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Integrated Watershed Monitoring Framework for Irrigation Water Quality: Targeting Critical Source Areas

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ABSTRACT
Hathmati river is a main source of irrigation water in Hathmati watershed in Sabarkantha district. Due to overuse of fertilizers and other irrigation activities havoc has been created to the irrigation water quality. Therefore, the quality of the water must be tested to check its suitability to use for irrigation purpose. To assess quality of irrigation water, four main parameters are Sodium %, Electrical Conductivity, SAR and RSC. Unfortunately, in Hathmati watershed, the surface water quality is not monitored though water is mainly supplied for irrigation. A framework of water quality monitoring is proposed in this study to monitor irrigation water quality for Hathmati watershed. Three stations in three sub watersheds have been selected and 19 water quality parameters have been considered and water quality indices (WQI) method used for assessing river health has been discussed. The literature focuses that water quality parameters are the most significant tool for assessing the river health. It is found that the river health of Hathmati River comes in excellent category but if we talk at sub watershed level, at the inlet, two sub watersheds Mankdi and Khandhol are having excellent water quality but while water enters in Himmatnagar it has been polluted and the reason for this may be Potassium content present in the fertilizer as this sub watershed is having maximum agricultural land, which gives an indication of pollution.
***Keywords* –** Water Quality, Framework, Watershed, Water Quality Index, Monitoring

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I. INTRODUCTION

Irrigation water is an unavoidable requirement for agricultural production. According to Vega et al. (1998), surface runoff is seasonal and highly affected by climatic conditions and, consequently, has a strong effect on the flow rates and pollutant concentrations in river water. This source is exposed to a variety of pollutants caused by the diffusion from nonpoint and point sources which are difficult to control, monitor, and evaluate, such as agricultural and industrial wastes (Ahuja, 2003). The substances of soluble salts and also its composition present in water will determine its quality for various purposes. Thus, quality is an important component of water for irrigated agriculture.

1.1 Irrigation Water Quality in India

Irrigation is one of the important uses of surface water for agricultural purposes in India. As water is readily available for irrigation in enough quantity, its quality has been neglected. Intensive use of nearly all good quality supplies means that new irrigation projects and old projects seeking new or supplemental supplies must rely on lower quality and less desirable sources. To avoid problems when using these poor-quality water supplies, there must be sound planning to ensure that the quality of water available is put to the best use. The gradual decline of Irrigation water quality in India is directly related to surface runoff from agricultural areas and over use of fertilizers as well as pesticides. Due to excessive use of chemicals for agricultural activities and reclamation of land, Irrigation water is being contaminated at an alarming rate in India which is now a matter of concern. However, with the rapid increase in the population of the country and the need to meet the increasing demands of agricultural productions and so for irrigation, the available water resources in many parts of the country are getting depleted and the water quality has deteriorated.

1.2 Irrigation Water Quality Problems

The substances which are dissolved in water determines its quality for irrigation use. Water used for irrigation should be within permissible limits of water quality criteria otherwise it could affect plant growth and crop production. Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts present in irrigation water are in relatively small but significant amounts. These salts are carried with the water to wherever it is used. In the case of irrigation, the salts are applied with the water and remain behind in the soil as water evaporates or is used by the crop. The suitability of a water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. The water quality is degraded mainly due to natural reasons along with over withdrawal of water and increased application of fertilizers. The water being used for irrigation may contain many impurities which in turn maybe taken up by crops.

1.2.1 Water quality-related problems in irrigated agriculture

Salinity

Salts present in water may reduce available water quantity to the crop which can affect the yield. EC and TDS are the most common parameters used for determining the irrigation water quality, with measure of its salinity.

Water infiltration rate

High sodium or low calcium content of water reduces the infiltration rate so sufficient water cannot be supplied to the crop adequately from one irrigation to the next.

Specific ion toxicity

Certain ions (sodium, chloride, or boron) from water accumulate in a crop cause crop damage and ultimately reduce yields. Toxicity of specific ions can determine quality of the irrigation water. Special attention should be given to boron as its toxicity occurs in very low concentrations but it is an essential nutrient for plant. Toxic levels of any single ion in the irrigation water might make the water unsuitable for irrigation.

Miscellaneous

Nutrients in excessive quantity may reduce quality; unsightly deposits on fruit or foliage may reduce marketability; excessive corrosion of equipment may increase maintenance and repairs.

