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IMPACT OF DOMESTIC SEWAGE AND INDUSTRIAL EFFLUENT ON WATER QUALITY OF THE KHAN RIVER, INDORE (INDIA)

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ABSTRACT

In the present study, various physico-chemical factors were assessed for the whole year (Jan 2009-Dec 2010), to determine the impact of domestic sewage and industrial effluents on the water quality of the Khan river. Physico-chemical factors like pH, temperature, conductivity, ammonia, nitrate, nitrite, sulphate, phosphate, total hardness, calcium hardness, chloride, BOD, COD, Ca, Na and K were found with maximum concentration during premonsoon. While, concentration of total solids, total suspended solids and DO was maximum during monsoon. The positive correlation was observed among all the physico-chemical factors except DO. The study reveals that the huge influx of domestic sewage and industrial effluent are the key factors enhancing pollution load in the Khan River.

KEY WORDS : Pollution, Domestic sewage, Industrial effluent, Physico-chemical factors

INTRODUCTION

Rivers throughout the world play significant role in the development of mankind and civilization. Industrialization and urbanization has resulted in an increase of pollutants, most of which being dumped into rivers (Gowd and Govil, 2008). Indore, the commercial capital of the state of Madhya Pradesh (India), is a rapidly growing city on account of flourishing trade and commerce, has developed on the bank of three small streams the Khan, the Chandrabhaga and the Saraswati. Both streams the Chandrabhaga and the Saraswati finally merge into the Khan River. In the last few years, due to the increase of residential colonies and industrial units in the city, the pollution load has increased many folds. The domestic sewage and industrial waste water is carried by below ground and surface drains, which is finally dumped into the Khan River (Rao *et al.,* 1978; Ganasan and Hughes, 1998; Sharma and Dubey, 2011). These sewer lines also receives large amount of municipal waste water and converted into the small *nallahs* (Sharma and Dubey, 2011). This has degraded the quality of the river. Regular monitoring of water quality parameters provides important information for the effective water management (Holloway and Dahlgren, 2001). Therefore, the present work is an attempt to study the impact of influx of domestic sewage and Industrial effluent on various physico-chemical parameters of the Khan River at Indore (M.P.), India, for the year 2009.

MATERIAL AND METHOD

Study Area

The river Khan, a tributary of the river Kshipra originates from the Vindhya range, flows down the forest at the Ralamandal sanctuary and accumulates at Limbodi (a small lake) around the stop dam (Latitude : 22°37'N and longitude : 75°54'E) near Indore, which is regarded as its origin point. It further flows a length of about 64 km through the Indore city, confluences with the Saraswati River at Krishnapura. Along with the river Saraswati it joins the river Kshipra at "Triveni Sangam". Finally, both rivers merge into the Chambal River. The Khan is a non- perennial river. About 110 MLD of sewage of Indore city and 70 MLD of Industrial waste is added to it per day which has worsen the quality of the river.

Depending on the source of pollutants along the course of the river five sampling stations has been selected. These are Limbodi (S1), Zoo (S2), College Bridge (S3), Bhagirathpura Bridge (S4) and Kabitkheri (S5). Limbodi, the first sampling station is surrounded by the village and agricultural fields. Different species of fishes also inhabits this site. Zoo, the second sampling station receives domestic sewage and domestic waste from the poorly developed colonies around it and Azad Nagar. Agricultural runoff and effluent from industries situated at Palda, Animal waste from Zoo and puja offering of the temples are also added to it here. College Bridge (near railway station), the third sampling station lies in the center of the city and receives huge influx of waste water from hospitals, colleges, hostels, wash house along with the pollutants of GPO (Grand Post Office). Bhagirathpura Bridge, the fourth sampling station is surrounded by farming fields and receives effluents from commercial market of Rajwara along with the pollutants of the river Saraswati. Industrial effluents of textile mills, electroplating industries, chemical industries and vanspati factories situated at Polo ground and Bhagirathpura are added to it. Palasia *nallah* containing the domestic sewage of the most populated zone of the city also joins it. Kabitkheri, the fifth sampling station is surrounded by agricultural fields. It receives a huge influx of pollutants of the city from Bhagirathpura, some below ground drains of the various industries located at Sanwer road and agricultural runoffs consisting of pesticides, insecticides and fertilizers also contaminates its quality.

