SATEM-2019 Special Issue

J. Indian Chem. Soc.,
Vol. 97, April 2020, pp. 577-586

Evaluating volatility in quality indexing of saline water during tidal backwater incursion in Western Canals of South 24-Parganas, West Bengal

Prasun Mukherjee*, Subhasish Das and Asis Mazumdar

School of Water Resources Engineering, Jadavpur University, Kolkata-700 032, India

E-mail: mukherjeeprasun3@gmail.com, subhasishju@gmail.com, asism.ju@gmail.com

Manuscript received online 18 December 2019, accepted 18 March 2020

Nearly 51% of the population in the western basins of South 24-Parganas districts of West Bengal, India is dependent on the canal network for agricultural purposes. Irrigation water supply by utilizing tidal backwater incursion offers an economical and potent approach to utilize the superfluous freshwater at the Hooghly River mouth which would else be untapped and flow to the Bay of Bengal. This escalates the risk of saltwater intrusion in the canal network during lean water periods. The study aims at the assessment of the extent of saline water intrusion and the volatility of water quality index of the canals due to the tidal water ingress. The study further intents to identify risk zones within the canal network in accordance to the analysis for sustainable management of the canal network and to further increase the serviceability of the canals during lean periods.

Keywords: Saltwater intrusion, water quality index, irrigation, tidal backwater, South 24-Parganas.

Introduction

Tidal backwater is an occurrence usually observed at the downstream of a river. The properties of tidal backwater are contingent on meteorological, astronomical, surface gradient and the hydrodynamic pattern of the stream. Amalgamation of tidal backwater and autochthonous riverine discharge create water level disparities which can be utilized for irrigation facilities by excavating tidal canals that will escort water from the riverbanks to the inland regions at high tide. Sluice gates need to be fabricated at the canal inlets so as to be opened at high tide, allowing water to enter the irrigation canals. The sluice gates need to be opened for a definitive time period reliant on the catchment area to be irrigated. The only major shortcoming in this otherwise sustainable and inexpensive process of irrigation includes a prodigious risk of saline water intrusion in the canal networks.

The western basins of South 24-Parganas district of West Bengal, India, require augmentation of irrigation water from canal network due to the erratic distribution of rainfall in the catchment region. The statistical analysis shows a steep dependency rate of nearly 51% of the agricultural laborers on canal irrigation. The canal network of the region is predominantly dependent on the tidal backwater of Hooghly River as its primary source of water. This increases the probability of saline water intrusion via tidal backwater ingress in the canal network. Research on the aspects of saline water intrusion in the region has been limited. Few reseachers confimed the existance of saline water intrusion in southern coastal areas of West Bengal[1–3]. The influence of salinity intrusion in the Piyali River basin (east of the study area) was examined by the analysis of soil samples along the stretch of the stream[4,5]. Rather a quantitative analysis was examined performed on the tidal backwater irrigation characteristics of Magrahat basin which constitutes a fragment of the current study area[6]. The central objective of the study is to ascertain the extent of penetration of saline water within the canal network. In the region the canals serve a two-fold purpose of drainage network and irrigation water supply in the region.

Water Quality Index (WQI) is extensively utilized by environmental planning and decision makers. The need for assessment of irrigation water quality was emphasized to circumvent the adverse impact on agricultural produce[7]. The use of low quality water for irrigation is a significant reason for the declining soil quality and agricultural produce cultivating on such soil[8]. Horton pioneered the concept of indices for representing gradations in water quality[9]. A single figure cannot convey the wider spectrum of water quality. Nevertheless, WQI was established on significant parameters provide a definitive indicator of irrigation water quality[10]. The present study advances on the prior notion intends to scrutinize not only the WQI but also different water quality parameters like pH, total dissolved solids, electrical conductivity, alkalinity, dissolved oxygen and the comparative analysis of the impact of tidal backwater ingress on the water quality of the canals.

Study area

The study area is spread along 11 blocks of the South 24-Parganas district of West Bengal (Fig. 1). Located in the east of Hooghly River, the area is a beneficiary of tidal backwater irrigation facilities supplemented by a network of canals within the region. The catchment areas selected for the study are:

(1) Keorapukur basin, (2) Kholakhali basin, (3) Magrahat basin,(4) Kulpi basin, (5) Hara-Hatuganj basin.

