Available online www.jocpr.com

Journal of Chemical and Pharmaceutical Research, 2012, 4(11):4774-4782

Research Article

ISSN : 0975-7384
CODEN(USA) : JCPRC5

Hydrological characteristics of abandoned Old Ganga Canal at Haridwar (Uttarakhand) India

Vinod Kumar* and A. K. Chopra

Department of Zoology and Environmental Science, Faculty of Life Sciences, Gurukula Kangri University, Haridwar-249404 (Uttarakhand) India

---

ABSTRACT

The hydrological characteristics of abandoned Old Ganga Canal at Haridwar were investigated during the year 2011. The samples were collected before the diversion (control) at Pathri Super passage (S), and after diversion at Pathri Super passage (S_1), Solani Aqueduct (S_2), Dhanuari (S_3), Piran Kaliyar (S_4), Mehawar Kalan (S_5) and Roorkee (S_6) sampling stations. Among various sampling stations, the quality of Old Ganga Canal water was severely deteriorated at Piran Kaliyar. The hydrological characteristics viz. temperature, turbidity, TS, EC, BOD, COD, Cl^-, Ca, Na, K, Mg, total phosphorus, nitrate nitrogen, SO_4^{2-}, Cd, Cu, Cr, Fe, Ni, Mn, Pb, Zn, SPC and FC of water were significantly ($P<0.05$) different at all the sampling stations in comparison to control. Among various sampling stations, Piran Kaliyar (S_4) showed maximum values of physico-chemical and microbiological parameters viz. temperature (19.68 °C), turbidity (11.88 NTU), TS (278 mg L^{-1}), EC (4.55 mg L^{-1}), BOD (270.42 mg L^{-1}), COD (289.74 mg L^{-1}), Cl^- (184.67 mg L^{-1}), Ca (199.64 mg L^{-1}), Na (63.85 mg L^{-1}), K (54.87 mg L^{-1}), Mg (165.84 mg L^{-1}), total phosphorus (42.87 mg L^{-1}), nitrate nitrogen (48.85 mg L^{-1}), SO_4^{2-} (234.55 mg L^{-1}), Cd (1.12 mg L^{-1}), Cu (1.74 mg L^{-1}), Cr (0.58 mg L^{-1}), Fe (5.69 mg L^{-1}), Ni (1.58 mg L^{-1}), Mn (0.36 mg L^{-1}), Pb (0.64 mg L^{-1}), Zn (1.87 mg L^{-1}), SPC (8.5×10^9 SPC ml $^{-1}$) and FC (9.6×10^8 FC 100 ml $^{-1}$) in canal water. The water quality index (WQI) rating of canal water was of bad at sampling stations S, S_1, S_2 and very bad at S_3, S_4 S_5 and S_6 sampling stations. Thus, the canal water was not found suitable for ecological health of Old Ganga Canal.

Keywords: Hydrological characteristics, Old Ganga Canal, water quality, WQI, contamination.

INTRODUCTION

Water quality is extremely important because constant access to good quality water is necessary for life as well as the economy [1, 5]. Since rivers constitute the main inland water resources for domestic, industrial, and irrigation purposes, it is imperative to have a monitoring program, providing a representative and reliable estimation of the quality of surface waters [22, 23], necessary to prevent and control water pollution [19, 7]. Contamination of river water by industrial effluents has been given much attention due to their low biodegradability and toxic effects [8, 9]. The scarcity of clean water and pollution of fresh water has therefore led to a situation in which one-fifth of the urban dwellers in developing countries, and three quarters of their rural dwelling population do not have access to reasonably safe water supplies [14, 15].

The abandoned old section of the Upper Ganga Canal originally constructed around 1850 by the East India Company. The construction of Upper Ganga Canal was conceived and constructed by Proby T. Cautley during the period 1840-1854, and he has been affectionately remembered as a British Engineer with an Indian heart. In the beginning one of the branches of river was a natural channel flowing near Haridwar, and it was made to divert the entire winter flow in the new branches [3]. The first time slice of phase- I propose to construct a parallel lined canal (Parallel Upper Ganga Canal) of 295 cumecs capacity beyond silt ejector 3 from 6 to 36 km and 177.5 to 240 km, 4 new cross drainage works on the Parallel Upper Ganga Canal namely Ranipur Syphon, Pathri Super Passage, Ratmau Aqueduct and Solani Aqueduct [3, 4, 5].

It was the biggest canal system ever undertaken at that time. It was and still is an engineering marvel it has aqueducts, super passages, massive sluice gates, spillways etc. But presently, this old section of the beautiful canal is in disuse and a new canal course has been constructed parallel to the old canal. The old canal is in a very pitiable condition. It is neglected and open to vandalism [4, 5]. The Old Ganga Canal now received the domestic waste as well as agricultural runoff from various villages *viz.*, Pathri barrage, Dhanuari, Piran Kaliyar, Mehawar Kalan and Roorkee. It receives water from Sonali River in rainy season and drains from the new canal. The canal is primarily an irrigation canal, although parts of it were also used for navigation, primarily for its construction materials [3, 4, 5]. The Upper Ganges Canal has since been enlarged gradually for the present head discharge of 10,500 ft^3/s (295 m^3/s). The system consists of main canal of 272 miles and about 4000 miles long distribution channels. The canal system irrigates nearly 9,000 km^2 of fertile agricultural land in ten districts of Uttar Pradesh and Uttarakhand. The Old Ganga Canal has its ecological importance as it has unique biological diversity in terms of flora and fauna in their riparian catchments. It supports a great population of wild flora and fauna as it flows near the Pathri forest division. Canals deposit nutrient runoff, especially phosphorous, into the wetlands. The natural algae and vegetation mix evolved under nutrient poor conditions, and the increased nutrients are changing plant communities from saw grass to cattail dominated this in turn changes oxygen levels and fish populations [30, 32, 33].