Sampling and Analysis

The surface water samples were collected from the selected sampling stations once in a first week of every month for the year 2009 (Jan 2009 - Dec 2009). Water samples were collected between 8.00 -10.00 am in mouthed, clean, acid washed plastic cans, rinsed with distilled water of two liter capacity. Samples were analyzed for various physico-chemical parameters such as temperature, pH, total Solids, total suspended solids, conductivity, chloride, total hardness, calcium hardness, ammonia, nitrate, nitrite, phosphate, sulphate, sodium, potassium, calcium, DO, BOD and COD. Temperature was measured by a thermometer at site and pH was measured with the help of pH meter in Lab within 1-2 hrs of sample collection. Similarly specific conductivity was measured with digital conductivity meter using single glass electrode. DO was fixed at the site in clean BOD bottles of 300mL capacity and further analysis were done in the laboratory within 1-2 hrs of sample collection. Rest of the parameters including DO was estimated in accordance with the procedure described in the Standard methods for the examination of sewage and Industrial wastes (APHA, AWWA, FSIWA, 2005). The data collected were subjected to Correlation coefficient for statistical analysis, to find both positive and negative correlation among the Physico- chemical parameters of the Khan River.

RESULTS AND DISCUSSION

A marked variation in all the parameters was observed in the Khan River at all the sampling stations.

The average of quantitative analysis of various physico-chemical factors are presented in Table 1

Slight variation in water temperature was observed in the Khan River from site S1 to site S5. Water temperature changes according to the climatic condition but it is also influenced by the kind of effluents added to it (Meitei *et al.,* 2004; Saksena *et al.,* 2008). As river approaches the center of city it is prone to industrial effluents and domestic sewage, which might has lead to the slight rise in temperature. The pH of the surface water at all sites was found towards the alkaline nature. The pH value rises with the rise in temperature which marks the presence of bicarbonates and carbonates of alkali and alkaline earth metals (Jamil, 1991; Sati and Paliwal, 2008). Higher concentration of total solids

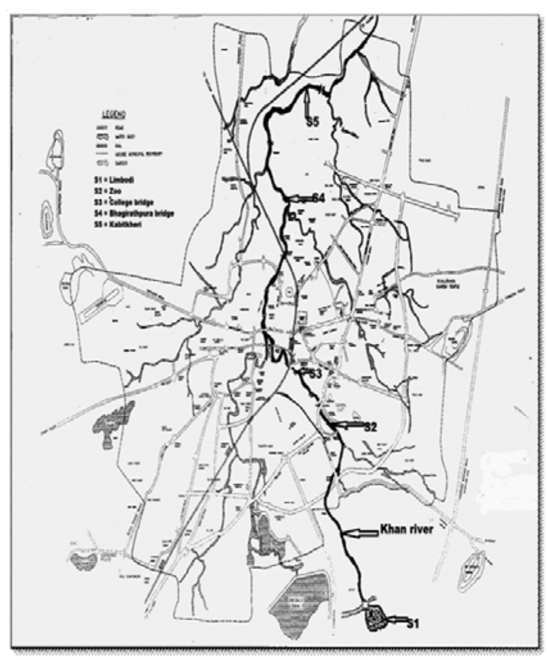


Fig. 1. Map of the Indore city showing the flow of the Khan River through it with sampling stations.

Table 1. Average values of all the physico-chemical parameters of the Khan River in Indore at five sampling stations for the year 2009.

