Assessment of Irrigation Water Quality Parameters at Upstream and Downstream of Kanhan River: A Case Study

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***Abstract*-- Water is fundamental constituent for food security, harvest and cattle. Farming requires huge amount of water with designated quality for irrigation and different production processes. Harvest and its production in the arid and semi-arid area is dependent on irrigated agriculture. The hot and dry weather of these areas needs that the water used for harvest does not have soluble salts in high amounts that are detrimental effect to the plants or have an adverse consequence on the soil properties. The Kanhan River is non-perennial, intermittent river and important right bank tributary of the Wainganga River originates from the high lands of Chindawara District of Madhya Pradesh and flows in south east course for about 160 kms before it enters in the Maharashtra state near Raiwari village in Saoner Taluka of Nagpur District. The Kanhan River water is the most important water resource for industrial and agricultural purposes in Madhya Pradesh and Maharashtra. Central Water Commission is monitoring water quality in Kanhan River for the more than 25 years. In the present study various parameters such as pH, Electrical Conductivity (EC), Sodium percentage (Na %), Boron(B), Sodium adsorption ratio (SAR), Residual sodium carbonate (RSC) Total Coliform(Tcol) and Faecal Coliform (Fcol) were studied to monitor the Water Quality status of Kanhan River for irrigation purpose. For this, the data of two Water Quality Monitoring Station namely Ramakona (upstream) and Satrapur (downstream) of recent five water years from 2014-15 to 2018-19 data has been used assessment of water quality.**

The analysis results show observed significant changes in pH (6.3 to 8.7), EC (181 to 1040), Na % (4% to 51%) , B (0.04 to 3.59 mg/L), SAR (0.1 to 2.9), RSC(0.0 to 2.20),Tcol(20 to 16000 MPN/100ml) and Fcol (20 to 16000 MPN/100 ml). The obtained data from both the monitoring location is compared with different well known national and international irrigation water Quality standards. It is observed that 90.1 % samples value of EC is suitable for soil of moderate drainage, 6.93 % samples value of percent sodium is permissible class, 4.95 % samples value of Boron is doubtful class, 3.96 % samples value of RSC is marginal class and 15 % samples of Faecal Coliform above the standard limit of World Health Organization. The various Physical (Photo- catalysis treatment, Thermal treatment, UV treatment) techniques and Chemical (Ozone treatment, Hydrogen peroxide treatment, Sodium hypochlorite treatment, Chlorine dioxide treatment) techniques are used to improve the Water Quality of Irrigation Water. In addition to that various management techniques are also used such as More frequent irrigation, Selection of salt tolerant crops and varieties, Use of extra water for leaching, Conjunctive use of fresh and saline waters, Cultural practices, in addition of an alternate source of water, crops production with low water requirements and Organic matter applications. By utilizing phytoremediation technology to get treated water for reuse for irrigation. The phytoremediation established a safe and economic technology for water treatment compared to the expensive conventional techniques.

Key words - Irrigation Water Quality, Kanhan River, Electrical Conductivity, Sodium Percentage, Coliform

I. INTRODUCTION

Water is a vital input into agriculture in nearly all its features contains an influential effect on the production of crops. It is well known fact that about 17% of the world's population are in India however only 4% of the earth fresh water resources. The distribution of these water resources across the large expanse of the country, is also not properly regulated. The increasing demands on water resources by India's rapidly growing population and declining quality of available water resources because of pollution and the additional necessities of industrial and agricultural growth (1). The requirement of quality water increasing rapidly, however, to maintain a supply of quality water is going to difficult assignment.