Major changes came to the system in the 19th century when Upper Ganga Canal was constructed parallel to the Old Ganga Canal from Pathri Super Passage to Roorkee. The estimated length of the canal was about 20 km. These drainage efforts substantially lowered the water levels and altered the north to south flow of the Old Ganga Canal [3]. Today Old Ganga Canal has been changed a seasonal canal and facing severe scarcity of water. Without water in canal, many species would not be able to move into interior wetlands. Canals open up wetlands not only for exotic species, but also native fish, as canals support movement and range expansion within the region [34, 35, 38].
At the same time there are adverse effects of domestic effluents on water quality and aquatic biota as well. Due to drainage of sewage effluent there is significant increase in TDS, turbidity, BOD, COD, chlorides, sulphates, nitrate nitrogen, total phosphorus and heavy metals like Fe, Zn, Cd, Cr, Cu, Ni, Mn and Pb of the receiving water bodies [9, 13, 16, 25]. Thus, these effluents pose an environmental problem mainly in terms of COD, color, toxicity and salinity [16, 23, 28, 29] and ultimately disrupt the ecological health. Keeping above in view the present investigation was undertaken to study the Hydrological characteristics of abandoned Old Ganga Canal at Haridwar (Uttarakhand), India.

EXPERIMENTAL SECTION

2.1. Study area, samples collection and analysis

The Old Ganga Canal originally originated from Har Ki Pauri and reaches to Pathri Super passage. A new canal was constructed at Pathri Super passage and most of the water was diverted in this new section of canal which runs about 20 km parallel from Pathri Super passage to Roorkee. The samples were collected before the diversion (control) at Pathri Super passage (S), Pathri Super passage (S_1), Solani Aqueduct (S_2), Dhanuari (S_3), Piran Kaliyar (S_4), Mehawar Kalan (S_5) and Roorkee (S_6). The samples were collected in the plastic containers, brought to the laboratory and were analyzed for various physico-chemical properties viz. temperature, turbidity, total solids (TS), pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), chlorides (Cl^-), calcium (Ca), sodium (Na), potassium (K), magnesium (Mg), total phosphprus, sulphate (SO_4^{2-}), nitrate nitrogen, heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr), iron (Fe), nickel (Ni), lead (Pb), manganese (Mn), zinc (Zn) and microbiological properties like Standard plate count (SPC) and Fecal coliform (FC) following standard methods [2].

2.2. Heavy metals analysis

For heavy metal analysis, 5-10 ml sample of water of canal were taken in digestion tube, added 3.0 ml conc. HNO_3 and digested on electrically heated block for 1 h at 145^o C. Then added 4.0 ml of $HClO_4$ and heated to 240^o C for an additional hour. Cooled and filtered through Whatman # 42 filter paper and makeup volume 50.0 ml and used for analysis following standard methods [2].

2.4. Statistical analysis
Data were analyzed for analysis of variance (ANOVA) to determine the difference between sample characteristics of different sampling stations located at Old Ganga Canal. The mean and standard deviation were also calculated with the help of MS Excel. Water Quality Index (WQI) was calculated following standard method [2].

RESULTS AND DISCUSSION

3.1. Characteristics of old Ganga canal water
The mean ± SD values of hydrological characteristics of Old Ganga Canal water at various sampling stations viz. S, S_1, S_2, S_3, S_4 S_5 and S_6 sampling stations are presented in Table 1.

3.2. Temperature, turbidity and TS
In the present study, the temperature, turbidity and TS of canal water was increased from 14.66 ^oC, 2.36 NTU and 168 mgL^{-1} to 14.85 ^oC, 2.45 NTU and 174 mgL^{-1} at S_1, 14.96 ^oC, 3.79 NTU and 187 mgL^{-1} at S_2, 15.22 ^oC, 4.99 NTU and 224 mgL^{-1} at S_3, 19.68 ^oC, 11.88 NTU and 278 mgL^{-1} at S_4, 19.14 ^oC, 9.74 NTU and 264 mgL^{-1} at S_5, and 18.94 ^oC, 6.88 NTU and 252 mgL^{-1} at S_6 respectively (Table 1). The values of temperature, turbidity and total solid were observed to be significantly (P<0.05) different at all the sampling stations in comparison to the water control. The values of temperature, turbidity and total solids were observed maximum at sampling station S_6 and it is likely due to discharge of untreated sewage in Old Ganga Canal at Piran Kaliyar (S_6) because there is no wastewater treatment facility at Piran Kaliyar. Awomeso et al. reported the drainage of textile effluent increase the total solids and turbidity of Ibeshe stream water in Nigeria. Total solids is not deemed to be associated with health effects, but it is rather used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of presence of a broad array of chemical contaminants [18, 19, 24]. According to Olayinka [18], effluents from textile industries are capable of increasing total solids of water body. Lee and Lin [13] described solids concentration as important characteristic of wastewater.