Sampling stations	S1 (Limbodi)	S2 (GPO)	S3 (College bridge)	S4 (Bhagirathpura bridge)	S5 (Kabitkheri)
Parameters	Avg ± SD	Avg ± SD	Avg ± SD	Avg ± SD	Avg ± SD
Water Temperature	23.16 ±3.14	25.55 ± 3.34	26.41 ± 3.51	27.03 ± 3.76	28.09 ± 3.81
pH	7.65 ± 0.08	7.84 ± 0.13	7.87 ± 0.14	7.95 ± 0.14	8.21 ± 0.15
Conductivity	224.55 ± 67.05	1587.25 ± 225.02	1725.16 ± 206.83	1710.83 ± 195.57	1910.16 ± 204.94
Total solids	132.91 ± 149.78	1325.08 ± 129.80	1436.83 ± 130.00	1476.66 ± 143.80	1739.51 ± 146.56
Total Suspended solids	27.08 ± 112.44	153.58 ± 143.48	164.66 ± 152.81	180.83 ± 184.13	212.91 ± 182.21
Total Hardness	144.33 ± 53.83	377.66 ± 20.48	402.00 ± 24.15	391.00 ± 39.87	420.83 ± 41.40
Calcium Hardness	65.77 ± 28.72	250.83 ± 30.75	281.16 ± 25.07	269.83 ± 22.50	321.00 ± 39.07
Chloride	25.76 ± 5.31	182.16 ± 47.78	199.58 ± 49.34	211.00 ± 43.74	236.91 ± 63.89
Ammonia	0.019 ± 0.01	3.276 ± 2.05	5.896 ± 3.16	6.211 ± 2.97	7.6 ± 3.03
Nitrite	0.008 ± 0.01	0.245 ± 0.16	0.271 ± 0.17	0.286 ± 0.17	0.378 ± 0.27
Nitrate	0.403 ± 0.45	8.466 ± 3.67	10.137 ± 4.42	10.98 ± 4.15	12.52 ± 3.83
Phosphate	0.017 ± 0.02	0.397 ± 0.31	0.673 ± 0.45	0.759 ± 0.41	1.196 ± 0.50
Sulphate	1.717 ± 1.37	25.75 ± 8.45	32.91 ± 9.52	36.58 ± 8.98	46.83 ± 9.27
DO	6.51 ± 0.93	0.15 ± 0.27	0.06 ± 0.12	* *	
BOD	3.67 ± 2.97	59.16 ± 31.78	75.08 ± 35.19	82.66 ± 37.76	104.66 ± 32.23
COD	11.08 ± 8.94	267.00 ± 77.26	283.66 ± 77.43	306.16 ± 87.39	342.08 ± 81.96
Ca	35.66 ± 11.48	100.41 ± 12.16	112.58 ± 10.11	108.41 ± 9.50	128.66 ± 15.72
Na	20.88 ± 7.60	94.08 ± 5.10	105.58 ± 8.34	98.41 ± 8.09	126.5 ± 17.57
K	5.44 ± 2.26	19.16 ± 5.35	24.00 ± 21.22	29.83 ± 8.79	38.08 ± 10.71

All the values are expressed in mg/L except pH, water temperature (in 0C), conductivity (µs/cm) and * represents absence of DO.

Table 2. Linear correlation coefficients of physico-chemical parameters of the Khan River in Indore, from Jan 2009- Dec- 2009.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
A	1																		
B	0.939	1																	
C	0.936	0.801	1																
D	0.959	0.848	0.996	1															
E	0.978	0.884	0.986	0.996	1														
F	0.921	0.776	0.999	0.992	0.978	1													
G	0.956	0.844	0.995	0.998	0.991	0.992	1												
H	0.961	0.841	0.996	0.999	0.996	0.992	0.996	1											
I	0.988	0.902	0.923	0.941	0.956	0.91	0.944	0.946	1										
J	0.981	0.909	0.978	0.992	0.997	0.968	0.99	0.989	0.958	1									
K	0.979	0.865	0.987	0.994	0.997	0.98	0.991	0.997	0.968	0.991	1								
L	0.976	0.978	0.854	0.89	0.92	0.833	0.893	0.889	0.968	0.937	0.917	1							
M	0.998	0.93	0.955	0.974	0.987	0.941	0.972	0.975	0.985	0.991	0.987	0.968	1						
N	-0.88	-0.71	-0.99	-0.97	-0.95	-0.99	-0.97	-0.98	-0.862	-0.94	-0.96	-0.77	-0.9	1					
O	0.997	0.923	0.96	0.978	0.99	0.948	0.977	0.979	0.985	0.993	0.99	0.963	1	-0.91	1				
P	0.953	0.83	0.997	0.998	0.994	0.993	0.994	0.999	0.934	0.985	0.994	0.875	0.968	-0.981	0.972	1			
Q	0.962	0.858	0.992	0.997	0.992	0.988	1	0.994	0.952	0.992	0.992	0.905	0.978	-0.962	0.982	0.991	1		
R	0.958	0.868	0.987	0.994	0.989	0.983	0.998	0.989	0.944	0.993	0.986	0.908	0.975	-0.954	0.979	0.986	0.999	1	
S	0.994	0.965	0.897	0.928	0.956	0.877	0.923	0.93	0.976	0.963	0.952	0.988	0.987	-0.827	0.983	0.921	0.932	0.93	1