The Kanhan river one of the important tributaries of Wainganaga River. The Kanhan River of Waingangā basin begin from the elevated lands of Chindawara district of Madhya Pradesh next to village Tarai as well as flows in south east course for about 160 kms before it enters in Maharashtra state near Raiwari village in Saoner Taluka of Nagpur district. The Kanhan River passes through Saoner, Nagpur, Kamptee and Mouda Tahsils of District Nagpur cover up a distance of approximate 80 kms, before it finally joins wainganga as a right hand tributary close to Jawahar Nagar ordnance factory in Bhandara district of Maharashtra. The Pench River is a tributary of the Kanhan River and confluence at Bina village, upstream from the Nagpur district of Maharashtra (2). Kanhan River water supply as a major water source for irrigation water, domestic water as well as drinking water sources for Nagpur district and nearby area.

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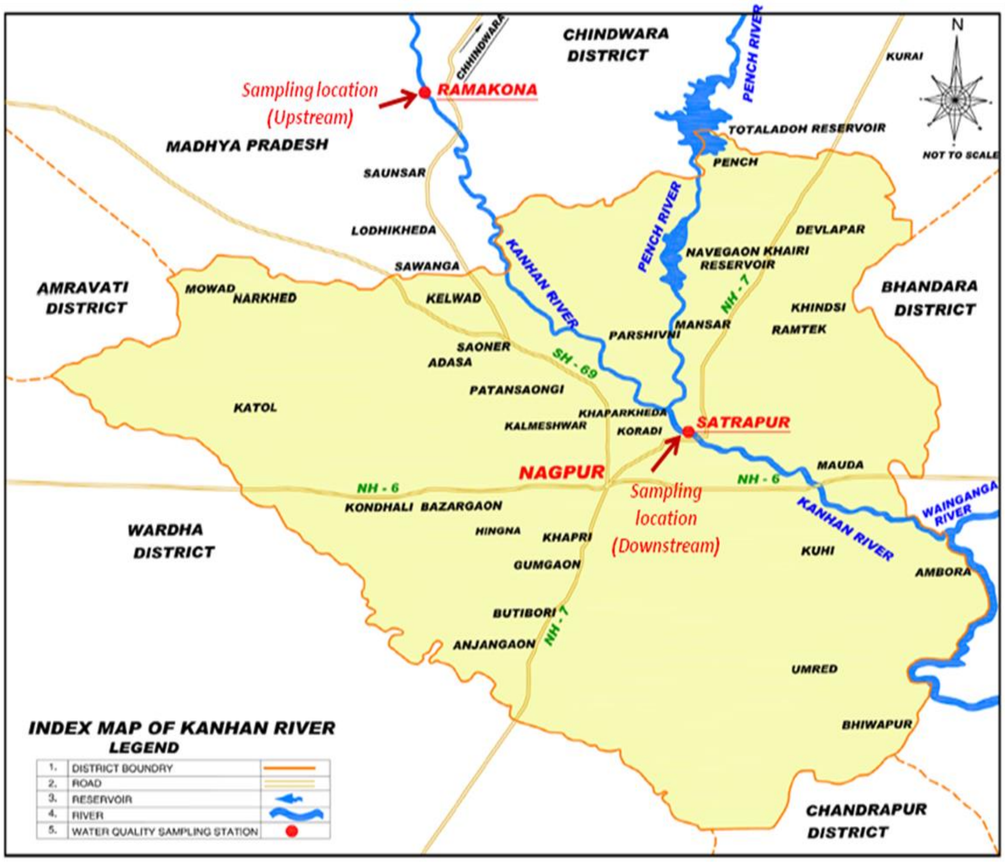

Fig. 1 Map of Kanhan River at Madhya Pradesh and Maharashtra

The monthly average discharge of upstream of Kanhan River at Ramokona water quality monitoring station is found maximum in July in year 2018. i.e. 26.468 cumecs and minimum in June i.e. 0.838 cumecs and at Satrapur water quality monitoring station is found maximum in September i.e.156.525 cumecs and minimum in June i.e. 0.384 cumecs. The discharge defines the quantum of flow of water in river, as there is no relation between discharge and studied parameters. Author not established any correlation between discharge and studied parameters The distance between Ramokona (Chindwara) water quality monitoring station at upstream and Satrapur (Nagpur) water quality monitoring station at downstream of Kanhan is 110 Kilometer.