1.2.2 Critical sources of poor Irrigation water quality

Critical sources of poor Irrigation water quality are the sources having higher chemical use rates, increased field salinity and soil erosion, accelerated pollutant transport with drainage flows, degradation due to increased deep percolation to saline formations, and greater instream pollutant concentrations due to reduced flows.

II. STUDY AREA

The Hathmati is a main tributary of Sabarmati which is one of the major rivers of Gujarat. It rises from the Gujarat Malwa hills south western foothills of the Rajasthan range near Godad at north latitude of 23°55’ and an east longitude of 73°29’ in Sabarkantha district. After traversing a course of 98 km, it meets the Sabarmati River near Ged, 20 km south west of Himatnagar in Sabarkantha district. The two main tributaries of Hathmati are Bodoli and Guhai having catchment areas of 119 km2 and 505 km2, respectively. The average annual rainfall in the catchment is 860 mm.

Irrigation water in Hathmati watershed comes from Hathmati River. The Hathmati watershed of Sabarkantha district is selected as a study area having 1558.41 km2 areas which lies between 23◦55’40” to 24◦02’00” N and 72◦44’51” to 73◦29’04” E. The river basin has various land use patterns, of which agricultural land use (60%), forests (15%), waste land (15%) and mixed land use (10%) are the important land use classifications. Nowadays, The Hathmati River is under a continuous threat due to sudden growth of agricultural activity due to availability of ample quantity of water and increased use of fertilizers by the farmers as this area is mainly agricultural land.

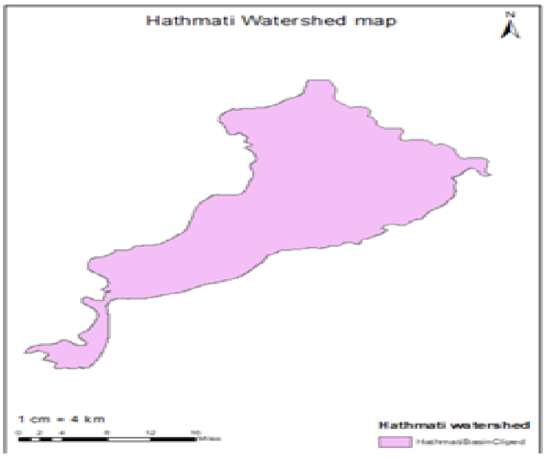

Fig. 1 Hathmati watershed map

2.1 Sampling Sites

To characterize the variability of water quality along the river basin, location of three sampling sites from three sub watersheds were selected. From these, one site Himmatnagar (N 23°59´, E 72°96´) was defined on the main stream at downstream, while one site Khandhol (N 23°41´, E 73°06´) was located on Guhai reservoir on Guhai river, and one site Mankdi (N 23°67´, E 73°20´) was located on the main stream from upstream to downstream, along the Hathmati River (Fig. 2).

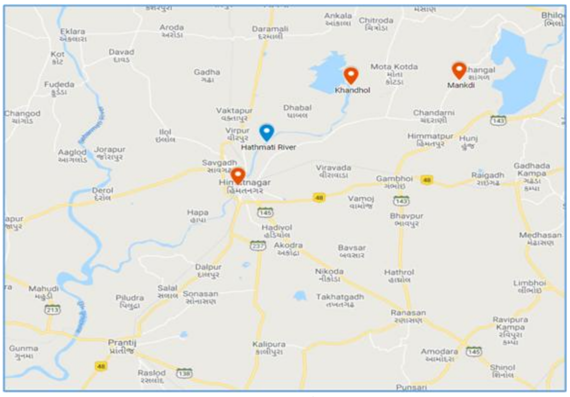

Fig. 2 Sampling sites for Hathmati river

III. IRRIGATION WATER QUALITY MONITORING FRAMEWORK

Water quality can be determined by the chemical, physical and biological parameters. It is a measure of the state of the water with respect to the necessities of human needs or purposes (Abbasi and Abbasi, 2012). The water pollution of rivers requires great efforts, and water quality is an important issue in the field of water resources planning and management and requires data gathering, analysis, and interpretation (Yehia and Sabae, 2011).

Water Quality Monitoring Framework illustrates a systematic process which will help monitoring authorities produce and convey the information needed to understand, protect, and restore our waters. The identification of critical pollutants and the target concentrations will be strongly influenced by the intended use of the irrigation water.

