Analysis of physico-chemical water pollution indicators by statistical evaluation & water quality index of Khan River at Indore, India

Devendra Dohare[1], Abhineet Nighojkar[2], Atul Kotiya[3]
[1]Assistant Professor, Civil Engineering & Applied Mechanics Department SGSITS Indore, MP, INDIA
[2]M-Tech (Environmental Engineer), Civil Engineering & Applied Mechanics Department SGSITS Indore, MP, INDIA
[3]Scientist, Regional Lab Madhya Pradesh Pollution Control Board, Indore, MP, INDIA

Abstract-The present study was done with the physico-chemical studies and assessed water quality by using the Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI). Parameter namely þH,EC,TDS,Na^+,K^+,Cl^-,SO_4 ,SAR, %Na and Boron were determined at important location of River Khan for post monsoon and winter season for a period of seven month (NOV 2013 to May 2014) from four different sites. The results were compared with standard value. The results obtained from the application of CCME WQI concludes that Khan River has all the parameter of class E standard. Hence this river is class E river and the Water can be used for irrigation, industrial cooling and controlled waste disposal.

Keywords*:* CCME WQI, Class E, Khan River, Physico-Chemical parameters, Statistical Evaluation

1. INTRODUCTION

To improve the economic condition of the country, the government of India is continuously encouraging industrialization .The industrial growth was essential but the pollution of the environment and water takes place due to it. It will take away the valuable resources and the human health, but the human health is again most essential for the industrialization.

The air and water are not depleted but rather render unfit for use. Water pollution is a large problem. In the wake of rising population, rapid urbanization and industrialization .Most of the water become waste water and may carry heavy load of polluting agents & substances. These polluting substances which may be present In the water ,when discharge in to the river or lake water ,change the physical ,chemical and biological characteristics of the water sources [5] , and thus curtail the other beneficial uses ,such as drinking ,open bath, recreation ,agriculture & fish culture etc. The chemicals generating from the industries and their subsequent release to their surrounding as well as the domestic water released into the drains raised a wide spread and increasing public concern over their adverse effects on human health and environment [3].

The khan river emerging from the uphill of Kshipra starts the journey flowing through Limbodi, Teen Imli, Azad Nagar, Daulatganj finally touching Krishnapura Chhatri. The level of pollution crossed the threshold after industrialization began in 60's. River Khan is highly polluted due to the discharge of domestic waste and Industrial waste from various Industries (Located within the catchment area of the river) like textile,mills ,chemical ,pharmaceuticals, electroplating , paper mill ,food processing etc. Located in different industrial estate of Indore city. In monsoon, these deposits along with the agricultural runoff pollutes river Khan & Kshipra, also endanger the aquatic life [8].

Table 1 Location of sampling stations

S.no	Sampling stations	Latitude and Longitude	Distance from krishnapura in km	Upstream or Downstream point of pollution	Remarks
1	Krishnapura Chhatri	22°72' N, 75°86' E	00	Upstream	Domestic flow in septic condition
2	Khatipura Bridge	22°72' N, 75°86' E	06	Upstream	Domestic+ Industrial waste
3	Khan bridge Sanwer by pass road	23°07' N,75°81' E	36	Downstream	Algal growth water used for irrigation
4	Sanwer bridge	23°07' N ,75°81' E	40	Downstream	Very high Algal growth water used for irrigation

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2. MATERIAL AND METHODS

2.1 **Sampling procedure and preservation**

The physico-chemical parameters of surface water of khan river studied in the month of November 2013-April 2014(post monsoon and winter) for a period of six month from four different sites. Water samples were analyzed for some physico-chemical parameters are given in table 3. The results obtained were compared with Class-E River standard IS 2296-1982[6].

For the study, Grab sample theory was selected as the base and the so the study was done at mid stream of river. After collecting the samples from the sites , it was brought to the laboratory within three hours to ensure the character of the parameters are same as it was found at the time of collection and after that it was preserved .On the following day ,all the experiments were done[9].

2.2 **Analytical Procedure**

Field parameters like temperature, þH, EC, turbidity, DO and TDS were determine at sampling site while other parameters were analyzed in laboratory using standard method. Whereas other such as total hardness by EDTA, alkalinity by volumetric methods, chlorides by titrating with AgNO3, sulphate and boron by spectro-photometric method. Na^+ and K^+ by flame photometer [1], [7].

