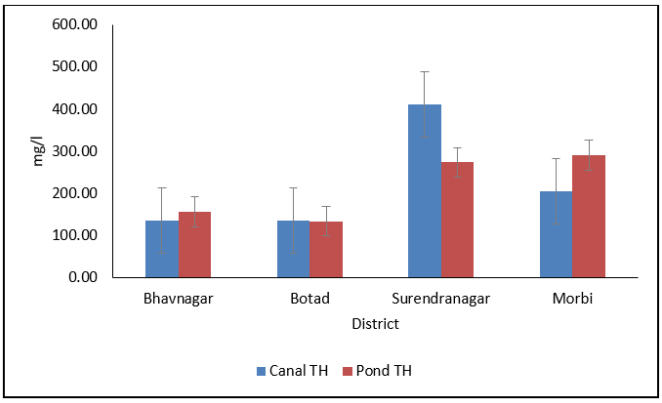

Figure 9: Total Hardness (average±SE) of water of canals and ponds in four districts

In the present study, the average of total hardness at the sites on canal ranged from 134.00 mg/l (Bhavnagar) to 410.69 mg/l (Surendranagar) (SE=77.77), whe its values at pond sites ranged from 133.33 mg/l (Botad) to 290.00 mg/l (Morbi) (SE=35.06) (Fig. 9). The values of total hardness of all the sites (considering pond and canal sites together) ranged between 40 mg/l and 3070.00 mg/l. The average values of total hardness of water (ponds and canals) of Bhavnagar and Botad districts were less than the permissible value prescribed by the Indian standards (IS 10500: 2012) for drinking water i.e. 200 mg/l [18]; whereas, for other two districts, viz. Morbi and Surendranagar, the values were found to be greater than the permissible limit. Considering all the four districts, there was a small difference (8.04 mg/l) in average total hardness of pond water (213.05 mg/l) and average total hardness of canal water (221.09 mg/l) (Fig.9). The minimum total hardness difference (2.33 mg/l) between pond and canal water was recorded for

Botad district, whereas maximum difference (137.30 mg/l) was recorded for Surendranagar district.

Nitrates

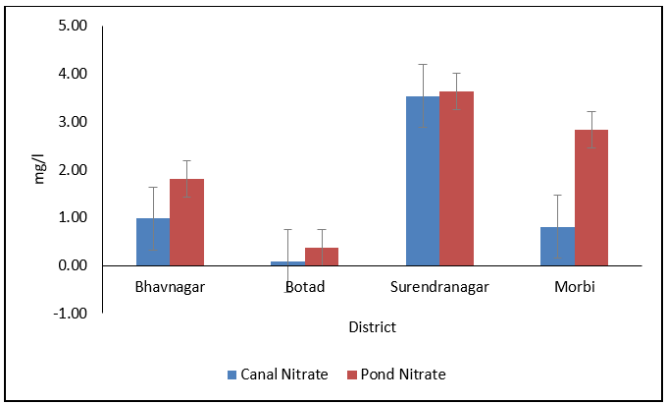

Figure 10: Nitrates (average±SE) of water of canals and ponds in four districts

The average values of nitrates at the sites on canal varied from 0.09 mg/l (Botad) to 3.54 mg/l (Surendranagar) (SE=0.66), whereas values of nitrates at sites of ponds varied between 0.37 mg/l (Botad) and 3.64 mg/l (Surendranagar) (SE=0.38) (Fig. 10). The values of nitrates at all the sampling sites (considering pond and canal sites together) ranged between 0.10 mg/l and 26.50 mg/l. The maximum permissible nitrates values as prescribed by WHO and BIS are 10 mg/l and 45 mg/l respectively for drinking water purpose. The average values obtained in the present study were less than maximum permissible values recommended by WHO and BIS and therefore, the pond waters were found suitable for drinking purpose from the view point of nitrates. Considering all the four districts, there was a small difference (0.81 mg/l) in average nitrates concentration of pond water (2.16 mg/l) and average nitrate concentration of canal water (1.35 mg/l) (Fig.10). The minimum nitrates difference (0.10 mg/l) between canal and pond water was recorded for Surendranagar district, whereas maximum difference (2.02 mg/l) was recorded for Morbi district.