3.3. pH and EC
Conductivity is the ability of a substance to conduct electricity. The conductivity of water is a more-or-less linear function of the concentration of dissolved ions. It can serve as an indicator of other water quality problems. If the conductivity of a stream suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Therefore, conductivity measurements can be used as a quick way to locate potential water quality problems [6, 7]. The pH is a measure of acidity or alkalinity of water. A pH of 7 is considered to be neutral. Acidity increases as pH values decrease, and alkalinity increases as pH values increase. The pH of water affects the solubility of toxic as well as nutritive chemicals which affect the availability of these substances to aquatic organisms. As acidity increases, most metals become more water soluble and more toxic [21, 22].

In the present study, the pH and EC of the Old Ganga Canal water was increased 7.68 and 2.22 dS m^{-1} at S_1, 7.74 and 2.28 dS m^{-1} at S_2, 7.92 and 2.36 dS m^{-1} at S_3, 8.74 and 4.55 dS m^{-1} at S_4, 8.64 and 4.12 dS m^{-1} at S_5 and 8.26 and 3.40 dS m^{-1} at S_6 respectively from their initial 7.56 and 0.12 dS m^{-1} levels (Table 1). The change in EC were found to be significantly (P<0.05) different while pH was recorded insignificantly (P>0.05) at all the sampling stations from the values noted at the control (S) sampling sites. The maximum pH and EC of the Old Ganga Canal water were observed at sampling stations S_6. The change in pH and EC might be connected with the release of chemicals from agricultural runoff and domestic wastewater discharge in Old Ganga Canal. One of the effects of EC in water is the impacts on the taste of water [17, 37, 38].

3.4. Dissolved oxygen, BOD and COD
Dissolved oxygen (DO) is the most important pollution assessment parameter of the receiving water bodies. Stabilization of organic matter, when discharged untreated or partially treated in receiving waters, leads to depletion of DO [13, 14]. Depletion of DO in natural water reduces its ability to sustain aquatic life. Biochemical oxygen demand (BOD) is a measure of the amount of oxygen that bacteria will consume while decomposing organic matter under aerobic conditions [16, 18]. If effluent with high BOD is discharged into a stream or river, it will accelerate bacterial growth in the river and consume the oxygen levels in the river. Chemical oxygen demand (COD) is a vital test for assessing the quality of effluents and waste waters prior to discharge. The COD test predicts the oxygen requirement to oxidize all organic material into carbon dioxide and water [12, 15].

Table 1. Hydrological characteristics of abandoned Old Ganga Canal at various sampling stations.