Here A = Water temperature, B = pH, C = Conductivity, D = Total solids, E=Total suspended solids, F= Total Hardness, G= Calcium Hardness, H= Chloride, I= Ammonia, J=Nitrite, K= Nitrate, L= Phosphate, M= Sulphate, N= DO, O= BOD, P= COD, Q= Ca, R= Na, S= K.

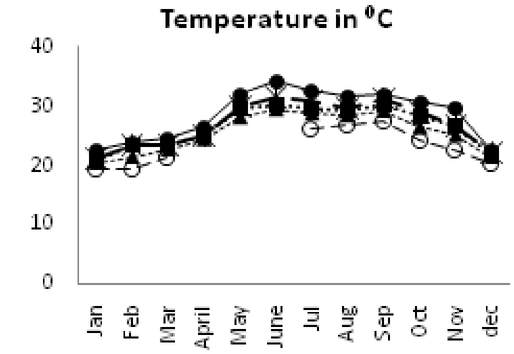
at S5 shows the accumulation of high concentration of carbonates, bicarbonates, chlorides, sulphates, phosphates and nitrates of Ca, Mg, Na, K, organic matter and inorganic salts. Surface runoff is a seasonal phenomenon (Singh *et al.,* 2004), which causes rise in total suspended solid concentration during monsoon. At site S5, total hardness increases due to high loading of organic substances, detergents, chloride, calcium and sulphate (Sati and Paliwal, 2008). High data of Calcium hardness reflects the high concentration of calcium (Das, 2002) in the river. Chloride bears a conjugational relationship with mineral contents, as the concentration of mineral increases, the chloride content also increases (Mohapatra and Purohit, 2002). High concentration of nitrates and ammonia at site S5, interprets the confluence of heavy domestic waste and organic matter containing nitrogenous compounds along with industrial effluent which can cause eutrophication (Sebastian *et al.,* 2008). Nitrite is an intermediate oxidation state of nitrogen, both in the oxidation and reduction of nitrate. Nitrite is used as a corrosion inhibitor in industrial process water and may enter into river with industrial discharge (APHA, 2005). Phosphate and sulphate concentration rises due to addition of fertilizers from agricultural runoffs, discharge of laundries, textile mills and domestic sewage. DO content determines the quality of water and decreases with rise in temperature (Rajagopal *et al.,* 2008). Reduction of DO occurs due to respiration of biota, decomposition of organic matter, oxygen demanding wastes and inorganic reducing agents such as hydrogen sulphide, ammonia, nitrite and ferrous iron (Sahu *et al.,* 2000; Saksena *et al.,* 2008). High value of BOD and COD determines the high concentration of organic matter and rate of microbial activity (Saksena *et al.,* 2008). Na, K and Ca concentration increases with the rate of confluence of Industrial effluents, agricultural runoffs and domestic sewage.

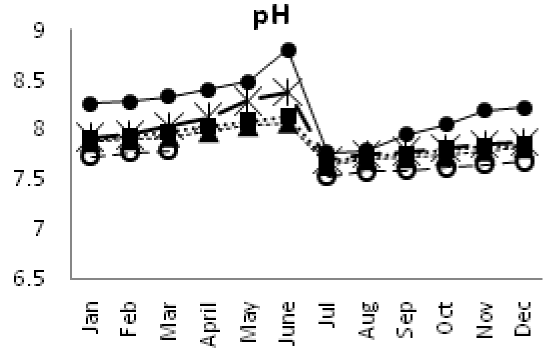
Statistical analysis of correlation coefficient among physico-chemical parameters of the Khan River is presented in Table 2.