Phosphates:

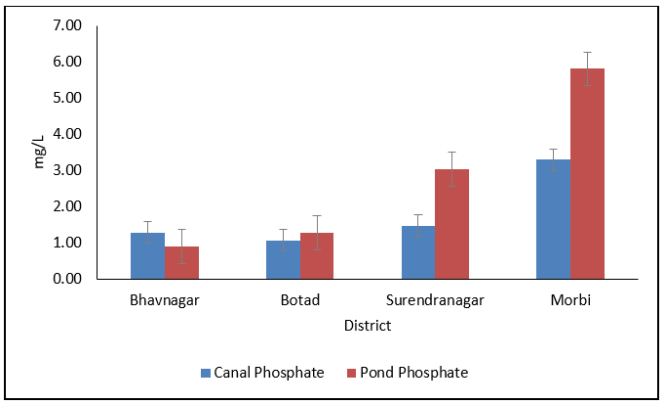

Figure 11: Phosphates (average±SE) of water of canals and ponds in four districts

If phosphates occur in high concentration, they can cause eutrophication of wetlands. Higher the phosphate concentration in a wetland, higher would be the possibility that the wetland is polluted. In the present study, the average of phosphates at the sites on canal varied from 1.06 mg/l (Botad) to 3.30 mg/l (Morbi) (SE=0.30), whereas values of phosphates at the sites for ponds varied from 0.90 mg/l (Bhavnagar) to 5.81 mg/l (Morbi) (SE=0.47) (Fig. 11). Altogether, the values of phosphates (considering pond and canal sites together) ranged between 0.04 mg/l and 25.50 mg/l. Considering all the four districts, there was a small difference (0.98 mg/l) in average phosphate concentration of pond water (2.75 mg/l) and average phosphate concentration of canal water (1.77 mg/l) (Fig.11). The minimum phosphate difference (0.21 mg/l) between canal and pond water was recorded for Botad district, whereas maximum difference (2.51 mg/l) was recorded for Morbi district.

Interlinkages of water quality parameters

The correlation matrix was applied to the results obtained in order to know the correlation among various water quality parameters (Table 2). There existed a strong positive correlation between salinity and conductivity (0.75) and there was a positive correlation between salinity and TDS (0.23) too. Furthermore, DO and temperature were found to have negative correlation with each other (-0.32)

which suggested that, at high water temperature, the DO might have decreased and vice versa. Similarly, TDS was found to be positively correlated with conductivity and salinity. Dissolved Oxygen showed negative correlation with six water quality parameters. Thus, Dissolved Oxygen can serve as the single useful index of water quality as with increase in the value of most of the parameters the concentration of DO decreased.

TABLE 2
CORRELATION MATRIX FOR SELECT PHYSICO-CHEMICAL PARAMETERS OF WATER

	pH	Temperature	EC	TDS	Turbidity	Salinity	DO	TH	Nitrate	Phosphate
pH	1.00									
Temperature	0.39	1.00								
EC	-0.11	0.02	1.00							
TDS	0.01	0.01	0.17	1.00						
Turbidity	0.02	-0.12	0.04	-0.06	1.00					
Salinity	-0.03	0.10	0.75	0.23	0.02	1.00				
DO	-0.15	-0.32	-0.11	-0.07	0.16	-0.19	1.00			
TH	0.10	0.11	0.10	-0.01	-0.07	0.13	0.00	1.00		
Nitrate	-0.23	-0.03	-0.02	0.02	0.15	-0.06	0.16	0.10	1.00	
Phosphate	0.00	0.32	0.15	0.01	0.25	0.21	-0.19	0.13	0.06	1.00

IV.CONCLUSION

The analysis of various physico-chemical parameters indicated that the canal water had comparatively lower values of most of the parameters (mainly TDS, Conductivity, Turbidity and Salinity) than pond water in Narmada Canal Command Area of Saurashtra region. Moreover, the values of pH, TDS and nitrates were found higher than that of the permissible values as per one or the other Standards (e.g. BIS, WHO or IS) for drinking water purpose. Therefore, it would be advisable to use the water of ponds for drinking purpose after proper treatment. Further, EC and salinity values were also high for waters of certain village ponds making them less suitable for drinking without treatment. However, as the values of all these parameters were lower for the canal waters, their continuous mixing with pond waters in the long run may lead to reduction of these values with respect to pond water, which in turn, will be beneficial for satisfying daily water needs of the local communities, mesophytic vegetation and freshwater animals.

V. ACKNOWLEDGEMENTS

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