Water quality indices are the tools for determining water quality. The main focus of this study is to decide whether water is suitable for irrigation or not. Different environmental problems, caused by the excessive wastes discharged from agriculture, is threatening and deteriorating the river water quality (Liu et al., 2012b). Furthermore, the trends of water quality in the Hathmati River have not been fully investigated. During the past several decades, numerous methods have been proposed for water quality assessment, however, still the most popular method is the use of water quality index (WQI) to make an assessment by translating large numbers of variables into a digital number.

Traditional monitoring approaches of water quality are based on comparisons of the determined variables with the normative standards, which provides partial information on the overall quality (Pesce and Wunderlin, 2000).

3.1 Application of irrigation water quality framework

This monitoring framework encompasses three main phases.

1. The first phase comprises design of monitoring framework, which should consider and include:

- The planning of a monitoring framework by choosing location for the sampling, with the help of preliminary surveys needed before the design is started, so that issues, problems and risk factors can be clearly identified and evaluated;
- The planning of frequency of sampling;
- The selection of physical (e.g., temperature, suspended solids, conductivity), chemical and biological variables, i.e., which variables are to be monitored for irrigation and in relation with different non-point pollution sources;
- Defining sampling procedures and operations, such as in situ measurements with different devices, manual or automated measurements.

2. The second phase defines laboratory facilities required for the monitoring programme.

- Setting up a system for ensuring the reliability of information obtained by monitoring which covers field and laboratory work, data analysis and compiling, as well as the application of WQ standards and indices; and
- Managing the data and reporting results and findings.

3. The third phase comprises by implementing the framework, with comparing data with Irrigation water quality standards. If data does not match the standards then finding out critical sources for pollution and reasons for unsuitability for using water for Irrigation purpose.

- Suggest some remedial measures for improving those unsuitable parameters.

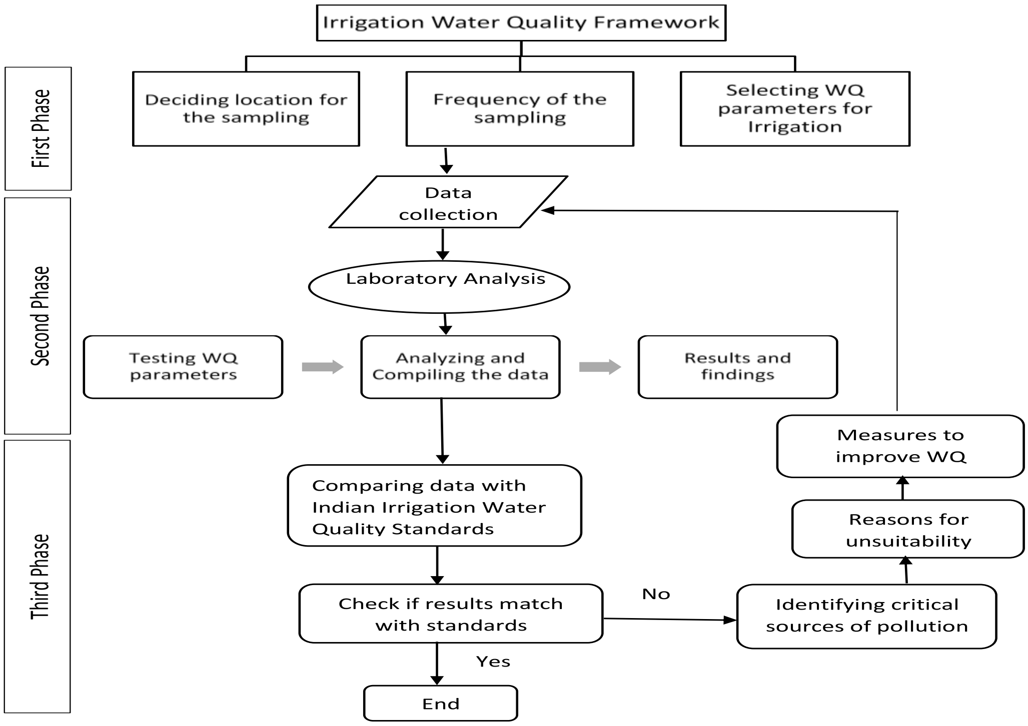

Fig. 3 Irrigation Water Quality Framework

3.2 Sampling strategy and analytical procedure

In this study, environmental variables obtained during a six-year monitoring period (2011–2016) is subjected to investigate the use of WQI on assessing the changing trends and classifying irrigation water quality in the Hathmati River. The water sampling was conducted in dry and wet seasons. Water samples from1m-5m below the water surface were collected. The measurement of water quality was conducted within 24 h after sampling. The results of water quality were summarized in Table 1.