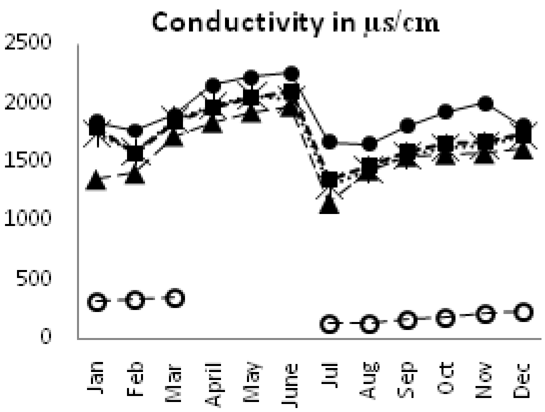
The result marks strong positive and negative correlation among the physico-chemical parameters of the Khan River. Each parameter is influenced by the concentration of the other. Conductivity, pH, total solids, total suspended solids, total hardness, calcium hardness, chloride, ammonia, nitrite, nitrate, phosphate, sulphate, BOD, COD, Na, K and Ca shows strong positive correlation with water temperature. This shows, as water temperature rises due to evaporation the concentration of these chemical factors also increases. DO show negative correlation (-0.88) with water temperature, as water temperature increases DO content decreases. A strong negative correlation was also observed between DO and other physico-chemical parameters. As pH, rate of conductivity and concentration of total solids, total suspended solids, total hardness, calcium hardness, chloride, ammonia, nitrite, nitrate, phosphate, sulphate, BOD, COD, Na, K and Ca increases, DO content is reduced or vice-versa. Ca is more positively correlated to calcium hardness and total solids as compared to other parameters. High Ca content influences Calcium hardness and total solids most. Positive correlation of conductivity was found with total solids, total suspended solids, total hardness, calcium hardness, chloride, ammonia, nitrite, nitrate, phosphate, sulphate, BOD, COD, Na, K and Ca. This reflects, high concentration of these parameters increases conductivity. BOD and COD are positively correlated to all parameters except DO.

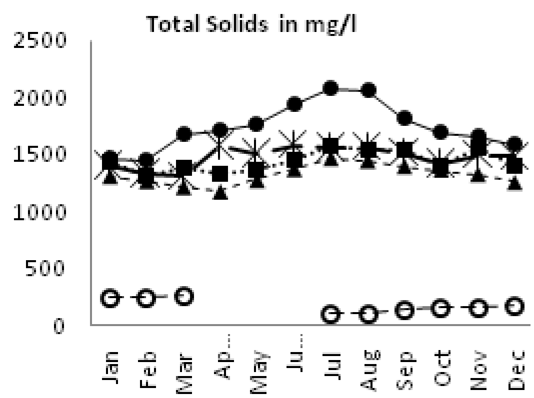
Monthly variations in the physico-chemical parameters at all sites along the Khan River is shown graphically for the whole year in Table 3

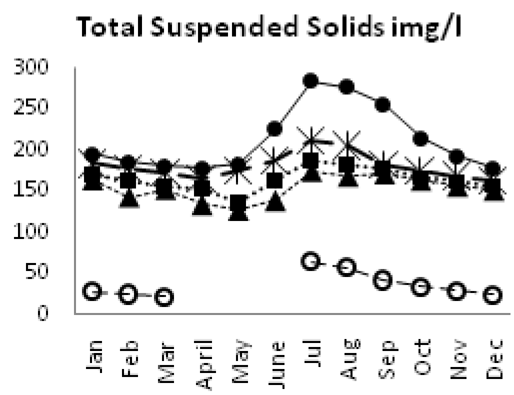
A wide variation in all parameters has been found among all sites. Dry season is critical for organic pollution, as flow in river is minimum (Shan *et al.,* 2011) and concentration of nutrients is maximum due to high rate of evaporation with rise in temperature. Concentration of Ammonia, nitrite, nitrate, sulphate, phosphate, total hardness, calcium hardness, chloride, BOD, COD, Na, K, and Ca was high in pre-monsoon (March, April, May and June). Whereas, these components are diluted during monsoon (July, August, September and October). Total suspended solids, total solids and DO content is more in July then in the month of June, by dissolution of rain water with silt, clay and salts with surface runoffs into the river. The pH also moves towards alkaline nature in pre-monsoon, comparatively falls down in monsoon and post-monsoon. During post monsoon as temperature is low, microbial activity is less resulting in decline of BOD, COD, nitrate, ammonia and nitrite concentration as compared to summers. DO content was maximum during monsoon at site S1, S2 and S3. DO decreases in post-monsoon and least in pre-