A detailed map has been adjoined in Fig. 1. The canals selected for the study are:

(1) Upper Keorapukur Khal, (2) Lower Keorapukur Khal, (3) Hotor Khal, (4) Suryapur Inner Channel, (5) Usti Nainan Outfall Channel, (6) Kata Khal, (7) Sangrampur Khal, (8) Upper Joynagar Khal, (9) Upper Dhanpota Khal, (10) Hara Khal, (11) Kulpi Khal, (12) Upper Hatuganj Khal, (13) Nazra Khal, (14) Srichanda Khal, (15) Dasani Khal, (16) Diamond Harbour Creek, (17) Kholakhali Khal, (18) Adi Ganga Canal, (19) Lower Dhanpota Khal, (20) Lower Hatuganj Khal.

Materials and methods

The following study focuses on the study of water quality before and after the influx of tidal water into the canals so as to understand the basic physical physicochemical parameters of the water available for irrigation in the irrigation network. The comparison also helps to analyze the effect of the introduction of tidal water into the irrigation network. This analytical comparison gives an overall perspective on the suitability of the water for the purpose of irrigation in the study area.

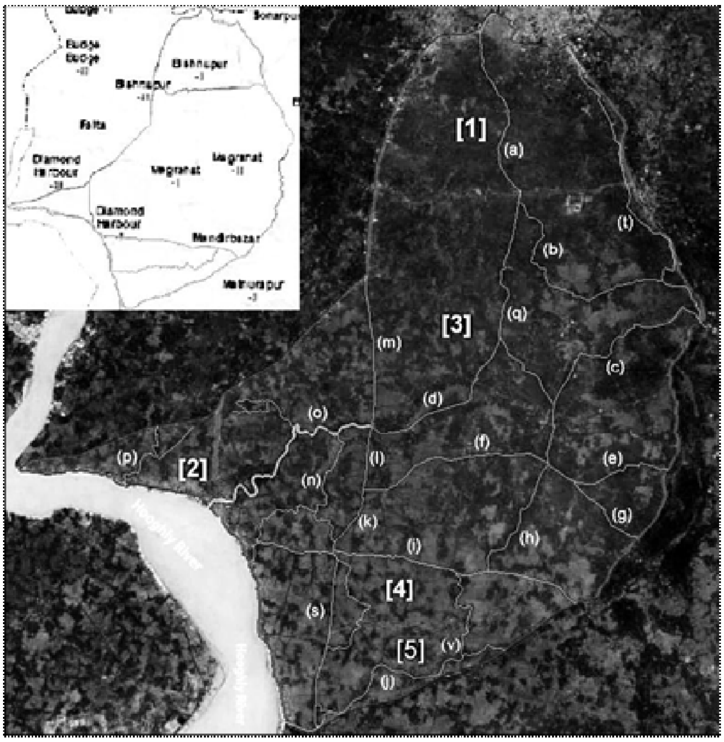

Fig. 1. Study area.

For the analysis of water quality, the study area was identified as a set of five catchment areas as mentioned before. The canals under study were demarcated to identify collection points within each canal. Global co-ordinate position of every sampling location was logged using Etrex10 Handheld GPS manufactured by Garmin. The water quality parameters were selected according to IS 11624: 1984[11], guidelines for the quality of irrigation water.

Field trips were conducted during the lean periods of November (2018), December (2018), January (2019), February (2019). The sampling of the canals was done in high tide and ebb periods at 53 locations within the canal network covering at least the inlet and outlet of each canal.

Temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO) and salinity parameters were measured on site, in before tide (BT) and after tide (AT) conditions using multi-parameter water quality meter field instruments. The alkalinity of the water was ascertained according to the guidelines of IS 3025 Part 23[12].

Results and discussion

The measurements were performed before and after the influx of tidal water and the results are shown in tabular format. A tabular representation has been done to easily compare and indicate the changes in the values before and after the tidal water influx.

A classification guideline had been suggested by Food and Agriculture Organization (FAO) of the United Nations (UN) for the ease of assessment of salinity levels of a certain water sample as shown Table 1. Water salinity conditions of

Table 1. Classification of saline water

Water class	Salt concentration (ppm)
Non-saline	< 500
Slightly saline	500–1500
Moderately saline	1501–7000
Highly saline	7001–15000
Very highly saline	15001–35000
Brine	>35000

and above highly saline class is strictly unsuitable for irrigational purposes. Only genetically morphed or very tolerant crops (barely any type of organic conventional crops) can be effectively cultivated with waters with moderately saline water conditions. Although the use of slightly saline water in crop production has been associated with stunted crop or reduced crop yield slightly saline water can also be used for the purpose of crop production in case of scarcity of water condition. Non-saline water conditions with salinity levels below 500 ppm remain the ideal parameter for crop cultivation.