Guidelines are available to evaluate quality of water for irrigation. For irrigation, water can be classified in five classes depending upon its chemical properties.

Water class	Sodium (Na) %	Electrical conductivity (mS/cm)	SAR	RSC meq/l
Excellent	< 20	< 250	< 10	< 1.25
Good	20 - 40	250 – 750	10 – 18	1.25 – 2.0
Medium	40 - 60	750 – 2,250	18 – 26	2.0 – 2.5
Bad	60 – 80	2,250 – 4,000	> 26	2.5 – 3.0
Very bad	> 80	> 4,000	> 26	> 3.0

Table 2 Guidelines for Evaluation of Irrigation Water Quality

3.2.1 Water Quality Indices

WQI is defined as a rating which reflects the combined influence of different water quality parameters on the overall water quality. WQI is a single score derived by considering different important parameters of water quality. It is an integration of the individual effect of all the parameters in right proportion in deciding the quality of water. The most popular method is calculating Water Quality Index to make an assessment by translating large number of variables into a single digital number (Abbasi and Abbasi, 2012). The primary WQI was suggested by Horton (1965) and subsequently other ideas were suggested as improvements to the original method. Numerous WQIs have been developed and approved around the world (Prasad and Kumari, 2008; Reza and Singh, 2010; Manoj et al., 2012; Dede, 2013), the differences between them being the statistical incorporation and translation of parameter values (Abbasi and Abbasi, 2012; Alobaidy et al., 2010; Lumb et al., 2011).

Parameter	**Himmatnagar**			**Khandhol**			**Mankdi**			**Avg of three stations**
	Range	**Avg**	**Std dev**	**Range**	**Avg**	**Std dev**	**Range**	**Avg**	**Std dev**	
pH	7.15-8.10	7.64	0.25	7.10-7.75	7.46	0.14	7.20-7.80	7.47	0.14	7.52
EC	8.11-2674	859.20	529.72	103-489	265.73	90.05	159-725	408.13	153.55	511.02
TDS	71-1440	552.25	328.05	77-752	166.36	103.15	132-475	256.00	77.03	324.87
P-Tot	0-3.02	0.33	0.56	0-2.62	0.37	0.59	0-2.09	0.29	0.43	0.33
Ca	12-72	35.03	14.40	12-36	22.04	6.12	16-44	25.52	7.28	27.53
Mg	7.29-72.90	31.68	16.37	4.86-46.17	14.08	7.42	7.29-36.45	17.53	5.25	21.10
Na	4.30-191.50	65.39	46.14	3.67-117	11.12	18.37	11.40-41.40	25.28	6.96	33.93
K	1.30-82	10.94	12.55	1-77	5.07	11.88	0.6-36.50	3.34	5.76	6.45
Cl	7.10-284	96.25	65.20	7.10-163.30	17.92	25.91	21.30-63.90	38.72	10.75	50.96
SO4	1-71.18	33.01	17.70	1.50-75.50	10.68	11.63	1.20-34.20	13.22	6.41	18.97
CO3	0-33	8.19	9.77	0-18	3.45	4.85	0-21	5.83	5.58	5.82
HCO3	51.90-366	179.09	78.10	40-48.80	103.28	37.74	64.10-198.30	120.23	31.25	134.20
F	0.05-0.45	0.18	0.10	0.05-0.42	0.13	0.07	0.05-0.28	0.16	0.07	0.16
HAR-Total	70.38-362.92	219.59	89.33	50.25-272.38	113.78	36.23	100.50-211.88	136.85	26.75	156.74
B	0-0.25	0.09	0.08	0-0.13	0.02	0.03	0-0.19	0.05	0.06	0.05
SAR	0.20-4.45	1.77	1.04	0.14-3.10	0.41	0.48	0.47-1.57	0.95	0.24	1.04
NO3-N	0-22	5.11	6.30	0-15.20	1.92	3.58	0-5.16	0.89	1.39	2.64
% Na	9.17-53.17	33.15	10.20	5.45-40.86	13.50	6.78	14.19-41.46	27.36	5.14	24.67
RSC	0	0	0	0	0	0	0-0.4	0	0	0