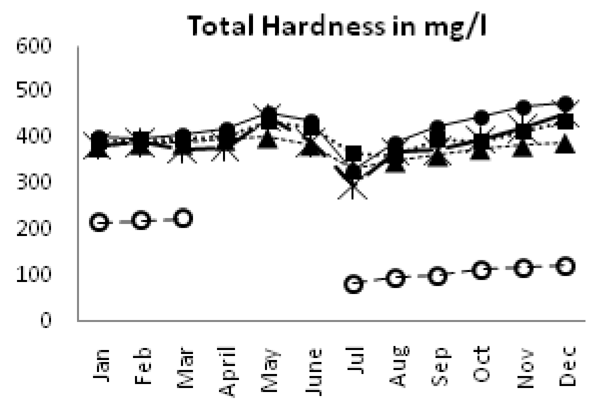

Temperature in ⁰C
0
10
20
30
40
Jan Feb Mar April May June Jul Aug Sep Oct Nov dec

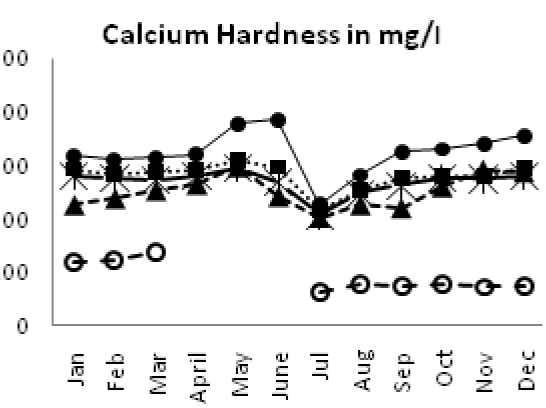

pH
6.5
7
7.5
8
8.5
9
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

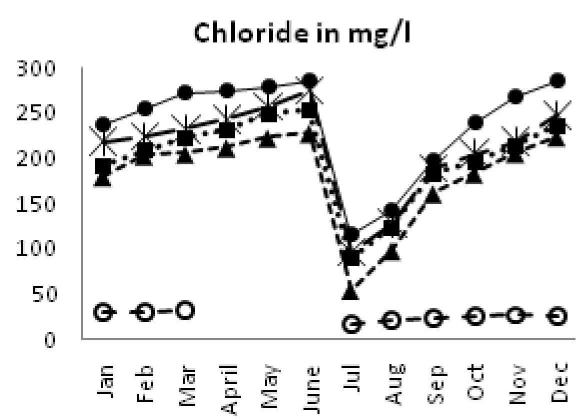

Conductivity in µs/cm
0
500
1000
1500
2000
2500
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

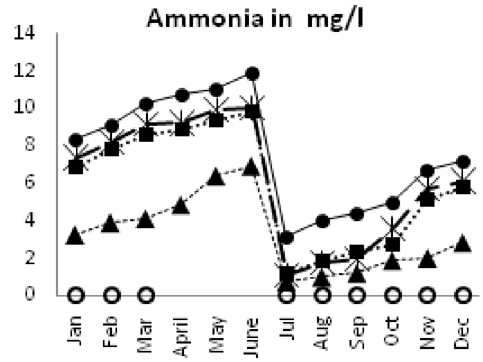

Total Solids in mg/l
0
500
1000
1500
2000
2500
Jan Feb Mar Ap... May Ju... Jul Aug Sep Oct Nov Dec

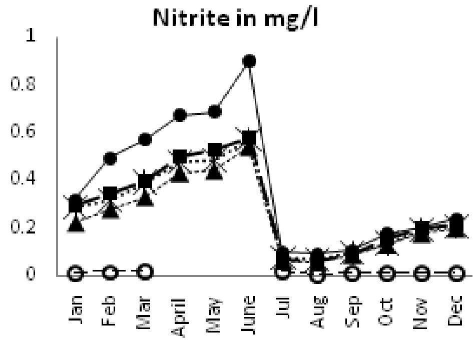

Total Suspended Solids img/l
0
50
100
150
200
250
300
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