The study shows that the ingress of tidal backwater within the canal network increases the average salinity of the canals. The major entry points at Kholakhali Sluice (P1), Diamond Harbour Sluice (O1), Hara Sluce (H1) and Kulpi Sluice (J1) have an average classification of moderately saline water, which decreases gradually as the water flows inland with relatively less change in salinity before and after tidal water ingress as shown in Table 2. A certain anomaly noted in this case is the slight increase of salinity further south-east of the

Table 2. Salinity analysis before and after tidal ingress

Canal name	Pt.	No.	Salinity (ppm)			Classification
			Before tide	After tide	Average	
Upper Keorapukur Khal	A	1	372	430	401	Non-saline
		2	403	486	445	Non-saline
Hotor Khal	B	1	269	350	310	Non-saline
		2	199	280	240	Non-saline
		3	144	200	172	Non-saline
		4	48	100	74	Non-saline
Suryapur Inner Channel	C	1	128	210	169	Non-saline
		2	298	350	324	Non-saline
		3	325	400	363	Non-saline
		4	480	540	510	Slightly saline

Table-2 (contd.)

Usti Nainan Outfall Channel	D	1	2118	2190	2154	Moderately saline
		2	463	540	502	Slightly saline
Kata Khal	E	1	845	930	888	Slightly saline
		2	979	1040	1010	Slightly saline
Sangrampur Khal	F	1	576	630	603	Slightly saline
		2	1022	1080	1051	Slightly saline
Joynagar Khal	G	1	776	840	808	Slightly saline
		2	1011	1090	1051	Slightly saline
Upper Dhanpota Khal	H	1	640	700	670	Slightly saline
		2	499	560	530	Slightly saline
Hara Khal	I	1	4121	4180	4151	Moderately saline
		2	2259	2340	2300	Moderately saline
		3	970	1050	1010	Slightly saline
		4	795	870	833	Slightly saline
		5	905	980	943	Slightly saline
Kulpi Khal	J	1	4874	4940	4907	Moderately saline
		2	3133	3210	3172	Moderately saline
		3	1876	1930	1903	Moderately saline
		4	1179	1240	1210	Slightly saline
		5	1517	1570	1544	Moderately saline
Upper Hatuganj Khal	K	1	1897	1980	1939	Moderately saline
		2	989	1060	1025	Slightly saline
Nazra Khal	L	1	2363	2430	2397	Moderately saline
		2	1855	1940	1898	Moderately saline
Srichanda Khal	M	1	1663	1740	1702	Moderately saline
		2	791	870	831	Slightly saline
Dasani Khal	N	1	2366	2450	2408	Moderately saline
		2	1179	1230	1205	Slightly saline
		3	3405	3490	3448	Moderately saline
		4	1558	1630	1594	Moderately saline
		5	2065	2150	2108	Moderately saline
Diamond Harbour Creek	O	1	3882	3940	3911	Moderately saline
		2	2916	2970	2943	Moderately saline
Kholakhali Khal	P	1	2035	2100	2068	Moderately saline
		2	1366	1430	1398	Slightly saline
		3	1070	1150	1110	Slightly saline
Lower Keorapukur Khal	Q	1	367	418	393	Non-saline
		2	327	405	366	Non-saline
		3	367	430	399	Non-saline
		4	340	397	369	Non-saline
Lower Hatuganj Khal	S	1	2008	2070	2039	Moderately saline
		2	3007	3070	3039	Moderately saline
Adi Ganga Canal	T	1	327	386	357	Non-saline
		2	310	394	352	Non-saline
Lower Dhanpota Khal	V	1	1028	1110	1069	Slightly saline
		2	613	670	642	Slightly saline