Table 1 WQ Parameters for Irrigation Water

In order to rapidly and easily obtain the information of water quality with a global vision, a water quality index (WQI) has been popularly applied in monitoring water quality in recent years, (Akkoyunlu and Akiner, 2012; Debels et al., 2005; Hoseinzadeh et al., 2015; Kannel et al., 2007; Pesce and Wunderlin, 2000; Suratman et al., 2015). It is proved that WQI is really a practical approach considering critical environmental variables which represent the pollution conditions in water body (Simões et al., 2008). Moreover, WQI can facilitate the changing trends of water quality. However, the calculation of WQI has been developed with different methods. In general, similar physical-chemical variables are considered, but the statistical integrations of variables are different among these methods in different reports.

3.2.2 Calculation of The Water Quality Index

For calculating WQI, BIS/FAO (BIS 10500, 1991/2002/2004 or FAO 1985) was used. Each of the 19 parameters (pH, EC, TDS, Phosphates, Ca, Mg, Na, K, Chlorides, Sulphate, Carbonate, Bicarbonate, Fluoride, Total hardness, Boron, Sodium Adsorption Ratio, Nitrates, % Na and RSC) for three stations has been assessed for deciding the suitability of Hathmati river water for irrigation purpose.

WQI is generally computed in three steps by several researchers (Water programme, 2007, Ramkrishnaiah et al 2009). Here a different approach of assigning weightage was considered to identify and highlight the location specific reasons for contamination of water.

At first, each parameter was assigned a weight (wi) according to its relative importance in overall quality of water for irrigation purposes based on percent of samples within the permissible limit as per the standards. The quality parameters will be assigned weights of 5, 4, 3, 2, 1 when 0-20, 21-40, 41-60, 61-80 and 81-100 % of samples are within the permissible limit respectively (Raychaudhuri et al 2011).

Secondly, the relative weight (Wi) is calculated using the equation:

$$\mathrm{Wi} = \frac{\mathrm{wi}}{\sum_{i=1}^{n} \mathrm{wi}} \quad (1)$$

where, Wi is the relative weight, wi is the weight of each parameter and n is the number of parameters.

In third step, quality rating scale (qi) has been assigned for each parameter by dividing its concentration in each water sample by its respective standard according to BIS guidelines and multiplying it with 100:

$$\mathrm{qi} = (\mathrm{Ci} \;/\; \mathrm{Si}) \times 100 \quad (2)$$

where qi is quality rating, Ci is the concentration of each parameter in each sample in mg/l, and Si is the Indian irrigation water standard for each parameter in mg/l according to the BIS 10500, 1991 or FAO guidelines respectively.

First SI is determined for each parameter, then it is used to determine the WQI as per the following equation

$$\mathrm{SIi} = \mathrm{Wi} \,.\, \mathrm{qi} \quad (3)$$

$$\mathrm{WQI} = \sum_{i=1}^{n} \mathrm{SIi} \quad (4)$$

SIi is the subindex of i^{th} parameter; qi is the rating of i^{th} parameter and n is the number of parameters.

The chemical analyses of the surface water and the percent compliance with the FAO guidelines/Indian Standards were estimated. For irrigation use the computed WQI values are classified into four categories based on the restrictions viz., none, slight, moderate and severe with WQI ranging as <150, 151-300, 301-450 and > 450 respectively (Raychaudhuri et al. 2014).

Weight (wi) was assigned to each parameter according to its relative importance in the overall quality of water for irrigation purposes as well as percent compliance from the FAO standards (Table 3). The parameter K has been assigned maximum weight of 4 due to its importance in water quality assessment as well as 60 % or more than 60 % of the samples are beyond the permissible limit. All other parameters are given the minimum weight of 1 as >= 80 % of the samples are within the permissible limit and of no harm for irrigation use.

The second step was followed and relative weight was assigned as per table3.