Parameters	Before diversion (S)	After diversion Sampling stations						F-calculated	CD
		Pathri Super passage (S_1)	Solani Aqueduct (S_2)	Dhanuari (S_3)	Piran Kaliyar (S_4)	Mehwar Kalan (S_5)	Roorkee (S_6)		
Temperature (^oC)	14.66 ±1.13	14.85a ±1.17	14.96 ±1.08	15.22 ±1.16	19.68a ±1.14	19.14a ±1.15	18.94a ±1.12	2.54^{*}	4.56
Turbidity (NTU)	2.36 ±1.20	2.45a ±0.19	3.79a ±1.05	4.99a ±1.68	11.88a ±3.11	9.74a ±2.23	6.88a ±2.04	5.38^{*}	3.88
TS (mg L^{-1})	168 ±6.97	174a ±7.34	187a ±9.55	224a ±8.12	278a ±7.50	264a ±8.60	252a ±7.98	8.32^{*}	10.54
pH	7.56 ±0.35	7.68 ±0.28	7.74 ±0.17	7.92 ±0.19	8.74 ±0.29	8.64 ±0.24	8.26 ±0.43	0.86^{NS}	0.10
EC (dS m^{-1})	0.12 ±0.05	2.22a ±0.37	2.28a ±0.53	2.36a ±0.76	4.55a ±0.86	4.12a ±0.83	3.40a ±0.77	3.88^{*}	1.21
DO (mg L^{-1})	8.44 ±1.12	8.21 ±1.17	8.05a ±1.08	7.69a ±1.02	4.22a ±1.04	5.82a ±1.03	6.41a ±1.09	22.10^{*}	3.14
BOD (mg L^{-1})	4.55 ±1.23	14.88a ±3.86	25.89a ±4.22	36.67a ±4.56	270.42a ±5.32	220.12a ±6.44	186.71a ±5.11	9.14^{*}	6.89
COD (mg L^{-1})	8.95 ±1.89	24.88a ±2.78	42.64a ±4.13	78.82a ±3.57	289.74a ±3.88	260.25a ±5.45	252.44a ±4.09	66.38^{*}	14.55
Chlorides (mg L^{-1})	87.41 ±2.56	92.86a ±3.52	112.78a ±4.88	136.85a ±3.99	184.67a ±4.57	172.85a ±4.77	160.36a ±3.61	112.85^{*}	6.98
Calcium (mg L^{-1})	142.58 ±2.31	148.75a ±4.20	152.87a ±3.70	162.85a ±5.34	199.64a ±4.50	180.28a ±4.47	178.36a ±5.21	125.37^{*}	7.36
Sodium (mg L^{-1})	26.36 ±2.55	29.88a ±4.67	32.78a ±4.70	45.25a ±3.44	63.85a ±5.00	58.74a ±4.10	52.31a ±5.29	137.28^{*}	9.30
Potassium (mg L^{-1})	18.96 ±1.42	22.54a ±2.50	26.58a ±3.55	39.49a ±2.98	54.87a ±4.01	49.36a ±4.61	44.58a ±3.40	108.74^{*}	5.87
Magnesium (mg L^{-1})	112.36 ±5.30	117.48a ±4.02	124.91a ±4.78	135.82a ±3.90	165.84a ±5.96	162.36a ±3.35	157.28a ±4.16	94.37^{*}	4.21
Total phosphorus (mg L^{-1})	4.34 ±1.12	5.66a ±4.23	7.40a ±3.49	±11.45a ±2.40	42.87a ±2.60	32.75a ±3.51	28.63a ±2.40	11.04^{**}	3.96
Sulphate (mg L^{-1})	124.35 ±3.85	135.40a ±4.45	138.96a ±3.87	162.38a ±5.96	234.55a ±4.46	228.74a ±4.20	210.24a ±3.20	27.24^{**}	10.84
Nitrate nitrogen (mg L^{-1})	0.54 ±0.06	12.28a ±3.77	12.48a ±3.28	26.85a ±2.20	48.85a ±3.47	24.85a ±2.17	18.96a ±2.10	24.57^{**}	7.86
Cadmium (mg L^{-1})	ND	0.14a ±0.04	0.16a ±0.05	0.18a ±0.07	1.12a ±0.08	1.06a ±0.09	0.86a ±0.04	12.44^{**}	0.36
Copper (mg L^{-1})	0.02 ±0.00	1.08a ±0.07	1.15a ±0.08	1.30a ±0.09	1.74a ±0.06	1.62a ±0.07	1.41a ±0.06	101.07^{**}	0.21
Chromium (mg L^{-1})	ND	0.22a ±0.05	0.28a ±0.06	0.36a ±0.07	0.58a ±0.05	0.42a ±0.06	0.40a ±0.08	68.70^{**}	0.09
Iron (mg L^{-1})	0.8 ±0.00	3.47a ±0.24	3.75a ±0.31	4.25a ±0.19	5.69a ±0.22	5.24a ±0.28	5.12a ±0.05	43.59^{**}	0.88
Nickel (mg L^{-1})	ND	1.01 ±0.45	1.06a ±0.09	1.18a ±0.08	1.58a ±0.07	1.35a ±0.06	1.14a ±0.08	34.20^{**}	0.24
Lead (mg L^{-1})	ND	0.30a ±0.05	0.36a ±0.06	0.46a ±0.04	0.64a ±0.09	0.56a ±0.06	0.45a ±0.07	142.36^{**}	0.14

Manganese (mg L^{-1})	0.12 ±0.00	0.14a ±0.07	0.18a ±0.06	0.26a ±0.09	0.36a ±0.07	0.32a ±0.05	0.29a ±0.06	26.47^{**}	0.39
Zinc (mg L^{-1})	0.63 ±0.04	1.42a ±0.03	1.52a ±0.07	1.64a ±0.06	1.87a ±0.03	1.75a ±0.04	1.72a ±0.05	18.94^{**}	0.08
SPC (SPC ml^{-1})	2.3×10^{2} ±31.00	5.3×10^{5a} ±39.00	7.8×10^{6}a ±45.00	6.9×10^{7}a ±56.00	8.5×10^{9}a ±46.00	4.8×10^{8}a ±54.00	9.5×10^{7}a ±39.00	524.87^{***}	36.98
FC (FC 100 ml^{-1})	1.6×10^{2} ±26.00	8.6×10^{6a} ±35.00	9.5×10^{6}a ±40.00	8.6×10^{7}a ±32.00	9.6×10^{8}a ±29.00	6.8×10^{6}a ±44.00	7.6×10^{5}a ±36.00	425.33^{***}	42.87

*Mean ±SD of six values; *, **, ***significantly different to the values before the diversion at P<0.05, 0.01 and 0.001 ANOVA; a-significantly different to the diversion point; CD-critical difference; NS-not significant; ND-not detected.*

Table 2. Water quality index before diversion Old Ganga Canal, Pathri Super passage and Solani Aqueduct sampling stations.