In current study, the water quality data of recent five year i.e. from 2014-15 to 2018-19 (water year) has been used assessment of water quality with reference to irrigation suitability. The water quality monitoring stations are Ramakona (upstream) and Satrapur (downstream). The map of Kanhan river and location of these stations in the study area is shown in Figure 1.

II. Materials & Methodology

The river water samples are collected during 08.00 AM to 10.00 AM on first day of every month during entire year and total 12 numbers of samples collected in one year from each location. The collected river water samples are preserved and transported as per the standard protocol from Waingangā water quality monitoring stations i.e. Ramakona (upstream) and Satrapur (downstream) to Waingangā Water Quality Laboratory, Central Water Commission, Nagpur for chemical and bacteriological analysis. The calibrated instruments/equipment are used as per the accuracy and precision prescribed in the procedure manual. Chemicals of analytical reagent grade and calibrated glassware are used during the analysis. The collected water samples are analysed for physical, chemical and bacteriological parameters using standard analytical procedure and/or instrumental methods (3). For the present study, 13 important water quality parameters are used, such as pH, Electrical Conductivity (EC), Boron (B), Sodium (Na), Potassium (K), Calcium (Ca), Magnesium (Mg), Bi-Carbonate Carbonate (HCO_3), Sodium Percentage (Na %), Sodium Adsorption Ratio (SAR), Residual Sodium Carbonate (RSC), Faecal Coliform (Fcoli) and Total Coliform (Tcoli).

III. Results and Discussion

The received water quality data of both the stations Ramakona and Satrapur compared with the various Indian Standards and international Standards for the suitability of irrigation water:

pH: The values of pH at Ramakona Water Quality Monitoring Station varied from 7.6 to 8.7 and Satrapur Water Quality Monitoring Station varied from 6.3 to 8.7 on Kanhan River during June 2014-15 to May 2018 -19 respectively (Table I).

TABLE I
Water Quality Data Summary of Kanhan River

Name of WQ Station		Ramakona					Satrapur				
WQ Parameters	**YEAR**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**	**2014-15**	**2015-16**	**2016-17**	**2017-18**	**2018-19**
EC_GEN (µmho/ cm)	Max	790	599	568	570	405	759	747	733	1040	737
	Min	181	283	219	372	206	235	317	241	440	258
	Avg	462	467	407	483	325	559	535	503	665	549
pH	Max	8.3	8.5	8.7	8.2	8.1	8.2	8.6	8.7	8.2	8.1
	Min	7.6	7.9	7.8	7.8	7.7	7.1	7.8	7.7	7.1	6.3
	Avg	7.9	8.1	8.3	8.1	8.0	7.8	8.2	8.2	7.8	7.6
B (mg/L)	Max	0.86	0.57	1.55	1.1	0.86	0.96	0.70	1.39	2.59	0.96
	Min	0.07	0.06	0.11	0.7	0.09	0.05	0.08	0.12	0.00	0.04
	Avg	0.33	0.21	0.74	0.9	0.5	0.32	0.20	0.54	0.66	0.35
% Na	Max	26	39	26	29	39	51	45	43	39	35
	Min	17	12	16	21	11	22	20	5	4	12
	Avg	23	23	23	26	21	33	31	30	29	28
RSC	Max	1.00	1.00	1.40	0.70	1.50	2.20	0.70	0.60	2.00	1.00
	Min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
	Avg	0.40	0.10	0.20	0.40	0.40	0.20	0.10	0.10	1.30	0.10
SAR	Max	1.00	1.50	1.40	1.10	2.00	2.90	2.30	2.20	2.00	1.80
	Min	0.60	0.40	0.00	0.70	0.40	0.70	0.70	0.10	0.20	0.50
	Avg	0.8	0.9	0.2	0.9	0.8	1.5	1.4	1.3	1.3	1.3
Faecal Coliform (MPN/100 ml)	Max	170	140	16000	1100	3000	800	220	16000	9000	5000
	Min	20	20	40	20	130	20	80	40	20	170
	Avg	83	67	2235	310	786	197	142	1741	1664	1199
Total Coliform (MPN/100 ml)	Max	2200	16000	16000	16000	1100	800	220	16000	9000	5000
	Min	20	40	100	20	300	20	80	40	20	170
	Avg	361	1850	5296	3812	648	197	142	1741	1664	1199