Parameter	**Units**	**FAO Standards**	**% compliance**	**Weight wi**	**Relative Weight Wi**
pH	--	6.0-8.5	100	1	0.04545
EC		1000	85.71	1	0.04545
TDS	mg/l	2000	100	1	0.04545
P-Tot	mg/l	2	96.43	1	0.04545
Ca	mg/l	400	100	1	0.04545
Mg	mg/l	60	98.21	1	0.04545
Na	mg/l	920	100	1	0.04545
K	mg/l	2	22.32	4	0.1818
Cl	mg/l	1065	100	1	0.04545
SO4	mg/l	1920	100	1	0.04545
CO3	mg/l	60	100	1	0.04545
HCO3	mg/l	610	100	1	0.04545
F	mg/l	1.5	100	1	0.04545
HAR-Total	mg/l	712	100	1	0.04545
B	mg/l	2	100	1	0.04545
SAR	--	3	93.75	1	0.04545
NO3-N	mg/l	45	100	1	0.04545
% Na	%	60	100	1	0.04545
RSC	--	2.50	100	1	0.04545
			Total	22	

Table 3 Weightage assigned to individual parameters

IV. RESULTS AND DISCUSSIONS

The WQI computed ranges from 45.80 at Mankdi to 122.86 at Himmatnagar (Table 4).

The lowest WQI value of 45.80 was recorded at Mankdi, which indicates no restrictions for using water for Irrigation. The WQI values of Khandhol and Himmatnagar were 58.01 and 122.86 respectively which also indicates no restrictions for using water for Irrigation. WQI for overall Hathmati river is 75.55. Majority of the samples are of good quality followed with no restrictions (Fig. 4).

Location	pH	EC	TDS	P-Tot	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	F	HAR-T	B	SAR	NO_3-N	% Na	RSC	WQI
HIMMAT NAGAR	4.09	3.91	1.25	0.75	0.40	2.40	0.32	99.44	0.41	0.08	0.62	1.33	0.55	1.40	0.20	2.68	0.52	2.51	0.00	122.86
KHANDHOL	3.99	1.21	0.38	0.84	0.25	1.07	0.05	46.09	0.08	0.03	0.26	0.77	0.39	0.73	0.05	0.62	0.19	1.02	0.00	58.01
MANKDI	3.99	1.85	0.58	0.66	0.29	1.33	0.12	30.36	0.17	0.03	0.44	0.90	0.48	0.87	0.11	1.44	0.09	2.07	0.00	45.80
HATHMATI RIVER	4.02	2.32	0.74	0.75	0.31	1.60	0.17	58.63	0.22	0.04	0.44	1.00	0.48	1.00	0.11	1.58	0.27	1.87	0.00	75.55

Table 4 Sub Index of all the parameters and Water Quality Index of surface water from different locations