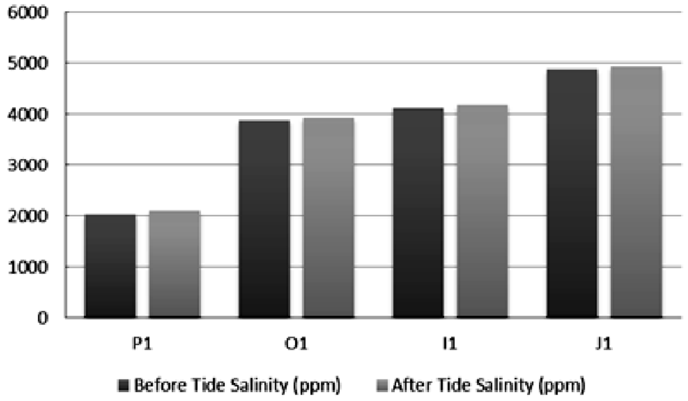

Fig. 2. Salinity conditions of ingress junctions.

study area as the salinity tends to slightly increase. This phenomenon is in all probability could be caused due to influx of water from the Piyali River. The water has a tendency to flow roughly 15 km inland (east) before shifting it's classification from moderately saline to slightly saline conditions, and further 11 km to convert to non-saline conditions from being slightly saline. It is also noted that salinity of water at southern tidal ingress junctions is more than the northern ingress junctions, as is being depicted in Fig. 2.

The rapidly growing demand for food supplies by the hastily growing population has caused the exploitation of water resources. Degradation of irrigation water quality effects the crop growth, development and yield. Higher EC impact the osmotic pressure of water and in turn distress the capability of the crops to absorb water through its roots. Adetailed evaluation of water quality before its use in irrigation purposes will aid in arresting the harmful effects on crop productivity. Owing to the utilization of low quality water the agricultural farmland gets hugely affected and affects the harvesting yield in several ways. Henceforth, the assessment of water quality has become an important aspect in the highly sensitive matter of irrigation water supply.

Nine water quality parameters were temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), alkalinity, dissolved oxygen (DO), DO Saturation (%), and Water Quality Index (WQI). The pH values determine the overall acidity or basicity of the water. It can be used as an indicator to determine the type of matter present in water. A lower pH value usually indicates the presence of organic waste in the water. The pH range in the canal network varied from 6.1–7.9. The TDS value had a wide range of 180–4469 ppm in before tide conditions and 158–4727 ppm in the after tide conditions. The tidal water ingress although improved the water quality in the immediate canals streams, the further inflow into the canal network increased the TDS. This is majorly due to surge created by the tidal ingress which drives the accumulation of solids inland. The EC values in the canal network ranges from 124–8645 mS/cm in before tide conditions to a range of 243–8753 mS/cm in the after tide conditions. The overall rise is average EC is predominantly due to the intrusion of saltwater in the canals. Although at several places in canals coinciding with sub-urban settlement have noted to have a relatively higher EC value even when the salinity is not alarming. This phenomenon is predominantly due to effects of pollution from external sources within the region. Alkalinity specifies the existence of carbonates and bicarbonates within the water sample. The alkalinity of the water ranges from 24–1389 during before tide conditions and 47–1407 in the after tide conditions. The DO and DO Saturation (%) values range from 1–7.8 ppm and 12.1–94.47 respectively in before tide conditions.

The DO and DO Sat (%) values range from 1.81–8.29 ppm and 21.53–98.59 respectively in the after tide conditions. The values clearly denote a steep improvement in the oxygen content in the water after the ingress of tidal backwater in the canal network. The detailed values have been presented for ease of understanding in tabular format in Table 3.

WQI is an important parameter calculated as a singular value determined from several other parameters. The WQI