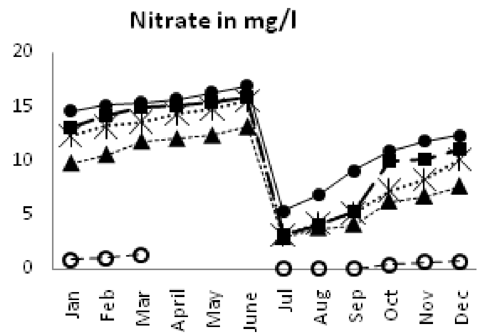

Total Hardness in mg/l
0
100
200
300
400
500
600
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

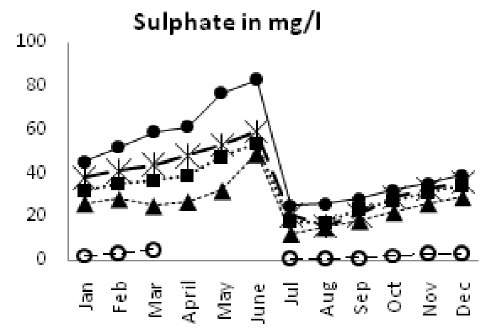

Calcium Hardness in mg/l
0
100
200
300
400
500
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

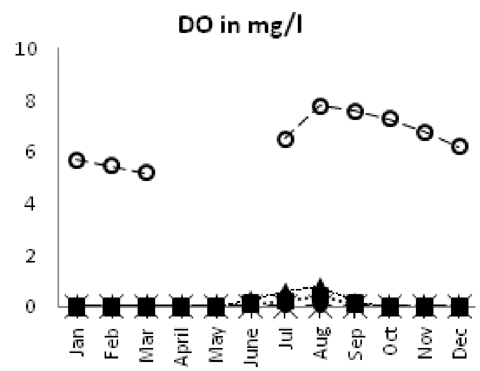

Chloride in mg/l
0
50
100
150
200
250
300
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

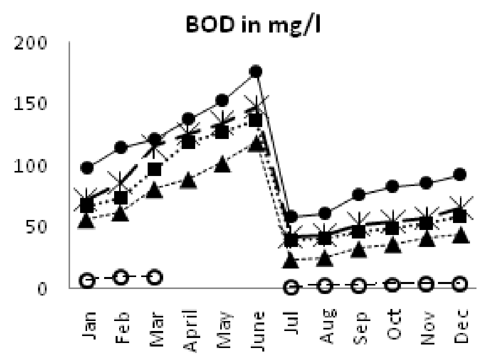

Ammonia in mg/l
0
2
4
6
8
10
12
14
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

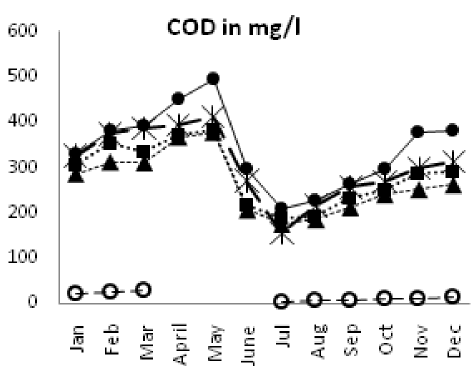

Nitrite in mg/l
0
0.2
0.4
0.6
0.8
1
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

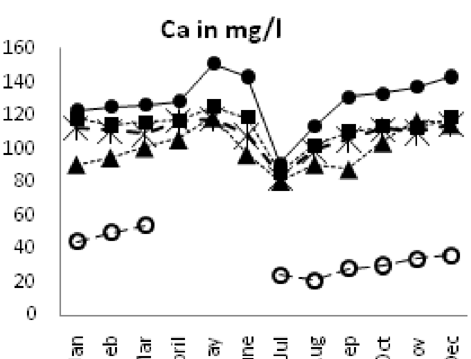

Nitrate in mg/l
0
5
10
15
20
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec


Sulphate in mg/l
0
20
40
60
80
100
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec


DO in mg/l
0
2
4
6
8
10
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec


BOD in mg/l
0
50
100
150
200
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec


COD in mg/l
0
100
200
300
400
500
600
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec


Ca in mg/l
0
20
40
60
80
100
120
140
160
Jan Feb Mar April May June Jul Aug Sep Oct Nov Dec