Parameter	Before diversion (S)			Pathri Super passage (S_1)			Solani Aqueduct (S_2)		
	Q-value	Weighting factor	Subtotal	Q-value	Weighting factor	Subtotal	Q-value	Weighting factor	Subtotal
pH	91	0.12	10.95	90	0.12	10.83	90	0.12	10.74
Change in temp	30	0.11	3.28	29	0.11	3.24	29	0.11	3.20
DO	7	0.18	1.23	7	0.18	1.20	7	0.18	1.18
BOD	61	0.12	7.32	21	0.12	2.58	7	0.12	0.86
Turbidity	91	0.09	8.22	91	0.09	8.20	88	0.09	7.93
Total Phosphorus	5	0.11	0.55	5	0.11	0.55	5	0.11	0.55
Nitrate Nitrogen	88	0.10	8.76	10	0.10	1.00	10	0.10	0.96
Total solids	31	0.17	5.26	31	0.17	5.22	30	0.17	5.16
Fecal coliforms	38	0.17	6.43	2	0.17	0.34	2	0.17	0.34
Total		1.17	52.00	-	1.17	33.15	-	1.17	30.92
Water quality index			44.44	-	-	28.33	-	-	26.43
Water quality rating			Bad	-	-	Bad	-	-	Bad

Table 3. Water quality index at Dhanauri and Piran Kaliyar sampling stations at Old Ganga Canal

Parameter	Dhanauri (S_3)			Piran Kaliyar (S_4)		
	Q-value	Weighting factor	Subtotal	Q-value	Weighting factor	Subtotal
pH	24	0.12	2.85	64	0.12	7.73
Change in temp	28	0.11	3.13	20	0.11	2.17
DO	6	0.18	1.14	4	0.18	0.74
BOD	2	0.12	0.24	2	0.12	0.24
Turbidity	85	0.09	7.69	73	0.09	6.57
Total Phosphorus	5	0.11	0.55	5	0.11	0.55
Nitrate Nitrogen	1	0.10	0.10	1	0.10	0.10
Total solids	29	0.17	4.99	28	0.17	4.78
Fecal coliforms	2	0.17	0.34	2	0.17	0.34
Total		1.17	21.04	-	1.17	23.21
Water quality index			17.98	-	-	19.84
Water quality rating			Very Bad	-	-	Very Bad

Table 4. Water quality index at Mehwar Kalan and Roorkee sampling stations at Old Ganga Canal

Parameter	Mehwar Kalan (S_5)			Roorkee (S_6)		
	Q-value	Weighting factor	Subtotal	Q-value	Weighting factor	Subtotal
pH	68	0.12	8.19	80	0.12	9.54
Change in temp	21	0.11	2.26	21	0.11	2.30
DO	5	0.18	0.93	6	0.18	1.11
BOD	2	0.12	0.24	2	0.12	0.24
Turbidity	76	0.09	6.88	82	0.09	7.35
Total Phosphorus	5	0.11	0.55	5	0.11	0.55
Nitrate Nitrogen	1	0.10	0.10	3	0.10	0.27
Total solids	28	0.17	4.83	29	0.17	4.87
Fecal coliforms	2	0.17	0.34	2	0.17	0.34
Total		1.17	24.33	-	1.17	26.58
Water quality index			20.79	-	-	22.71
Water quality rating			Very Bad	-	-	Very Bad

In the present study, DO was decreased 8.21 mgL^{-1} at sampling station S_1, 8.05 mgL^{-1} at S_2, 7.69 mgL^{-1} at S_3, 4.22 mgL^{-1} at S_4, 5.82 mgL^{-1} S_5 and 6.41 mgL^{-1}at S_6 respectively from it initial level 8.44 mgL^{-1}. The maximum decrease in dissolved oxygen was noted at sampling station S_4 and it is likely due to discharge of huge quantity of untreated domestic effluent in Old Ganga Canal. The BOD and COD of the canal water at sampling station S were recorded 4.55 mgL^{-1} and 8.95 mgL^{-1}. The BOD and COD were increased 14.88 mgL^{-1} and 24.88 mgL^{-1} at sampling station S_1, 25.89 mgL^{-1} and 42.64 mgL^{-1} at S_2, 36.67 mgL^{-1} and 78.82 mgL^{-1} at S_3, 270.42 mgL^{-1} and 289.74 mgL^{-1} at S_4, 220.12 mgL^{-1} and 260.25 mgL^{-1} at S_5 and 186.71 mgL^{-1} and 252.44 mgL^{-1} at S_6 sampling stations respectively (Table 1). The dissolved oxygen, BOD and COD were recorded to be significantly ($P<0.05$) different at all the sampling stations in comparison to the control sampling station. High BOD and COD might be due to presence of high oxidizable organic matter and rapid consumption of dissolved inorganic materials. The higher bacterial load (SPC and FC) in textile effluent might be due to presence of more dissolved solids and organic matter in the effluent [23, 24, 34, 35].

The low DO of the stream might be linked directly to high value of nutrients (nitrate and phosphate) observed from the stream with subsequent high coliform populations which might have reduced the DO [5]. This implies that the effluent discharge from the textile industry might have released high oxygen-demanding wastes [4]. Environmental implication of low DO is death of aquatic organisms [4]. High COD in water indicates the presence of biologically resistant organic substances [20]. The elevated values of COD in this study were in line with the study of Olayinka [18] who found a high value of COD in groundwater close to textile effluent discharge. Poor water quality can have an adverse effect on aquatic diversity. Water quality can be adversely affected by pollution; for example, chemicals entering the canals via discharge pipes or seeping from dumped containers. In some locations there are storm water overflows, which in times of severe rain, can on occasions cause an inflow of raw sewage [23, 24, 25]. In addition the impact on water quality of less obvious sources of pollution, particularly diffuse sources, can be considerable. Diffuse pollution sources tend to drain slowly and indiscriminately from farm, residential, industrial or derelict land bordering the canals, reservoirs or their tributaries [16, 29, 30].