The result does not show any trend however the percentage of sample's result are increasing (out of range) from upstream to downstream. The Ramakona and Sarapur 2.4 % and 5.0 % respectively out of the pH range of BIS. As per the Classification of Inland surface waters (BIS: 2296-1982), the water having pH in the range 6.0 – 8.5 is suitable for D class of water (Irrigation, Industrial Cooling, Controlled Waste disposal). At Ramokona, upstream of Kanhan river the analysis results of pH shown 2.4 % samples are out or range as per the Classification of Inland surface waters and at Satrapur, downstream of Kanhan river the pH shown 5.0 % samples are out of range as shown in Figure 2(a) and 2(b). It is observed from the results upstream to downstream; slightly more number of samples is out of range. The increases in pH and contributes to alkalinization due to a biological perspective, in-stream microbial processes such as de-nitrification, sulphate reduction, etc (4).

Electrical Conductance: The values of EC at Ramakona Water Quality Monitoring Station varied from 181 to 790 µmhos/cm and Satrapur Water Quality Monitoring Station varied from 235 to 1040 µmhos/cm on Kanhan River during June 2014-15 to May 2018 -19 (Table I). The quantity of water transported all the way through a crop is directly related to yield, as a consequence, irrigation water with high EC decrease yield potential (5). The water quality classified by U.S. Salinity Laboratory (USSL) for judging their suitability for irrigation use, this classification is accepted world widely. The USSL classify irrigation water quality into four classes on the basis of EC as shown in Table II (6). At Ramokona, upstream of Kanhan river the analysis results of EC shows that the 7.31% samples under C1 category, it is suitable for most crops and soils), 90.24 % samples under C2 category (250 - 750) Suitable for soil of moderate drainage, 2.43 % samples under C3 category (750 - 2250) Unsuitable for soil of restricted at drainage and at Satrapur, downstream of Kanhan river the EC shown at 3.3 % samples under C1 category, it is suitable for most crops and soils, 90.0 % samples under C2 category (250–750), it is suitable for soil of moderate drainage 6.7 % samples under C3 category (750- 2250), it is unsuitable for soil of restricted at drainage. It is observed from the results EC value increases in percentage of samples for different classes from upstream (Ramakona) to downstream (Satrapur) as shown in Figure 3 (a) and (b). The increases in EC due to dissolved inorganic substances in water are in the ionized form. The EC value is depend on quantity of water, if quantity of water is increasing / decreasing due to high or low rainfall, which affect the dilution of pollutant, at last show increase or decreases in EC.

TABLE II
Irrigation water quality on the basis of EC (6)

Class	Salinity hazard	EC (µS/cm)	Suitability criteria
C1	Low	<250	Suitable for most crops and soils
C2	Medium	250–750	Suitable for soil of moderate drainage
C3	High	750–2,250	Unsuitable for soils of restricted drainage
C4	Very high	>2,250	Unsuitable for average condition

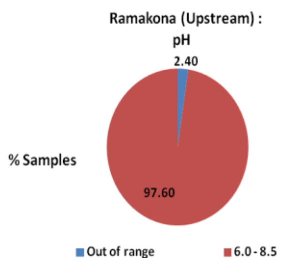

Fig. 2(a)

