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Water quality of an Indian tributary affected by various industrial effluents- a case study

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Abstract. Industrialization and urbanization are modern need and trends. Such trends affect the natural ecosystem of rivers. Indian rivers face such problems in a high ratio. The aim of this study is to investigate the cause and amount of pollution in a tributary river Krishni. Pre-monsoon sampling of Krishni river water was performed as per APHA standard. Water samples were collected from different sites of Krishni river. Physiochemical parameters as well as trace elements concentrations have been analysed and results were compared with BIS-2012, WHO-2017 and EPA-2001 recommendations. The presence of high BOD, COD, TDS and others physiochemical parameters along with heavy metals reveals that tributary is highly polluted owing to industrial and domestic discharge either directly or through drains. High values of these parameters are harmful for the ecological health of the river because it makes survival of aquatic flora and fauna at risk. On the basis of the results obtained by the present study, it was concluded that level of the pollution in river Krishni is at alarming phase, where if strong action for the rejuvenation of river not takes place, river becomes a dead pool.

Keywords: Krishni river; tributary; trace metal; rejuvenation

1. Introduction

India is a land of faith and religions. People worship plants, rivers etc from the ancient time. The water of river like Ganga and Yamuna used to purify ourselves as they called holy rivers. But today we reached at a point where we have to purify these rivers so that their holy nature remains constant. In addition to be a developing country India facing its worse water crisis from the past few decades. To mitigate these water crises rejuvenation of river is the need of hour. Several action plans take place for the rejuvenation of north flowing river like Ganga, Yamuna and also for Hindon but there is a lack of efforts in case of small rivers or tributaries. As we all know that until the pollution in these tributaries not taking seriously, the target of rejuvenation of large river can't be achieved. It is due to the fact that tributary rivers merges into large river at the end of their journey and puts their polluted water into the large river. No matter how many action plans for

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cleaning of large river take place, but it can't be rejuvenated until its tributary facing huge pollution. One such polluted river is Krishni, which is a tributary of Hindon river. Aim of this study is to identify type, amount and source of pollution in Krishni river. Unplanned urbanization and industrialization are the major threats to water pollution (Zakir *et al*. 2016). A number of studies on different river and their pollution level were carried out by many researchers. A comparative study of surface water in river Godavari, Krishna and Tungbhadra was conducted by Mitra (1982). Similar study in the comparison between rivers Ganga, Yamuna and Kali was conducted by Bhargava (1977), where quality of Yamuna river water in Agra was studied by Sangu *et al.* (1984). Characterization of point sources and water quality assessment of river Hindon was conducted by Sharma *et al.* (2014), where Effects of river Krishni water quality on the nearby hand pumps was studied by Dhakyanaika and Kumara (2010) and Bharti *et al.* (2019). Assessment of the seasonal variation in water quality of Brahmani river was conducted by Mohanty and Nayak (2017). High amount of total coliform bacteria and high BOD values was reported by CPCB-2016 in the river Yamuna, Gomti, Rapti, Saryu, Rihand and Hindon in Uttar Pradesh. In addition to large river some minor river or tributaries are also considered to be analysed by CPCB in 2006 where comparative study of river Matla and Saptamukhi was carried out by R. Bose *et al.* (2012). The water samples taken from Ganga river in Kanpur reported to be contaminated by a organophosphate pesticide Malathion (Kumar *et al.* 2019). In all of the above studies none of the rivers were reported to be pollution free. This is the main issue for the present as well as for future generation to be overcome as polluted water is a health hazard to living being (Rajmohan *et al*. 2012, Samo *et al.* 2017).

2. Materials and methods

2.1 Study area

Krishni River is an intermittent in nature, which flow only during monsoons. In the absence of

Fig. 1 Krishni River containing Blackish water

Table 1 Code of Sampling locations and their Importance along with their Geo-coordinates