Table 3. Water quality parameters

Canal name	Pt.	No.	pH		TDS		EC		Alkalinity (ppm)		DO (ppm)		DO saturation (%)	
			BT	AT	BT	AT	BT	AT	BT	AT	BT	AT	BT	AT
Upper Keorapukur Khal	A	1	6.5	6.4	560	640	812	928	167	191	1.2	2.09	14.53	24.86
		2	7.3	7.2	542	644	874	1038	161	192	5.7	6.52	69.04	77.54
Hotor Khal	B	1	7.2	7.5	446	568	603	768	133	169	3.2	3.94	38.76	46.86
		2	7.5	7.4	320	438	457	625	95	130	4.8	5.5	58.14	65.41
		3	7.3	7.2	234	317	339	459	70	94	5.3	5.99	64.19	71.24
		4	7.4	7.5	180	158	124	243	24	47	6.1	6.75	73.88	80.28
Suryapur Inner Channel	C	1	7.8	7.8	219	346	305	480	65	103	4.6	5.32	55.71	63.27
		2	7.2	7.8	437	507	662	768	130	151	6.7	7.36	81.15	87.53
		3	7.5	7.7	459	556	717	868	137	165	7.4	8.04	89.63	95.62
		4	7.6	7.6	678	755	1027	1144	202	225	4.9	5.56	59.35	66.12
Usti Nainan Outfall Channel	D	1	7.8	7.2	3335	3439	4018	4144	993	1024	5.2	6.03	62.98	71.71
		2	7.3	7.4	606	698	993	1144	180	208	6.1	6.71	73.88	79.8
Kata Khal	E	1	7.7	7.7	1243	1358	1727	1886	370	404	6.5	7.22	78.73	85.87
		2	7.4	7.4	1463	1546	1977	2090	435	460	5.7	6.44	69.04	76.59
Sangrampur Khal	F	1	7.6	7.7	850	923	1214	1318	253	275	5.2	5.9	62.98	70.17
		2	6.4	7.4	1337	1406	2056	2163	398	419	7.3	7.95	88.42	94.55
Joynagar Khal	G	1	7.8	7.5	1213	1305	1597	1717	361	388	5.4	6.16	65.40	73.26
		2	7.5	7.5	1099	1178	2036	2182	327	351	5.9	6.44	71.46	76.59
Upper Dhanpota Khal	H	1	7.8	7.3	923	1002	1337	1452	275	298	3.6	4.29	43.6	51.02
		2	7.1	7.2	734	816	1064	1183	218	243	3.4	4.09	41.18	48.64
Hara Khal	I	1	7.6	7.6	4594	4654	7409	7507	1367	1385	7.6	8.22	92.05	97.76
		2	7.4	7.5	3027	3127	4264	4404	901	931	6.8	7.51	82.36	89.32
		3	7.4	7.3	1372	1476	1960	2108	408	439	5.5	6.2	66.62	73.97
		4	7.5	7.6	1143	1241	1632	1773	340	369	3.1	3.8	37.55	45.19
		5	7.2	7.4	1030	1108	1839	1979	306	330	6.2	6.76	75.09	80.4
Kulpi Khal	J	1	7.8	7.2	4669	4727	8645	8753	1389	1407	7.5	8.04	90.84	95.62
		2	7.4	7.3	3052	3121	5759	5889	908	929	6.9	7.43	83.57	88.36
		3	7.4	7.5	2336	2398	3594	3689	695	714	3.2	3.85	38.76	45.79
		4	7.2	7.2	1618	1695	2345	2456	482	504	3.3	3.99	39.97	47.45
		5	7.9	7.4	1774	1831	2957	3051	528	545	5.1	5.7	61.77	67.79
Upper Hatuganj Khal	K	1	7.6	7.6	2614	2719	3631	3777	778	809	2.6	3.3	31.49	39.01
		2	6.1	7.8	1516	1616	1995	2127	451	481	3.5	4.3	42.39	50.54

Table-3 (contd.)

Nazra Khal	L	1	7.4	7.3	2844	2918	4444	4559	846	868	6.90	7.54	83.57	89.67
		2	7.5	7.2	2241	2335	3557	3707	667	695	5.1	7.5	61.77	89.32
Srichanda Khal	M	1	6.9	6.3	2188	2281	3217	3354	651	679	5.9	6.78	71.46	80.63
		2	7.6	7.4	1121	1224	1625	1773	334	364	1.0	1.9	12.11	22.48
Dasani Khal	N	1	7.5	7.6	2803	2894	4449	4594	834	861	6.5	7.13	78.73	84.8
		2	7.4	7.2	1618	1682	2345	2438	482	501	7.2	7.89	87.21	93.83
		3	7.3	7.5	3668	3752	6217	6360	1092	1117	6.1	6.69	73.88	79.56
		4	6.3	6.2	2121	2211	3030	3159	631	658	4.3	5	52.08	59.46
		5	7.2	6.1	2670	2770	3926	4074	794	825	3.6	4.28	43.60	50.90
Diamond Harbour Creek	O	1	7.3	7.2	4348	4408	7013	7110	1294	1312	6.8	7.42	82.36	88.25
		2	7.2	7.1	3289	3345	5391	5483	979	995	7.4	8.01	89.63	95.26
Kholakhali Khal	P	1	7.8	7.5	2285	2352	3873	3987	680	700	7.8	8.29	94.47	98.59
		2	7.4	7.2	1611	1680	2685	2800	479	500	6.6	7.2	79.94	85.63
		3	7.6	7.3	1394	1490	2145	2292	415	443	4.3	6.4	52.08	76
Lower Keorapukur Khal	Q	1	7.3	7.6	521	588	802	904	155	175	6.2	6.85	75.09	81.47
		2	7.8	7.2	447	544	721	878	133	162	5.4	6.02	65.40	71.60
		3	7.8	7.3	505	585	802	928	150	174	5.3	5.93	64.19	70.52
		4	7.4	7.7	479	552	748	862	142	164	6.7	7.34	81.15	87.29
Lower Hatuganj Khal	S	1	7.4	7.6	2257	2321	3826	3934	672	691	5.8	6.39	70.25	76
		2	7.6	7.8	3161	3222	5546	5652	941	959	6.4	6.97	77.52	82.89
Adi Ganga Canal	T	1	6.6	6.5	361	420	721	840	107	125	1.02	1.93	12.35	22.95
		2	7.5	7.6	598	745	687	856	178	222	2.34	3.21	28.34	38.18
Lower Dhanpota Khal	V	1	6.8	6.3	1819	1952	2067	2219	541	581	1.03	1.91	12.48	22.72
		2	7.4	7.4	964	1046	1285	1395	287	311	1.06	1.81	12.84	21.53