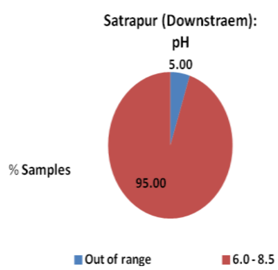

Fig. 2(b)

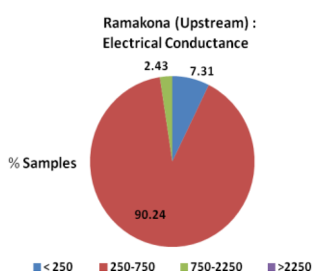

Fig. 3(a)

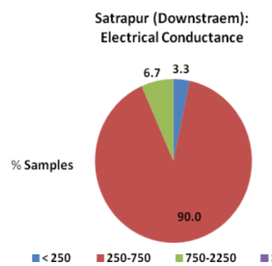

Fig. 3(b)

Sodium percent: SAR is a main parameter for the determination of the suitability of irrigation water because it is responsible for the sodium hazard (6). The values of Na% at Ramakona Water Quality Monitoring Station varied from 11 to 39 % and Satrapur Water Quality Monitoring Station varied from 4 to 51 % respectively on Kanhan River River during June 2014-15 to May 2018 -19 (Table I). The widely is accepted USSL classification is shown in Table III. The value of Na% in increases in percentage of samples for different classes from upstream (Ramakona) to downstream (Satrapur) as shown in Figure 4. The high concentrations of Na% due to pollution from industrial discharges or sewage effluent. At Ramokona, upstream of Kanhan river the analysis results of Na Percent shows 41.5 % samples under Excellent class (> 20 %) , 58.5 % samples under Good Category (20-40 %), and at Satrapur downstream of Kanhan river, Na Percent 3.3 % samples are under the excellent category (> 20 %), 85.0 % samples under Good Category (20-40 %), 11.7 % samples under Permissible class with reference to Irrigation water quality. It is clearly shows that % sodium percentage is increases from upstream (Ramakona) to downstream (Satrapur) as shown in Figure 4 (a) and (b).

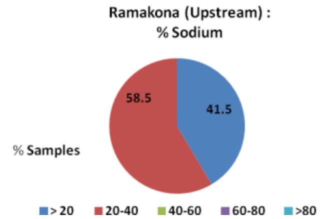

Fig. 4(a)

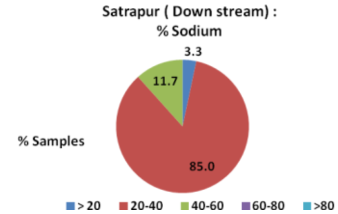

Fig. 4(b)

Sodium adsorption ratio (SAR): Sodium vulnerability is commonly expressed in terms of the sodium adsorption ratio (SAR). SAR is calculated from the ratio of sodium to calcium and magnesium. SAR is a important parameter for the use of the appropriateness of irrigation water because it is responsible for the sodium hazard (7). The values of SAR at Ramakona Water Quality Monitoring Station varied from 0.0 to 2.0 and Satrapur Water Quality Monitoring Station varied from 0.1 to 2.9 respectively on Kanhan River during June 2014-15 to May 2018 -19 (Table I). The widely accepted USSL classification is shown in Table IV with reference to SAR (6). The all sample values of SAR are within low limit SAR in upstream (Ramakona) and downstream (Satrapur). The value of SAR of all samples are under the S1 Class (Used for irrigation on almost all soils with little danger of developing harmful levels of sodium) with reference to Irrigation water quality on the basis of SAR.