2.3 **Data Analysis**

Mean, Variance, Standard Deviation and % Co variance were calculated and present in table-1 and correlation matrix for the water quality parameters were calculated as per standard method obtained value discussed as negative and positive relation with various parameters across the study area.

2.4 Water Quality Index:

The CCME WQI is based on a formula developed by the British Columbia Ministry of Environment, Lands and Parks that was modified by Alberta Environment, The Index incorporates three elements: scope - the number of variables not meeting water quality objectives; frequency - the number of times these objectives are not met; and amplitude - the amount by which the objectives are not met. The index produces a number between 0 (worst water quality) and 100 (best water quality). These numbers are divided into 5 descriptive categories to simplify presentation [2].

The CCME Water Quality Index takes the form:

$$\text{WQI} = 100 - \left(\frac{\sqrt{F1^2+F2^2+F3^2}}{1.732}\right)$$

Where

F1 represents the percentage of variables that depart from their objectives at least once, relative to the total number of variables measured:

$$F1 = \left[\frac{\text{No .of failed variables}}{\text{Total no of variables}}\right] X\ 100$$

F2 represents the percentage of failed individual tests:

$$F2 = \left[\frac{\text{No. of failed test}}{\text{Total no of test}}\right] X\ 100$$

F3 is an asymptotic capping function that scales the normalized sum of the excursions from objectives (nse)

To yield a range between 0 and 100:

$$F3 = \left[\frac{\text{nse}}{0.01\text{nse} + 0.01}\right]$$

The collective amount by which individual tests are out of compliance is calculated by summing the departures of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those departing from objectives). The nse variable is expressed as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\text{No of tests}}$$

For the cases in which the test value must not exceed the objective:

$$\text{excursion}_i = \left(\frac{\text{Failed test value}_i}{\text{Objective}_j}\right) - 1$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_i = \left(\frac{\text{Objective}_j}{\text{Failed test value}_i}\right) - 1$$

For the cases in which the objective is zero

$$\text{excursion}_i = \text{Failed test value}_i$$

3. RESULTS AND DISCUSSION

The þH of the surface water at all sites was found to be of alkaline in nature. It was found that þH value rises with the rise in temperature which marks the presence of

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bicarbonates and carbonates of alkali and alkaline earth metals [10]. The þH values of water samples varied between 7.30 to 7.8 and the mean value was 7.6.

In the present study the value of Electrical Conductivity of river khan ranged from 947 to 1415 µS/cm and the average value was 1195 µS/cm. The higher EC of the river khan is due to domestic waste pollution. High EC values were observed at four sampling points namely S1, S2, S3, and S4 indicating the presence of high amount of dissolved inorganic substances in ionized form in river khan.

Total dissolved solids denote mainly the various kinds of mineral present in the water [11]. The amount of total dissolve solid ranges between 701 to 964 mg/L and the mean value was 847 mg/L. Due to contamination of domestic waste water, garbage, fertilizer, etc in the natural surface water, the value of TDS was reported to be high.

Alkalinity of water is due to the presence of hydroxides, carbonates and bicarbonates. Higher alkalinity, more neutralized agent needed to counteract it [10]. The amount of total alkalinity recorded ranges between 420 to 640 mg/L and the mean value was 536 mg/L. The addition of large amount of sewage waste and organic pollutant also effect photosynthesis rate, which also result in death of plants and living organism.

Hardness is caused by divalent metallic ions that are capable of reacting with sops to form precipitate. And with certain anions present in the water to form scale. Hardness of water mainly depends upon the amount of calcium or magnesium salts or both [10]. The hardness values ranged from 360 mg/L to 575 mg/L and the mean value was 468 mg/L.

The Sulphate ranged from 31 mg/L to 50 mg/L and the mean value was 41 mg/L.

The greater source of chlorides in water is disposal of sewage and industrial waste. The amount of chloride recorded in the water ranged between 120 mg/L to 420 mg/L and the mean value was 300 mg/L. The high chloride concentration of the water may be due to high rate of evaporation or due to organic waste from animals.

The Sodium Absorption Ratio in the study area varied in the ranged 6.86 mg/L to 15.28 mg/L and the mean value was 9.77 mg/L and % Na ranged 16.14 mg/L to 34.42 mg/L and the mean value was 23.19 mg/L found within the prescribed limit. If the values are exceeding the stipulated standard limits these may have adverse effects on crop.