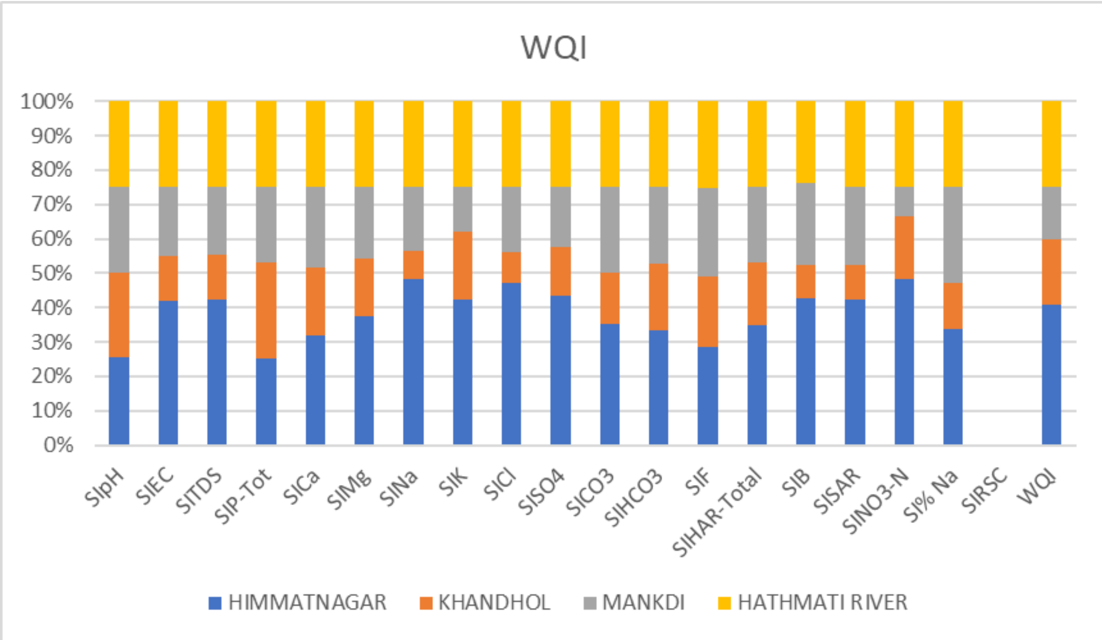

Fig. 4 WQI stacked column

The high value of WQI has been found at these locations mainly due to higher values of potassium in the surface water which can be due to over use of fertilizers (Fig. 5).

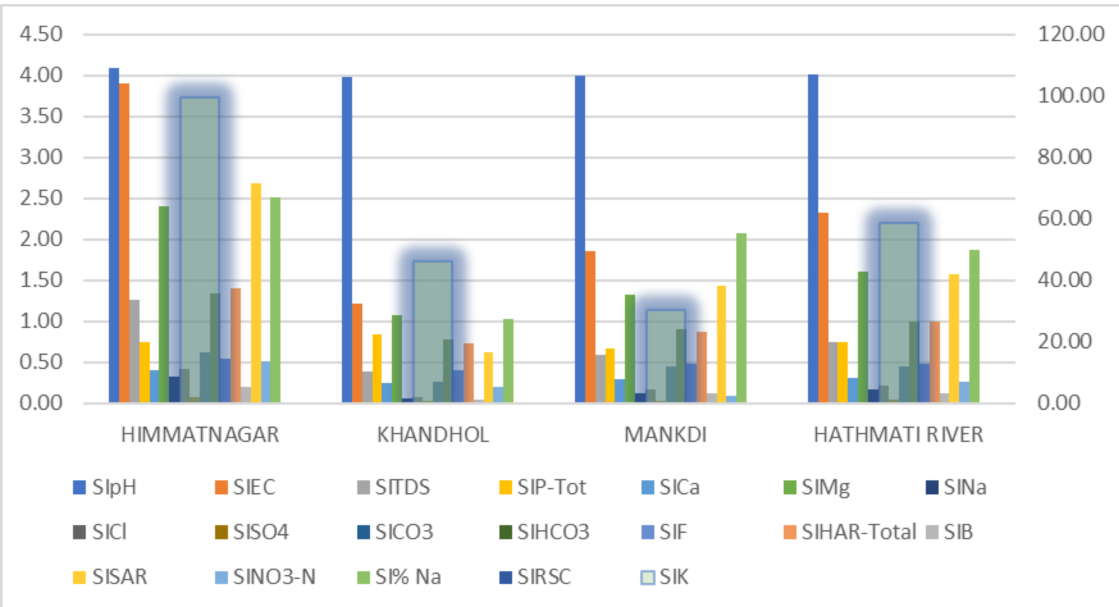

Fig. 5 WQI for all parameters at different locations

V. CONCLUSIONS AND RECOMMENDATIONS

There was a reduction in WQI at downstream as site is near to urban area and various pollutants and also large quantity of return flow from agricultural land are entering into river water. It has been cleared that during the path of Hathmati river Water Quality is good at upstream sub watersheds Mankdi and Khandhol which contains 16-17% of agricultural land and also contains water bodies while at downstream, Himmatnagar sub watershed contains nearly 53% of agricultural land and due to which use of fertilizers by farmers is very excessive. Mostly Indian soils are low in N content so there is no effect of Nitrogen from fertilizers. Potassium - another element that contributes to poor water quality could be attributed to the applications of nitrogen-phosphorus-potassium (NPK) fertilizers by the farmers as well as may be from the nature of soil and sub-surface formations. The WQI developed is an integration of different parameters important for maintaining water quality. It was found to be an important tool in assessing the suitability of water for irrigation. It will also help in identifying the causative factor and its level of contamination which in turn will help in resolving the contaminants.

In Hathmati watershed surface water is the main source of irrigation and excessive use of fertilizers in rivers and land deteriorates the water quality. Agriculture is the largest sector for fresh water use in Hathmati watershed. The WQI of surface water along Hathmati watershed was estimated for irrigation based on the water quality data obtained for SWDC, Gandhinagar and also validated through ground trothing. All of the samples collected were found of good quality with no restrictions. It has been observed that in some areas there is high potassium concentration for which the water has severe restriction for irrigation. Long-term planting without K fertilizers may results in the decrease of K fertility. We should avoid excessive use of chemicals for agricultural activities and reclamation of land. Nevertheless, there are also some management practices which include proper leaching, increasing irrigation frequencies, avoiding overhead irrigation, avoiding the use of fertilizers containing chloride or boron, selecting the right crops, etc.