TABLE III
Irrigation water quality on the basis of % Na (7)

S. No.	Water class	% Na
1	Excellent	<20
2	Good	20–40
3	Permissible	40–60
4	Doubtful	60–80
5	Unsuitable	>80

Residual Sodium Carbonate: Residual sodium carbonate (RSC) is one more term employ while evaluates irrigation water sources for Na+ hazard. Carbonates and bicarbonates have a high affinity to form insoluble precipitates with Calcium and Magnesium. When these precipitates are formed, it is desirable to have surplus divalent cations available to bind with all HCO_3^- and CO_3^{--} ions and excess to help aggregate soil particles. The values of RSC at Ramakona Water Quality Monitoring Station varied from 0.04 to 1.50 and Satrapur Water Quality Monitoring Station varied from 0.00 to 2.20, respectively on Kanhan River River during June 2014-15 to May 2018 -19 (Table I). Wilcox (7) categorizes Irrigation water with reference to RSC shown in Table V. At Ramokona, upstream of Kanhan river the analysis results of RSC of 95.1

% samples are under the Safe Category (< 1.25), 4.9 samples are Marginal (1.25 – 2.50) and at Satrapur downstream of Kanhan river, RSC 96.7 % samples are under the safe category (< 1.25), 3.3 samples are Marginal (1.25 – 2.50). It is clearly shows that RSC results no significance changes from upstream (Ramakona) to downstream (Satrapur) as shown in Figure 5 (a) and (b). A higher value of SAR indicate a risk of sodium (alkali) and substitution of Ca^{2+} and Mg^{2+} in the soil in the course of a cation exchange process that damage soil structure, mostly permeability, and which ultimately influence the fertility condition of the soil and diminish crop yield (8).

TABLE IV

Irrigation water quality on the basis of SAR (7)

Class symbol	Class of water	SAR value	Suitability
S1	Low sodium water	< 10	Used for irrigation on almost all soils with little danger of developing harmful levels of sodium.
S2	Medium sodium water	10–18	May cause an alkalinity problem in fine-textured soils under low leaching conditions. It can be used on coarse textured soils with good permeability.
S3	High sodium water	18–26	May produce an alkalinity problem. This water requires special soil management such as good drainage, heavy leaching, and possibly the use of chemical amendments such as gypsum.
S4	Very high sodium water	>26	Very high sodium water is usually unsatisfactory for irrigation purposes.

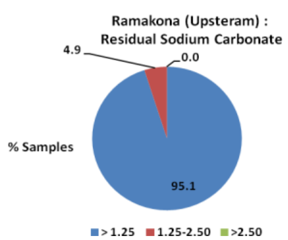

Fig. 5(a)

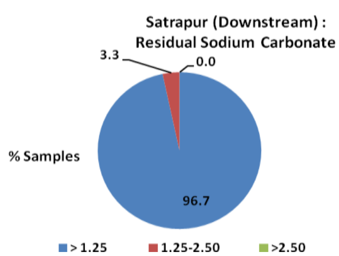

Fig. 5(b)

Boron: Boron is an important in low concentration however toxic at high concentration is boron level in irrigation water. The values of B at Ramakona Water Quality Monitoring Station varied from 0.06 to 1.55 and Satrapur Water Quality Monitoring Station varied from 0.04 to 2.59, respectively on Kanhan River during June 2014-15 to May 2018 -19 (Table I). Rowe and Abdel-Magid categarised Boron Concentration in Table VI for sensitive, semi tolerant and tolerant group of crops (9).

At Ramokona, upstream of Kanhan river the analysis results of Boron 58.5 % samples are under the Excellent Class (< 0.33), 22 % Good Class, (0.33-0.67), 9.8 % Permissible Class (0.33-1.00), Doubtful Class 9.7 % (1.00-1.25), Unsuitable Class 2.4 % (> 1.25) and at at Satrapur downstream of Kanhan river 55.0 % samples are under the Excellent Class (< 0.33), 23.3 % under Good Class (0.33-0.67), 16.7 % under Permissible Class (0.33-1.00), 1.67 % under Doubtful Class (1.00-1.25), 3.3 % Unsuitable Class (> 1.25). It is clearly shows that B results significance changes from upstream (Ramakona) to downstream (Satrapur) as shown in Figure 6 (a) and (b). The boron concentration is increasing due mixing of industrial discharges or detergents in untreated sewage effluents.