3.5. Chlorides, calcium, sodium, potassium and magnesium

The chlorides, calcium, sodium, potassium and magnesium of the canal water at sampling station S were recorded 87.41 mgL^{-1}, 142.58 mgL^{-1}, 26.36 mgL^{-1}, 18.96 mgL^{-1} and 112.36 mgL^{-1} respectively. The values of chlorides, calcium, sodium, potassium and magnesium were increased 92.86 mgL^{-1} 148.75 mgL^{-1}, 29.88 mgL^{-1}, 22.54 mgL^{-1}, and 117.48 mgL^{-1} at sampling station S_1, 112.78 mgL^{-1}, 152.87 mgL^{-1}, 32.78 mgL^{-1}, 26.58 mgL^{-1} and 124.91 mgL^{-1} at S_2, 136.85 mgL^{-1}, 162.85 mgL^{-1}, 45.25 mgL^{-1}, 39.49 mgL^{-1} and 135.82 mgL^{-1} at S_3, 184.67 mgL^{-1}, 199.64 mgL^{-1}, 63.85 mgL^{-1}, 54.87 mgL^{-1} and 165.84 mgL^{-1} at S_4, 172.85 mgL^{-1}, 180.28 mgL^{-1}, 58.74 mgL^{-1}, 49.36 mgL^{-1} and 162.36 mgL^{-1} at S_5 and 160.36 mgL^{-1}, 178.36 mgL^{-1}, 52.31 mgL^{-1}, 44.58 mgL^{-1} and 157.28 mgL^{-1} at S_6 sampling stations respectively (Table 1). The chlorides, calcium, sodium, potassium and magnesium of the canal water were recorded to be significantly ($P<0.05$) different at all the sampling stations in comparison to control. The findings are supported by the authors [17, 18, 19].

3.6. Total phosphorus, nitrate nitrogen and sulphates

The total phosphorus, nitrate nitrogen and sulphates in canal water were 4.34 mgL^{-1}, 0.54 mgL^{-1} and 124.35 mgL^{-1} respectively at S sampling station. The values of total phosphorus, nitrate nitrogen and sulphates were found 5.66

mgL^{-1}, 12.28 mgL^{-1} and 135.40 mgL^{-1} at S_1, 7.40 mgL^{-1}, 12.48 mgL^{-1} and 138.96 mgL^{-1} at S_2, 11.45 mgL^{-1}, 26.85 mgL^{-1} and 162.38 mgL^{-1} at S_3, 42.87 mgL^{-1}, 48.85 mgL^{-1} and 234.55 mgL^{-1} at S_4, 32.75 mgL^{-1}, 24.85 mgL^{-1} and 228.74 mgL^{-1} at S_5 and 28.63 mgL^{-1}, 18.96 mgL^{-1} and 210.24 mgL^{-1} at S_6 sampling stations. The values of total phosphorus, nitrate nitrogen and sulphate were significantly ($P<0.01$) different at all the sampling sites in comparison to the control (Table 1). Effluent discharge generally adds significant quantities of salts such as sulfates, phosphates, bicarbonates, chlorides of sodium, calcium, potassium and magnesium to the aquatic environment [23, 24]. Over time, silt gathers on the canal bed. This combined with submerged rubbish thrown into canals and general debris tends to reduce the navigable depth [26, 27]. Dredging operations remove this and hence improve the canals for navigation. This aims to improve the benthic habitat for wildlife, and also to increase the water's aesthetic appearance. Higher content of N and P in wastewater increase the aquatic weeds species in the canal and can also physically impede water-flow [18, 19, 20].