S. No.	Code	Sampling locations	Locational importance	Geo-coordinates	
				Latitude (N)	Longitude (E)
		Saharanpur District			
1.	KR1	River Krishni U/s of Village Kachrai	D/S of Saharanpur	29˚42' 48.6"	77˚28' 57"
2.	KR2	River Krishni U/s of Village Nanauta, near Sugar mill	D/s of Saharanpur	29˚40' 30.72"	77˚28' 14.52"
3.	KR3	Bridge on River Krishni at U/s of Bhnera Khemchand village	D/S of Nanauta Sugar mill	29˚40' 10.92"	77˚26' 51.36"
		Shamli District			
4.	KR4	Bridge on River krishni U/S near Thana Bhawan Town	D/s of Nanauta Sugar mill	29˚35' 18.6"	77˚25' 42.96"
5.	KR5	River Krishni D/S near Thana Bhawan village	D/S of Thana Bhawan Town Sewage	29˚33' 37.44"	77˚24' 48.24"
6.	KR6	Bridge on River Krishni near Kairi Village	D/S of Thana Bhawan Town sewage	29˚30' 21.96"	77˚24' 27.36"
7.	KR7	Bridge on River Krishni near Banat village	D/S of Sikka paper mill effluent	29˚28' 9.12"	77˚21' 40.32"
8.	KR8	Bridge on River Krishni U/s of Village Bhikki Deh	D/S of Shamli sugar mill and Distillery effluent	29˚26' 12.84"	77˚20' 40.92"
9.	KR9	Bridge on River Krishni U/S of Village Kabraut	D/S of Shamli sugar mill and Distillery effluent	29˚24' 34.92"	77˚20' 58.2"
10.	KR10	River Krishni near Sunna Village	D/S of Shamli Sewage drain	29˚20' 31.92"	77˚20' 23.28"
11.	KR11	Bridge on River Krishni near Dangrol village	D/s of Shamli Sewage drain	29˚18' 2.88"	77˚21' 3.24"
		Baghpat District			
12.	KR12	River Krishni near Asara village	D/s of Shamli Effluent drain	29˚14' 53.88"	77˚18' 58.68"
13.	KR13	River Krishni near Gopalpur Khadana village	U/S of Ramala Sugar mill drain	29˚13' 14.88"	77˚19' 9.84"
14.	KR14	Bridge on River Krishni near Sujti village	U/s of Ramala Sugar mill drain	29˚13' 51.6"	77˚18' 57.96"
15.	KR15	River Krishni near Ibrahimpur Majra village	D/S of Ramala Sugar mill drain	29˚12' 31.68"	77˚19' 15.96"
16.	KR16	Bridge on River Krishni U/S of village Gangnauli	D/S of Ramala Sugar mill drain	29˚12' 10.44"	77˚19' 14.16"
17.	KR17	Bridge on River Krishni U/S of Bamnauli village	D/S of Ramala Sugar mill drain	29˚8' 40.56"	77˚21' 20.52"
18.	KR18	Bridge on River Krishni D/S of Ranchar village	D/S of Ramala Sugar mill drain	29˚7' 53.76"	77˚22' 14.88"
19.	KR19	River Krishni near Rahatna village	D/S of Ramala Sugar mill drain	29˚7' 38.64"	77˚23' 13.2"
20.	KR 20	Bridge on River Krishni near Barnawa village	U/S of confluence to Hindon River	29˚6' 26.28"	77˚25' 15.96"

fresh water, river carries mostly industrial and domestic wastewater discharged from nearby town