TABLE V

Irrigation water quality on the basis of RSC (8)

S. N.	Water class	RSC
1	Safe	<1.25
2	Marginal	1.25–2.5
3	Excellent	>2.5

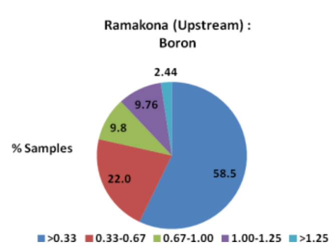

Fig. 6(a)

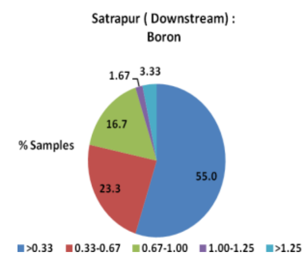

Fig. 6(b)

Coliform: The discharge of raw sewage causes microbiological contamination in rivers and pose health risks in its reuse. According to Classification of Central Pollution Control Board for Designated Best Use of Inland Surface Water place the maximum Total Coliform standard at 5,000 MPN/100ml for Class C (Drinking water source with conventional treatment followed by disinfection). The United States Environmental Protection Agency (USEPA) and the US Agency for International Development stringent guidelines for wastewater use (9). For the irrigation crops likely to be eaten uncooked, no detectable faecal coliform bacteria are allowed in 100 ml (compared with the 1989 WHO guidelines of less than 1000 faecal coliform bacteria/100 ml), and for irrigation of commercially processed and fodder crops the guideline limit is less than 200 faecal coliform bacteria/100 ml (10). The values of Total and Faecal coliform at Ramakona Water Quality Monitoring Station varied from 20 to 16000 MPN/100 ml and Satrapur Water Quality Monitoring Station varied from 20 to 16000 MPN/100 ml, respectively on Kanhan River during June 2014-15 to May 2018 -19 (Table I). At Ramokona, upstream of Kanhan river Total coliform 17.1 % samples and at Satrapur downstream of Kanhan river 26.6 % samples are more than 5000 MPN/100 ml which are above Class C Drinking water source with conventional treatment followed by disinfection. At Ramokona, upstream of Kanhan river faecal coliform 9.7 % samples and at Satrapur downstream of Kanhan river 20.0 % and are more than 1000 MPN /100 ml above the WHO guidelines for Faecal

Coliform bacteria. It is observed that significance changes from upstream (Ramakona) to downstream (Satrapur) for both Total Coliform and Faecal Coliform as shown in Figure 7 (a), (b) respectively. The higher values of Total Coliform and Faecal Coliform most probably arise from untreated wastewater/sewage water discharged into river, open defecation practices and animal activities as well other human activities in nearby area. The various sewage nallah of Lodikheda, Borgaon, Satnoor, Kheritaygaon etc are flow to words the Kanhan river.

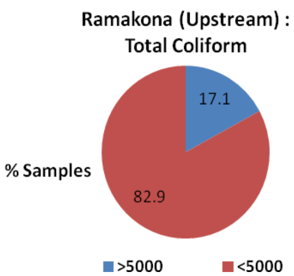

Fig. 7(a)

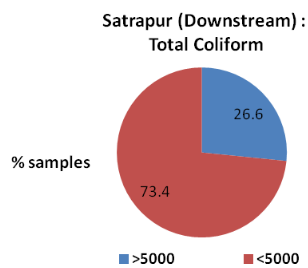

Fig. 7(b)

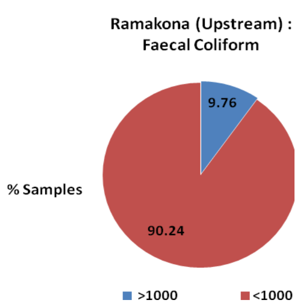

Fig. 8(a)