3.7. Heavy metals

The heavy metals are at very low concentrations in the natural environment. They are introduced to surface waters as waste by human activities. Some of the metals of concern for human and aquatic health are cadmium, lead, copper, mercury, selenium, and chromium etc. The content of Cu, Fe, Mn and Zn were recorded 0.02 mgL^{-1}, 0.08 mgL^{-1}, 0.12 mgL^{-1}, and 0.63 mgL^{-1} respectively while Cd, Cr, Ni and Pb were not detected in canal water at control sampling station. The values of these metals were increased Cd (0.14 mgL^{-1}), Cu (1.08 mgL^{-1}), Cr (0.22 mgL^{-1}), Fe (3.47 mgL^{-1}), Ni (1.01 mgL^{-1}), Mn (0.14 mgL^{-1}), Pb (0.30 mgL^{-1}) and Zn (1.42 mgL^{-1}) at S_1sampling station, Cd (0.16 $mg\ L^{-1}$), Cu (1.15 mgL^{-1}), Cr (0.28 mgL^{-1}), Fe (3.75 mgL^{-1}), Ni (1.06 mgL^{-1}), Mn (0.18 $mg\ L^{-1}$), Pb (0.36 mgL^{-1}) and Zn (1.52 mgL^{-1}) at S_2, Cd (0.18 mgL^{-1}), Cu (1.30 $mg\ L^{-1}$), Cr (0.36 mgL^{-1}), Fe (4.25 mgL^{-1}), Ni (1.18 mgL^{-1}), Mn (0.26 $mg\ L^{-1}$), Pb (0.46 $mg\ L^{-1}$) and Zn (1.64 mgL^{-1}) at S_3, Cd (1.12 mgL^{-1}), Cu (1.74 mgL^{-1}), Cr (0.58 mgL^{-1}), Fe (5.69 mgL^{-1}), Ni (1.58 mgL^{-1}), Mn (0.36 mgL^{-1}), Pb (0.64 mgL^{-1}) and Zn (1.87 mgL^{-1}) at S_4, Cd (1.06 mgL^{-1}), Cu (1.62 mgL^{-1}), Cr (0.42 mgL^{-1}), Fe (5.24 mgL^{-1}), Ni (1.35 mgL^{-1}), Mn (0.32 mgL^{-1}), Pb (0.56 mgL^{-1}) and Zn (1.75 mgL^{-1}) at S_5 and Cd (0.86 $mg\ L^{-1}$), Cu (1.41 mgL^{-1}), Cr (0.40 mgL^{-1}), Fe (5.12 mgL^{-1}), Ni (1.14 mgL^{-1}), Mn (0.29 $mg\ L^{-1}$), Pb (0.45 mgL^{-1}) and Zn (1.72 mgL^{-1}) at S_6 respectively. The metal contents increased significantly ($P<0.01$) in sub canal water at all the sampling sites after discharge of textile effluent (Table 1). The content of metals was observed to be significantly ($P<0.01$) different at all the sampling stations. Health implications of high concentration of lead include anemia, kidney damage and cerebral edema [6, 8]. Chromium, zinc and potassium values lie within the permissible limits [24, 25, 26] as given by Yusuff and Sonibare [25, 26]. Sekhar et al. and Vinod and Chopra [21, 23, 24] have correlated heavy metal contamination to industrial effluent discharge. Urbanization and population growth in Piran Kaliyar a pilgrim city has rapidly increased in the volumes of wastewater generated in the region to about 20,000 $m^3\ day^{-1}$. Since there is no proper wastewater disposal system, untreated domestic sewage is released directly into the canal. Canal receives wastewaters from small scale industries such as commercial laundries, textile dyeing operations, hospital, the slaughterhouse, and miscellaneous dischargers such as petroleum and other oily waste from motor vehicle workshops. Furthermore, since the canal is topographically situated at a low elevation, a large number of side canals drain into the Mid-canal with their heavy pollutant loads [36, 37, 38].

3.8. SPC and FC

Bacterial parameters, such as fecal coliform and standard plate count which serve as indicators of fecal pollution were studied. The SPC and FC in unpolluted canal water were found 2.3×10^2 SPC $ml^{-1}$and 1.6×10^2 FC100 ml^{-1}. Their values increased in water to 5.3×10^5 SPC $ml^{-1}$and 8.6×10^6 FC100 ml^{-1} at S_1 sampling station, 7.8×10^6 SPC $ml^{-1}$and 9.5×10^6 FC100 ml^{-1} at S_2, 6.9×10^7 SPC $ml^{-1}$and 8.6×10^7 FC100 ml^{-1} at S_3, 8.5×10^9 SPC $ml^{-1}$and 9.6×10^8 FC100 ml^{-1} at S_4, 4.8×10^8 SPC $ml^{-1}$and 6.8×10^6 FC100 ml^{-1} at S_5 and 9.5×10^7 SPC $ml^{-1}$and 7.6×10^5 FC100 ml^{-1} at S_6 sampling stations respectively. The values of SPC and FC were noted to be significantly ($P<0.001$) different at all the sampling stations in comparison to control sampling station (Table 1). The presence of FC in Old Ganga Canal water is an indication of contamination by human sewage or animal droppings which could contain disease-causing organisms [37, 38].

4. Water quality index (WQI)

Water quality index is a 100 point scale that summarizes results from a total of nine different measurements like temperature, turbidity, total solids, pH, dissolved oxygen, biochemical oxygen demand, nitrate nitrogen, total phosphorus and fecal coliform. The 100 point index can be divided into several ranges viz. excellent (90-100), good (70-90), medium (50-70), bad (25-50) and very bad (0-25). In the present study, the WQI rating of Old Ganga Canal water was of bad (44.44) at sampling station S, and it declined to bad (28.33) at S_1, bad (26.43) at S_2, bad (19.84) at S_3, very bad (17.98) at S_4, very bad (20.79) at S_5 and very bad (22.71) at sampling station S_6 (Table 2, 3, 4).

CONCLUSION

It was concluded that Old Ganga Canal has high chemical and biological contaminants in terms of physico-chemical and microbiological parameters. Drainage of domestic wastewater considerably increased the physico-chemical, microbiological characteristics and metal contents viz. TS, EC, pH, BOD, COD, Cl^-, Ca, Na, K, Mg, total phosphorus, nitrate nitrogen, SO_4^{2-}, Cd, Cu, Cr, Fe, Mn, Ni, Pb, Zn, SPC and FC of canal water. The study suggested that the wastewater being discharged into the canal by the localities have considerable negative effects on the water quality of canal and the water is not good for human consumption and ecological health of canal. WQI showed that the canal water quality changed bad to very bad after discharge of wastewater. Thus, domestic wastewater and agricultural runoff deteriorates the water quality of Old Ganga Canal which is an ultimate source of potable and irrigation water as well. It is therefore recommended that the wastewater from different localities especially from Piran Kaliyar should be treated before being disposed into the canal. Further investigation is required on the water quality of Old Ganga Canal and its impact on ecological components.