was calculated using JavaScript webmaster software developed by Oram Brian and the results acquired for each point is reported in tabular format in Table 5. WQI values range from 0–100, of which 0 is the lowest quality and 100 being excellent quality. WQI ranges have been further classified from poor to excellent according to the values obtained as shown in Table 4. The average water quality index of the canals improved at least one class for majority of the points after the influx of tidal backwater.

Table 4. Water quality index legend

Range	Classification
81–100	Excellent
71–80	Very good
61–70	Good
51–60	Fair
41–50	Average
31–40	Below average
0–30	Poor

Table 5. Water Quality Index before and after tidal ingress

Canal name	Pt.	No.	WQI before tide	Classification	WQI after tide	Classification
Upper Keorapukur Khal	A	1	30	Poor	31	Below avg.
		2	59	Fair	64	Good
Hotor Khal	B	1	45	Average	45	Average
		2	58	Fair	59	Fair
		3	63	Good	65	Good
		4	72	Very good	72	Very good
Suryapur Inner Channel	C	1	57	Fair	58	Fair
		2	67	Good	64	Good
		3	69	Good	67	Good
		4	51	Fair	56	Fair
Usti Nainan Outfall Channel	D	1	54	Fair	59	Fair
		2	61	Good	64	Good
Kata Khal	E	1	63	Good	64	Good
		2	59	Fair	62	Good
Sangrampur Khal	F	1	53	Fair	58	Fair
		2	61	Good	68	Good
Joynagar Khal	G	1	55	Fair	60	Fair
		2	61	Good	61	Good
Upper Dhanpota Khal	H	1	43	Average	47	Average
		2	42	Average	46	Average
Hara Khal	I	1	68	Good	67	Good
		2	65	Good	66	Good
		3	57	Fair	61	Good
		4	42	Average	44	Average
		5	61	Good	63	Good
Kulpi Khal	J	1	68	Good	68	Good
		2	65	Good	66	Good
		3	42	Average	44	Average
		4	41	Average	46	Average
		5	52	Fair	57	Fair
Upper Hatuganj Khal	K	1	38	Below avg.	42	Average
		2	36	Below avg.	46	Average
Nazra Khal	L	1	65	Good	67	Good
		2	54	Fair	67	Good

Table-5 (contd.)

Srichanda Khal	M	1	58	Fair	55	Fair
		2	33	Below avg.	36	Below avg.
Dasani Khal	N	1	64	Good	64	Good
		2	66	Good	68	Good
		3	61	Good	63	Good
		4	42	Average	44	Average
		5	44	Average	38	Below avg.
Diamond Harbour Creek	O	1	65	Good	66	Good
		2	66	Good	66	Good
Kholakhali Khal	P	1	67	Good	68	Good
		2	64	Good	65	Good
		3	49	Average	61	Good
Lower Keorapukur Khal	Q	1	62	Good	63	Good
		2	58	Fair	60	Fair
		3	54	Fair	60	Fair
		4	67	Good	65	Good
Lower Hatuganj Khal	S	1	59	Fair	61	Good
		2	63	Good	63	Good
Adi Ganga Canal	T	1	33	Below avg.	33	Below avg.
		2	39	Below avg.	40	Below avg.
Lower Dhanpota Khal	V	1	31	Below avg.	28	Poor
		2	34	Below avg.	35	Below avg.