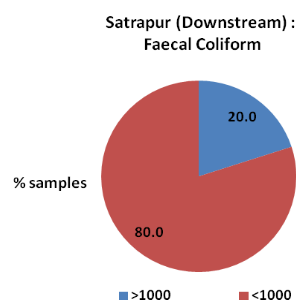

Fig. 8(b)

IV. Techniques of Waste Water Treatment for Reduction of Contaminants

Water quality management is a vital component in the maintenance of sustainable irrigated agriculture systems in India as well as all over the World. A number of characteristic such as water quality evaluation, water source safety, agriculture water management, salinity management, water table management, management drainage water as well as examine and manage to protect the river water quality for an irrigated region and for downstream consumer. Water quality control within the system have need of good field and system level management, appropriate agronomic follows to manage salinity and other water pollutants.

A range of Physical treatment (Photo- catalysis treatment, Thermal treatment, UV treatment) techniques, Chemical treatment (Ozone treatment, Hydrogen peroxide treatment, Sodium hypochlorite treatment, Chlorine dioxide treatment) techniques, Biological treatment (Slow filters, Artificial constructed wetlands) techniques and Cleaning of the water distribution system (Steam treatment, Chemical treatments, Treatment for bicarbonate clogging) are used to improve the Water Quality of Irrigation Water. In addition to that different other management methods are also employing such as more frequent irrigation, selection of salt tolerant crops and use of additional water for leaching, conjunctive use of fresh and saline water, cultural practices, mixing with an alternate source of water, growing crops with low water necessities and use of organic matter.

TABLE VI
Limits of boron in irrigation water (9)

Class of water	Crop group: Sensitive	Crop group: Semi tolerant	Crop group: Tolerant
Excellent	< 0.33	<0.67	<1.00
Good	0.33 to 0.67	0.67 to1.33	1.00 to 2.00
Permissible	0.67 to 1.00	1.33 to 2.00	2.00 to3.00
Doubtful	1.00 to 1.25	2.00 to 2.50	3.00 to 3.75
Unsuitable	> 1,25	> 2.5	>3.75

Now a day, all over world the use of phytoremediation techniques is for treatment of water and reuse for irrigation because many Plants have capacity to adsorb, absorb, metabolize, accumulate, stabilize, or even volatilize organic or inorganic contaminants. The phytoremediation techniques have advantages over conventional methods of wastewater remediation such as enhancement of the quality of polluted irrigation water through a phytoremediation method in a hydroponic batch culture system (12), remediation of Boron contaminated Water and soil with Vetiver Phytoremediation Technique (13), *Eichhornia crassipes, Pistia stratiotes, Nelumbo lutea and Marsilea quadrifolia* are efficiently reduced Colour, Temperature, pH, Total Dissolved solids, Dissolve Oxygen, Biochemical Oxygen Demand, Chemical oxygen Demand, Chlorides and Sulphates significantly (14), *Eichhornia crassipes, Hydrilla verticillata, Jussiaea repens, Lemna minor, Pistia stratiotes and Trapa natans* are significant decrease in pH, conductivity, Total Dissolved Solids, Total Suspended Solids, chlorine, sulphur, BOD & COD (15). A few success studies mentioned above and utilizing phytoremediation technology to get treated water for reuse for irrigation.

V. Conclusion

The analysis results show observed significant changes in pH (6.3 to 8.7), EC (181 to 1040), Na % (4% to 51%) , B (0.06 to 2.59 mg/L), SAR (0.0 to 2.9), RSC(0.04 to 2.20), Tcol(20 to 16000 MPN/100ml) and Fcol (20 to 16000 MPN/100 ml). The obtained data from both the monitoring location is compared with different well known national and international irrigation water Quality standards. It is observed that in water quality parameters namely pH, Electrical Conductance, Sodium absorption ratio, Residual Sodium Carbonate are not changes significantly, however Sodium Percentage, Boron, Total Coliform and Faecal coliform shown significance changes from upstream (Ramakona) to downstream (Satrapur).

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