It may be concluded from the study that WQI defined based on chemical characteristics have been acceptable and can predict the suitability for irrigation purpose based on Indian standards and FAO. The methodology is quite simple, adaptable and programmable to develop a software towards decision support system for monitoring water quality. Generally, once a trend in non-point pollution sets in, as use of fertilizers accelerates day by day, there is a possible risk of water quality deterioration in near future.

REFERENCES

[1]. Abbasi, T., Abbasi, S.A., 2012. “Water quality indices. Elsevier, Amsterdam, Netherlad, pp. 384”.
[2]. Ahuja, S., 2003. “Monitoring water quality pollution assessment, analysis, and remediation. Elsevier, Amsterdam, Netherlands, pp. 375”.
[3]. Al-Gizzy H.S.N., 2005. “Hydrology of Shatt Al-Gharraf and its investment, M.Sc Thesis, Univ. of Basrah, Basrah, pp. 130pp”.
[4]. Alobaidy, A.H.M.J., Abid, H.S., Maulood, B.K., 2010. “Application of water quality index for Dokan Lake Ecosystem, Iraq. J. Water Res. Prot. 2, 792–798”.
[5]. Couillard, D. and Lefebvre, Y. (1985). “Analysis of water indices. Journal of Environmental Management, 21(2): 161-179”.
[6]. Dede, O.T., Telci, I.T., Aral, M.M., 2013. “The Use of Water Quality Index Models for the Evaluation of Surface Water Quality: A Case Study for Kirmir Basin, Ankara, Turkey. Water Qual. Expo Health 5, 41–56”.
[7]. Dinius, S.H. (1987). “Design of an index of water quality. Water Resources Bulletin, 23(5): 833-843”.
[8]. Dunnette, D.A. (1980). “A geographically variable water quality Index used in Oregon. Journal of Water Pollution Control Federation, 51(1): 53-61”.
[9]. Ewaid, S.H., 2016. “Water Quality Assessment of Al – Gharraf River, South of Iraq by the Canadian Water Quality Index (CCME WQI)”. Iraqi J. Sci. 57 (2A), 878–885.
[10]. Horton, R.K., 1965. “An index number system for rating water quality. J. Walter Poll. Cont. Fed. 37 (3), 300–306”.
[11]. Joung, H.M., Miller, W.W., Mahannah, C.N. and Guittjens, J.C. (1979). “A generalized water quality index based on multivariate factor analysis. Journal of Environmental Quality, 8(1): 95-100”.
[12]. Landwehr, J.M. and Deininger, R.A. (1974). Discussion: “An objective water quality index. Journal of Water Pollution Control Federation, 46(7): 1804-1809”.
[13]. Lumb, A., Sharma, T.C., Bibeault, J.F., 2011. “A Review of genesis and evolution of water quality index (WQI) directions. Water Qual. Expo. Health 3, 11–24”.
[14]. Meiloul, A.J. and Collins, M. (1998). “A proposed index for aquifer water-quality

assessment: the case of Israel's Sharon region. Journal of Environmental Management, 54: 131-142”.

[15]. Richardson, A.M. (1997). “Development of an estuarine water quality index (eWQI) for New South Wales. BSc. (Honours), University of Sydney. Sydney”.

[16]. Stambuk - Giljanovic, N. (1999). “Water Quality evaluation by index in Dalmatia. Water Research, 33(16): 3423-3440”.

[17]. Yehia, H., Sabae, S., 2011. “Microbial pollution of water in El-salam canal Egypt.American-Eurasian J. Agric. Environ. Sci. 11 (2), 305–309”.

[18]. IS 10500: 2012. “Indian Standard DRINKING WATER — SPECIFICATION (Second Revision)”.

Payal Shah, et. al. “Integrated Watershed Monitoring Framework for Irrigation Water Quality: Targeting Critical Source Areas.” *International Journal of Engineering Research and Applications (IJERA)*, vol.11 (1), 2021, pp 17-25.