3.1 Correlation Analysis

Correlation Analysis is a statistical technique used to indicate the nature and degree of relationship existing between one variable and the other(s). It is also used along with regression analysis to measure how well the regression line explains the variations of the dependent variable with the independent variable [4]. Out of the 276 correlation coefficient, eight strong correlation between EC and TDS(.87), Temperature and EC(.85), Na^+ and K^+ (.92),Na^+ and SAR(.96), K^+ and SAR (.91), Na^+ and %Na (.91) ,K^+ and %Na (.89), SAR and %Na(.98) were found . Negative correlation values were found in 113 cases. Most parameter shows weak correlation with the other parameters.

3.2 Water Quality Index

The results obtained with respect to the physico chemical parameters of the water samples of the River Khan are shown in Tables 1 to 4. By applying the equations in the materials and methods explained, the values of F1, F2 and F3 are calculated for stations S1, S2,S3 and S4. The F1, F2 and F3 values and CCME WQI values are present in the table 2 respectively.

In CCME WQI model, the index changes in direct proportion to changes in all three factors. Accordingly, the final WQI value was calculated to be 42 at station S1 and S4 respectively. At station S2 and the WQI calculated was 41.Based on these findings all sites are categorized as poor (Range 0 to 44). The test value shown in table 1 to 4 represents the failed values of the water chemistry variables at all the stations objective of Sodium, Potassium is zero hence the execution are equivalent to the number of times by which a concentration is greater than (or less than) the objective.

Table 2 the calculated values of factors and CWQI for class E

Data Summary	F1 (Scope)	F2 (Frequency)	F3 (Amplitude)	CWQI	Categorization (Rating)
Krishnapura chhatri	30	22	93.16	42	poor
Khatipura	30	22	95.14	41	Poor
Khan Bridge Sanwer by pass road	30	22	94.44	41	Poor
Sanwer bridge	30	22	94.55	42	Poor

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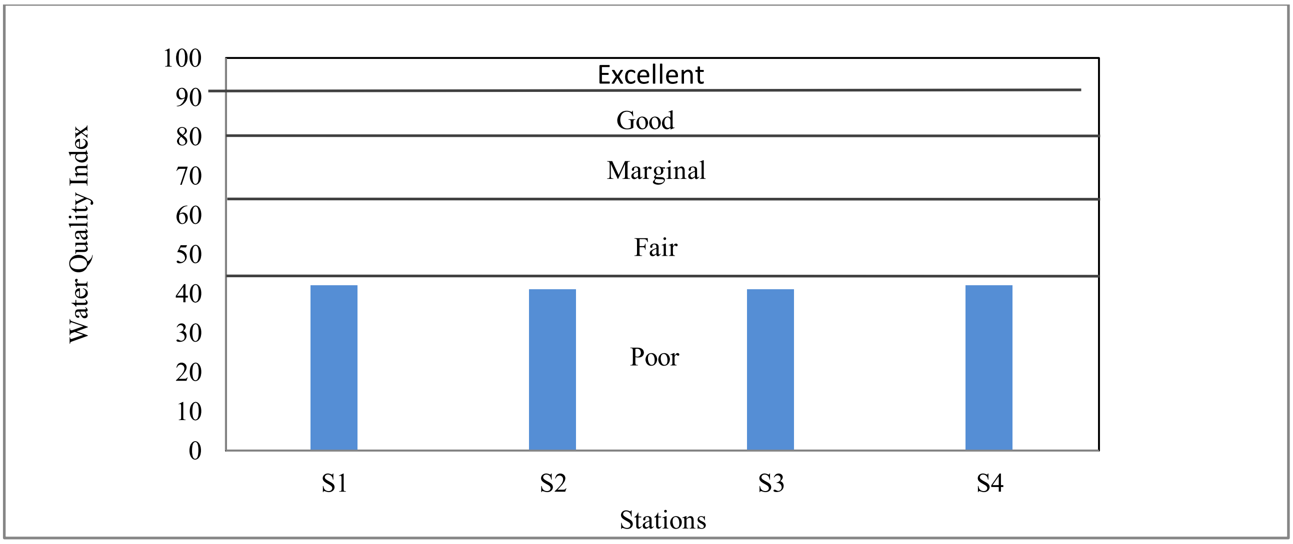