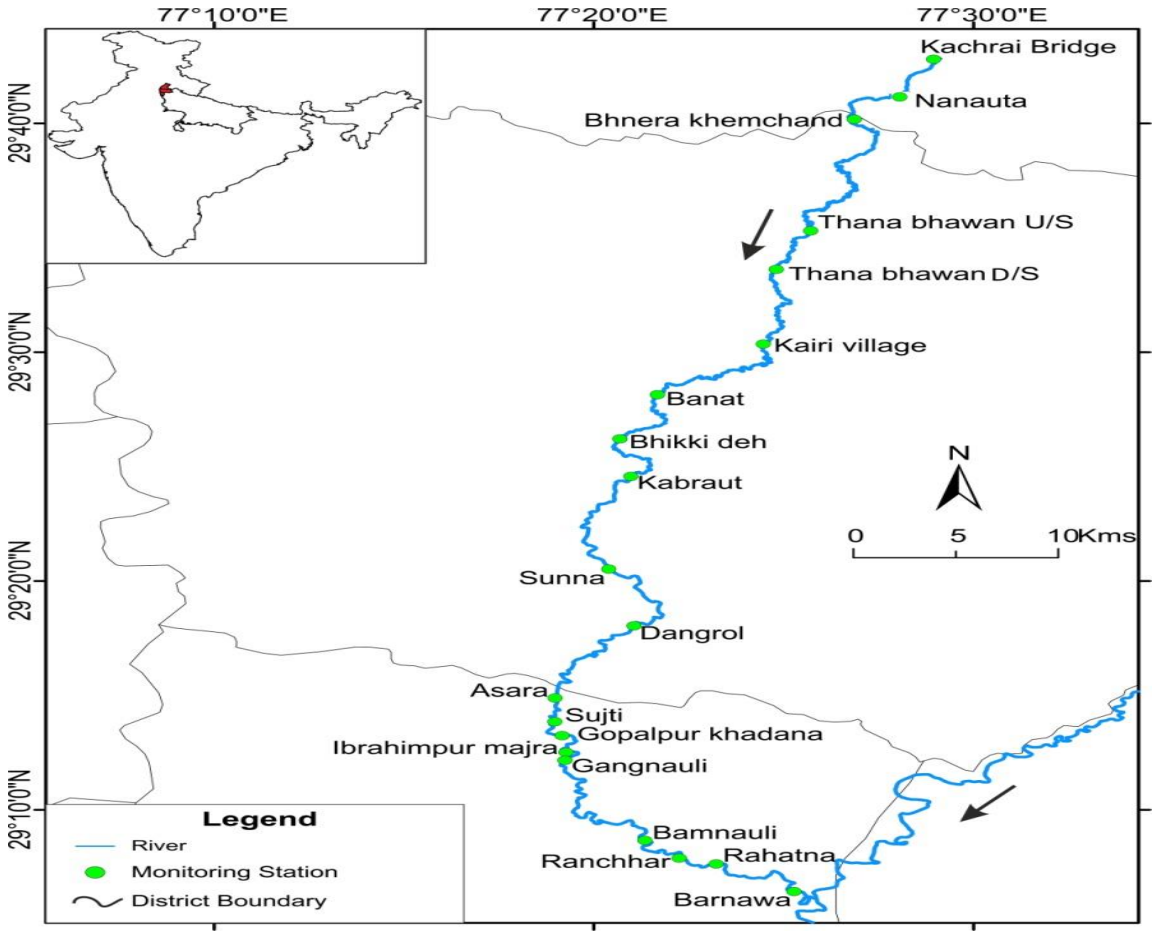

Fig. 2 Location map of River Krishni sampling stations along with district boundary

of Saharanpur, Shamli and Baghpat district of western U.P (Dhakyanaika and Kumara 2010). It is a tributary of Hindon river and cover 78 km stretch along side industrial as well as agricultural intensive area. River get colossal measure of treated and untreated waste from various huge, medium and small scale industries, for example sugar, distillery etc. The water level of Krishni river fluctuates from season to season, furthermore relies on upon the industries arranged in its catchment city or town. The shading and smell additionally may differ with season, in monsoon it conveys muddy water however in other season its shading absolutely changes to dark with a terrible smell as shown in Fig. 1. Individuals living in the towns or villages of the catchment of Krishni river are constrained to live with such unsuitable smell (Lewis 2007). A total of 20 River water samples collected from the entire stretch of the Krishni river. Sampling locations along with their latitude and longitude are listed in Table 1 and their location map along with district boundary shown in Fig. 2 produced through ArcGIS 10.1 software.

2.2 Sampling and data analysis

Before collecting water samples, survey of area was done and found that contaminated water of

Table 2 Range of concentration of various parameters along with their analytical method and standard