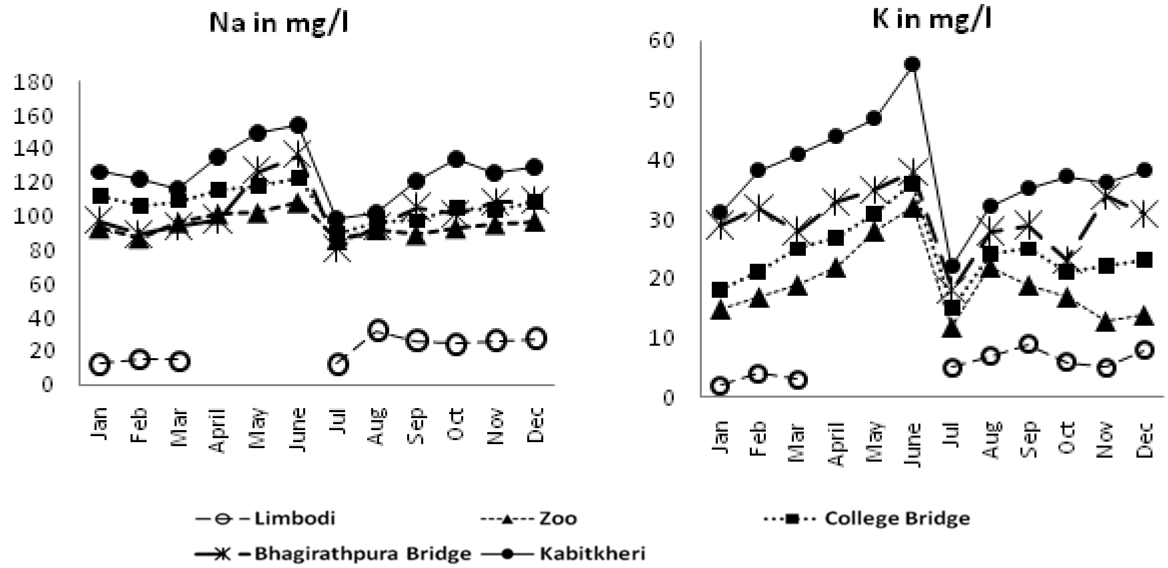


Fig 2. Graphs representing monthly variation in physico-chemical parameters of the Khan River in Indore at five sampling stations throughout the year. During April, May and June sampling station Limbodi is dry.

monsoon due to bulk influx of municipal waste water, industrial discharge, enhanced microbial activity and rise in temperature (Sankar *et al.,* 2010).

CONCLUSION

The present study reveals, the urgent need to take measures, to minimize pollution load in the Khan River. Among all the sampling sites, Limbodi has negligible pollution load while Zoo, College Bridge, Bhagirathpura Bridge and Kabitkheri are heavily polluted.Constant and bulk influx of domestic sewage, domestic waste, agricultural runoff and industrial effluent at various points along the Khan river has worsen the water quality.Direct use of such untreated water at site S4 and S5 for irrigation may leads to bioaccumulation of metals and other nutrients in vegetables, crops and cereal plants grown at the bank of river. Consumption of such vegetables, crops and cereal plants grown in the fields along the S4 and S5 can cause health hazards in human beings and animals. Underground seepage of toxic substances with water in soil, can contaminates the soil and water of wells, hand pumps and bore well, near the bank of river.Bulk accumulation of organic waste 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 microorganism.To overcome these problems and to minimize level of pollution, preventive measures should be taken by the government. Well designed, effective sewage system and drainage system should be constructed, to prevent direct mixing of domestic sewage and domestic waste with the river water.Industrial effluents should be pretreated, to reduce the harmful effect of their contents.Direct use of the Khan River for irrigation should be banned specially at S4 and S5 (in fields before STP), only after proper dilution to permisicible limit irrigation can be allowed. Regular monitoring of the river, effective implementation of environmental protection laws can keep check to minimize the pollution load.Health status of the people and animals living in poorly developed colonies, near the river bank should be periodically checked, to reduce the rise of any epidemic. Use of eco-friendly, cost-effective technique of phytoremediation at most polluted zones can be helpful to control pollution in the Khan river.

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Botany, P.M.B Gujarati Science College, Indore, India.

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