Figure 1 Canadian Water Quality Index for Class E-river

Table 1 Statistical summary of surface water quality of River Khan

Water parameters	Units	Minimum	Maximum	Mean	Variance	Standard Deviation	%CV
Turbidity	mg/l	25.30	70.95	47.46	140.80	11.86	.25
Temperature	ºC	18.75	29.97	25.01	17.14	4.14	.165
EC	µs/cm	947.25	1415.25	1194.98	25421.39	159.4409	.134
TDS	mg/l	701	963.87	846.90	4708.22	68.61	.081
þH	-	7.305	7.8	7.56	0.041	0.144	.019
DO	mg/l	0	1.225	0.694	0.109	0.331	.476
BOD (3d,27ºC)	mg/l	25.5	72	47.38	217.0	14.73	.310
COD	mg/l	58.5	123.75	95.30	409.17	20.22	.212
Cl^- (as Cl)	mg/l	120	420	300.44	13430.6	115.89	.380
TA(as $CaCO_3$)	mg/l	420	640	536.32	3374.59	58.09	.108
TH(as $CaCO_3$)	mg/l	360	575	468.30	3334.52	57.74	.123
Ca^{2+}(as Ca)	mg/l	120	455	273.73	6659.33	81.60	.294
Mg^{2+}(as Mg)	mg/l	117.5	352.5	192.25	3144.76	112.15	.583
SO_4 (as SO_4)	mg/l	31.73	49.955	41.36	19.48	4.414	.106
F (as F)	mg/l	0.117	0.945	0.549	0.613	0.253	.460
B (as B)	mg/l	0.619	2.00	0.993	0.133	0.365	.367
NH_3 N (as N)	mg/l	6.337	7.015	6.74	0.038	0.196	.290
NO_3 (as NO_3)	mg/l	12.335	22.29	16.50	9.63	3.104	.251
PO_4 (as P)	mg/l	0.5345	3.63	1.889	2.35	1.086	.577
Na^+	mg/l	102.17	232.78	148.26	1358.60	36.859	.248
K^+	mg/l	8.75	30.24	18.29	48.21	6.943	.379
SAR	-	6.86	15.28	9.77	7.12	2.669	.272
%Na	-	16.14	34.42	23.19	27.36	5.231	.225

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Table 3 Monthly averages of various physico-chemical parameters of all the sampling sites 1-4 during November 2013 - May 2014

Parameters	Units	15-Nov	30-Nov	15-Dec	30-Dec	15-Jan	30-Jan	15-Feb	28-Feb	15-Mar	30-Mar	15-Apr	30-Apr	15-May	30-May
Turbidity	NTU	30.75	35	40	44.59	49.01	55.53	53.5	25.3	70.93	53.48	59.17	49.85	49.87	47.45
Temperature	°C	24.25	25.50	22.25	18.75	20.37	20.75	20.1	23.1	27.75	29.45	28.89	29.27	29.87	29.97
EC	µs/cm	1043	1138	1123	1108	1140	1026	1051	947	1246	1361	1362	1363	1402	1415
TDS	mg/l	750	750	818	837	857	879	793	831	701	840	895	882	875	963
þH	-	7.80	7.82	7.65	7.50	7.48	7.47	7.39	7.30	7.43	7.55	7.58	7.59	7.64	7.61
DO	mg/l	1.12	0.77	1	1.22	0	0.7	0.7	1	0.7	0.7	.55	.575	.275	0
BOD (3d,27°C)	mg/l	72	25	66	28	71	55	45	46	35	36	39	44	54	48
COD	mg/l	120	68	124	120	118	92	80	77	59	95	96	98	91	100
Cl^- (as Cl)	mg/l	181	168	123	120	206	340	420	280	380	387	410	395	380	420
TA (as $CaCO_3$)	mg/l	562	487	501	515	537	572	480	420	575	640	606	582	493	535
TH (as $CaCO_3$)	mg/l	392	527	551	575	440	360	470	472	417	447	467	482	467	482
Ca^{2+} (as Ca)	mg/l	207	295	340	455	252	185	265	120	220	255	290	288	293	365
Mg^{2+} (as Mg)	mg/l	185	232	211	120	190	175	205	352	197	192	185	153	174	117
SO_4 (as SO_4)	mg/l	37.12	37.32	40.36	41.12	39.74	41.4	45.8	43.8	42.30	31.73	40.50	43.23	49.95	45.09
F (as F)	mg/l	.627	.613	.547	.732	.117	.194	.184	.577	.380	.628	.550	.665	.945	.922
B (as B)	mg/l	.949	1.43	.977	.619	.875	.735	.627	.735	2.0	.810	.95	.89	1.10	1.18
NH_3 N (as N)	mg/l	6.87	6.89	6.55	6.49	6.95	6.78	7.01	6.68	6.60	6.33	6.84	6.67	6.96	6.76
NO_3 (as NO_3)	mg/l	12.33	12.97	7.95	20.54	17.27	19.6	15.6	12.4	17.25	22.29	15.84	17.52	16.58	12.75
PO_4 (as P)	mg/l	.534	.920	.580	1.62	1.80	.734	.852	1.66	2.72	3.63	3.46	2.97	2.80	2.10
Na^+	mg/l	102	102	113	125	164	203	232	145	147	133	135	137	175	154
K^+	mg/l	8.75	8.78	9.69	10.65	19.51	38.3	30.2	21.7	20.85	20.13	14.22	19.37	22.60	21.25
SAR	-	7.33	7.01	6.86	7.35	11.22	15.22	15.2	9.53	10.21	8.95	8.84	9.00	10.09	9.95
%Na	-	20.47	16.14	16.89	17.59	26.72	34.4	32.1	22.7	25.04	21.99	21.64	21.91	23.55	23.37