Conclusion

The investigation of the canal network in the western basins of South 24-Parganas, West Bengal, in terms of water quality was vital to understand the suitability of system for irrigation purposes. The tidal backwater ingress breathes life into the canal network of the region. The water quality index was analysed to improve to the minimum of one class after the ingress. Further inland where the canals did not receive adequate quantity of ingress of tidal backwater the water quality tends not improve as much in terms of water quality. It was also noted during survey that the canals in various places were subject to heavy silting, and wastes (plastic, domestic garbage, slaughterhouse waste) that were dumped into the canals. It resulted incomplete impediment in the water quality and hydraulics of the canals. On multiple occasions sewage pipelines from individual and collective households discharged their effluents in the canals. The tidal backwater is unable to reach the due to excess sedimentation, pollution, encroachment which has blocked the usual flow of water. Supplementing the inland canals with tidal backwater would greatly aid in improving the water quality in the region. Where lateral expansion is unconceivable, excavating the canals, regular maintenance, and reducing the development of encroachment in the canal stretches could greatly assist the recovery of the water quality of the canals by the supplementation of tidal backwater.

The salinity levels in the canal network exhibits conditions from non-saline to slightly saline, with gradual increase of salinity to moderately saline with ingress of tidal backwater. Higher salt concentrations influence the osmotic pressure of solution and inturn affect the ability of the plants to absorb water through their roots. However, an appropriate evaluation of the water quality prior to its use in irrigation will help in arrestingany harmful effect on plant productivity and groundwater recharge. Because of the utilization of poor or perilous quality water the agricultural land gets affected and harms the harvest yield in different ways. The accumulation of salts in root zone, limited the availability of water and plant can take up lesser water which resulted in high plant stress and decreased crop yields. The increase of salinity in the initial ingress junctions is an could be combat by the efficient operation of the sluice gates, so as to allow the ingress of water after the initial surge of tidal backwater when the salinity would be low. The beneficiary agricultural lands in the initial stretches of the canals could also be supplemented with groundwater and by rainwater harvesting for adequate supply of irrigation water. The influence of tidal backwater feeding in the non-monsoon period not only allows for multi-cropping and fish collection but also acts an active waste and flood water drainage network for the region. The maximization of sustainable use of natural resources is the key in the economic development of the region.

References

1. P. K. Maity, S. Das and R. Das, *J. Indian Chem. Soc.*, 2018, **95**, 205.
2. S. Chakraborty, P. K. Maity and S. Das, *Environment, Development and Sustainability*, 2020, **22(4)**, 3805.
3. P. K. Maity, S. Das and R. Das, *Indian Journal of Environmental Protection*, 2017, **37(1)**, 31.
4. S. Dhar, S. Das and A. Mazumdar, "Salinity Intrusion Impact on the Piyali River of the Sundarbans", International Conference on Emerging Technologies in Environmental Science and Engineering, Aligarh, Uttar Pradesh, 2009, 383-391.
5. S. Das, M. Nayek, S. Das, P. Dutta and A. Mazumdar, *Indian Journal of Environmental Protection*, 2014, **34(12)**, 1010.
6. S. Das, P. K. Roy and A. Mazumdar, *REASON - A Technical Magazine*, 2012, **XI**, 29.
7. N. Mohammed, *European Journal of Scientific Research*, 2011, **571**, 15.
8. R. S. Ayers and D. W. Westcot, "Water quality for agriculture", FAO irrigation and drainage, Vol. 29, No. 1, U.N. FAO, Rome, 1985.
9. R. K. Horton, *Water Pollution Control Federation*, 1965, **37**, 300.
10. K. Yogendra and E. Puttaiah, "Determination of Water Quality Index and Suitability of an Urban Waterbody in Shimoga Town, Karnataka", The 12th World Lake Conference, 2008.
11. IS 11624:1984, Indian Standard, Guidelines for the Water Quality of Irrigation Water, Bureau of Indian Standard, New Delhi, India.
12. IS 3025 (Part 23):1986, Indian Standard, Methods of Sampling and Test (Physical and Chemical) for Water and Wastewater, Bureau of Indian Standard, New Delhi, India.