REFERENCES

[1] D Absalon, M Matysik, *Geomorphology*, **2007**, 92(3–4), 106–118.
[2] APHA. In: *Standard Methods for the Examination of Water and Wastewater.* 21st Ed. Washington, DC. **2005**, 1368.
[3] PT Cautley. In: Ganges canal. London. **1864**.
[4] CPCB. Status of sewage treatment plants in the Ganga Basin, **2007**.
[5] MOEF. Status of River Ganga: State of Environment & Water Quality, **2009**.
[6] JA Awomeso, AM Taiwo, AM Gbadebo, JA Adenowo, *J. Appl. Sci. Environ. Sanit.*, **2010**, 5 (4), 353-359.
[7] G Chapelle, E Petts, *Oikos*, **2004**, 612-623.
[8] S D'Amelio. Preliminary water quality at Springbank Dam, Thames river, London, Ontario. Trout Unlimited Canada Technical report no. ON-020. **2007**, 7-11.
[9]. ABM Egborge. Industrialization and heavy metal pollution in Warri River, University of Benin Press, Inaugural lecture series, **1991**, 32.
[10] V Emongor, E Kealotswe I Koorapetse S Sankwasa, S Keikanetswe, *J. Appl. Sci.*, **2005**, 5, 147-150.
[11] Federal Environmental Protection Agency (FEPA). Water Quality, Federal Water Standards, Guidelines and Standard for Environmental Pollution Control in Nigeria, National Environmental Standards – Part 2 and 3, Government Press, Lagos, **1991**, 238.
[12] FM Howari, KM Banat, *J. Hydrol Hydromech.*, **2002**, 50(1), 50.
[13] MO Jaji, O Bamgbose, OO Odukoya, TA Arowolo, *Environ. Monit. Assess.*, **2007**, 133, 473–482.
[14] Jaya Rathore, *Int. J. Env. Sci.*, **2011**, 2 (2), 560-568.
[15] AR Khwaja, Rashmi Singh, S.N. Tandon, *Environ. Monit. Assess.*, **2001**, 68**,**19–35,
[16] CC Lee, SD Lin. Handbook of Environmental Engineering Calculations, McGraw Hill, New York. **1999**, 1504.
[17] B Lloyd, R. Helmer. Surveillance of drinking water quality in rural areas Longman Scientific and Technical. New York: Wiley, **1992**, 34–56.
[18] AS Mathuthu, FM Zaranyika, SB Jonnalagadda, *Environ. International*, **1993**, 19, 51–61.
[19] VV Morokov, *Journal of Water Res.*, **1987**, 14, 1027–1041.
[20] AA Olajire, FE Imeokparia, *Environ. Monit. Assess.*, **2001**, 69, 17–28.
[21] KO Olayinka, *Nigerian J. Health and Biomedical Sci.*, **2004**. 3, 44-50.
[22] KP Singh, A Malik, S Sinha, *Analytica Chimica Acta*, **2005**, 538(1–2), 355–374.
[23] CC Sawyer, PL McCarty. Chemistry for Environmental Engineers, McGraw Hill, New York, **1978**, 331–514.
[24] KC Sekhar, NS Chary, CT Kamala, JV Rao, V Balaram, Y Anjaneyuly, *Environ. International*, **1993**, 29, 601–611.
[25] V Simeonov, JA Stratis, C Samara, G Zachariadis, D Voutsa, A Anthemidis, *Water Res.*, **2003**, 37(17), 4119–4124.
[26] Vinod Kumar, AK Chopra, *J. Chem. Pharm. Res.*, **2011**, 3(6), 7-22.
[27] Vinod Kumar, AK Chopra, *J. Environ. Sci. Technol.*, **2012**, 5 (2), 109-118.
[28] Vinod Kumar, AK Chopra, RK Chauhan, *J. Chem. Pharm. Res.*, **2012**, 4(9), 4206-4211.
[29] World Health Organisation, World Health Organization's Guidelines for Drinking water, Vol. 1, Geneva. **1998**.

[30] World Health Organisation, Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture, *Technical Report Series* **1989**, 778.
[31] M Johannessen, A Henriksen, *Water Resources Research*, **1978**, 14, 615-619.
[32] S Krishnaswami, Sunil K Singh, *Current Science*, **2005**, 89.
[33] J Alan, R Ferrier, D Waters, *Hydrological Processes*, **1993**, 7, 193-203.
[34] SK Pandey, AK Singh, SI Hasnain, *J. Aquatic Geochem.*, **1999**, 5, 357-379.
[35] N Semwal, JS Jangwan, *Int. J. Chem. Sci.*, 2009, 7(2), 607-616.
[36] V Bhardwaj, DS Singh, AK Singh, *Environ. Earth Sci.*, **2009**, 59(5), 1099–1109.
[37] S Kumar, IB Singh, M Singh, DS Singh, *J. Geol. Soc. India*, **1995**, 46 545–555.
[38] PK Rai, A Mishra, BD Tripathi, *Aquatic Ecosystem Health and Management*, **2010**, 13 352–361.