4. CONCLUSION

The present study reveals that the significant physico-chemical parameters analyzed for the water samples of river khan in at all the four stations during the study period (Nov 2013 to May 2014). The increase in the values of parameters from Station 1 to Station 4 clearly indicates increasing amount of pollutants in the Khan River. It was investigated that there is urgent need to take measures, to minimize pollution load in the Khan River. Among all the sampling sites, Krishna pura, khatipura, Khan Bridge at Sanwer by pass road and Sanwer Bridge are heavily polluted.

The study reveals that DO, BOD& COD values are not in permissible limit. There is almost no DO found at all stations while BOD from organic material contamination in water is exceeding to a benchmark big extent and the COD is matching the limit of industrial usage purpose.

The khan river water is highly polluted due to presence of high level of turbidity due to soil runoff, total alkalinity due to dissolve gases,

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total hardness due to presence of calcium(Ca^{2+}) and magnesium(Mg^{2+}) ions in a water supply, nitrate due to runoff from fertilizer use; leaking from septic tanks, sewage; erosion of natural deposits, phosphate.

The presence of above parameters shows the extent of the pollution in River Khan. Since these parameters are not present in any type of River water fit for use (Class A-Drinking water without conventional treatment, Class B- for outdoor bathing, Class C- drinking water with conventional treatment, Class D-water for fish culture and wild life propagation).

The study had shown evenly spreaded pollution level throughout the run of the rivers. Although the stations S1 &S2 like nallahs flows through the city but stations S3 & S4 one having the same quality even after treatment of the water. Direct use of such quality water for irrigation may leads to bioaccumulation of metals and other toxic substances in vegetables, crops and cereal plants grown at the bank of river which are health hazardous for human. Bulk accumulation of organic waste in Khan River may give rise to many fatal soil borne, air borne and water borne diseases among the inhabitants of the bank area due to spread of micro-organism.

The results obtained from the application of CCME-WQIs model, WQI for Khan River was found in all sites 42 which indicated that water quality of this river was Poor and frequently impaired. Further, condition often departs from natural or desirable levels. This low level of WQI in Khan River could be attributed by 10 numbers of variables and 140 number of test along the period of study by applying the CCME equation on results of water quality analysis.

The results obtained from the application of CCME WQI had concluded that khan River because all the parameter of class E standard. Hence this river is class E river and the Water can be used for irrigation, industrial cooling and controlled waste disposal.

All the parameters were also compared with Class C standards, The CCME results had shown that WQI of the Khan River is poor , indicating the urgent need for prevention of polluting sources and formulation of conservation strategies. This index doesn't give any weighted numbers but treats the values of parameters in mathematical way to ensure that all parameters contribute adequately in the final number of the index.

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