S. No	Parameters	Range of Concentration in River water		Units	Analytical Methods	EPA, 2001 Recommen-dations for Surface water	BIS, 2012 Recommendations for Drinking water		WHO, 2017 guideline for Drinking water
		Min	Max.				Acceptable limits	Permissible Limits	
1	Colour	456	1043	Hazen	Spectrophotometric	100	5	15	15
2	Ph	6.5	8.1	-	pH meter	5.5-9	6.5-8.5	NR	ND
3	E. C	230	1087	µmhos cm^{-1}	Electrometric conductivity meter	1000	750	3000	600
4	TDS	346	1044	mg L^{-1}	Filtration and Gravimetric	ND	500	2000	600
5	COD	98.6	1015	mg L^{-1}	Open reflux	-	ND	ND	20
6	BOD	15	442	mg L^{-1}	5 days incubation, 20˚C	5	5	ND	5
7	Turbidity	48.6	92.6	NTU	Nephelometric	ND	1	5	4
8	Phosphate	11	52	mg L^{-1}	Stannous chloride	0.7	ND	ND	ND
9	Sulphate	34	242	mg L^{-1}	Turbidimetric	200	200	400	250
10	T. A	800	1700	mg L^{-1}	Titrimetric	-	200	600	200
11	Cl	88.6	542	mg L^{-1}	Argentometric titration	250	250	1000	250
12	T. H	150	840	mg L^{-1}	EDTA titrimetric	ND	200	600	200
13	F	0.63	2.3	mg L^{-1}	Colorimetric	1.7	1	1.5	1.5
14	Na	3.6	49.4	mg L^{-1}	ICP-MS	200 -	ND	ND	50
15	Ca	10.6	42.8	mg L^{-1}	ICP-MS	ND	75	200	ND
16	Mg	7	24.5	mg L^{-1}	ICP-MS	ND	30	100	ND
17	K	11.4	62.5	mg L^{-1}	ICP-MS	ND	ND	ND	ND
18	Fe	0.6	5.11	mg L^{-1}	ICP-MS	2.0	0.3	NR	0.3
19	Se	13.5	22.9	mg L^{-1}	ICP-MS	0.01	0.01	NR	0.04
20	Cd	0.02	0.07	mg L^{-1}	ICP-MS	0.005	0.003	NR	0.003
21	B	10.3	20.1	mg L^{-1}	ICP-MS	2.0	0.5	1	2.4
22	As	BDL	3.9	mg L^{-1}	ICP-MS	0.05	0.01	0.05	0.01
23	Mn	0.20	1.06	mg L^{-1}	ICP-MS	0.3	0.1	0.3	0.1

BDL- Below Detection Limit, ND- Not Defined, NR- No Relaxation

Krishni river in Saharanpur, Shamli and Baghpat district could be responsible for a number of life threatening diseases such as cancer, bone deformity and paralysis among residents of several villages along its banks. In a single village named Gangnauli of Baghpat District 112 people have died due to cancer in the last two years and 47 are currently battling this disease (The Hindu reports 2014).

20 river water samples were collected during pre-monsoon 2015 along the river, and from

upstream and downstream locations of confluence points of drains, in order to identify the pollution sources. Samples were collected using labelled and pre-treated teflon bottles. All the water samples were analyzed for 13 physiochemical parameter such as colour, pH, electrical conductivity, turbidity, total alkalinity, total hardness, COD, BOD, TDS, sulphates, phosphates, fluoride, chloride and 10 trace metals like Mn, Fe, Na, Ca, Mg, K, Cd, Se, B, As using standard procedures recommended by APHA, 1976. Parameters like pH was checked onsite. The samples were preserved for heavy metals and other physiochemical analysis. All the collected river water samples are preserved at 4°C by using thermo-coalbox with ice packs and the samples were then transferred to the laboratory for further analysis. All the analytical parameters along with their range in river water samples, their analytical technique and their comparisons with Bureau of Indian Standard (BIS-2012), Environmental Protection Agency (EPA-2001) and World Health Organization (WHO-2017) are summarized in Table 2.

3. Results and discussions

Water samples were collected from various sampling points along the river as well as upstream and downstream location of the drains or industries, so that the influence of the drains/ industries on river water quality can be assessed. The samples collected were analysed for physiochemical as well as heavy metals contamination. The detailed results of all the parameters at each sampling location are summarized in Table 3 and Table 4.

pH: It is the measurement of acidic/basic/neutral nature of water. The range of pH values in the river water samples obtained in the range 6.5-8.1, which indicate that all the sample's pH value lies within the range recommended by EPA-2001, WHO-2017 and BIS-2012.

E.C: Electrical conductivity is the measurement of ions present in the water samples. E. C values lies in the range 230-1087 µmhos cm^{-1}, which reveal the presence of high amount of ions in the river water samples. This study found that 20%, 95% and 75% samples cross the EPA-2001, WHO-2017 and BIS-2012 acceptable limit for drinking water, respectively.

Turbidity: It is the presence of suspended impurities in the water stream. Its value lays in the range 48.6- 92.6 NTU. Which indicate the high amount of suspended impurities is present in water and water is highly turbid as we can't see threw it. The turbidity of the entire river water sample was above the limits recommended by various standards.

Colour: The nature of pure water is colourless, tasteless, and odourless. The presence of any colour in the water stream makes it polluted and unfit for the use. The value of this parameter obtained in the range 456-1043 hazen, which indicate the high amount of colour in the river as seen in Fig. 1.

TDS: Total dissolved solid value ranged from 346-1044 mg L^{-1}, which indicate the presence of huge amount of solids in the river water. 17 samples out of 20 cross the WHO-2017 limits, while 95% samples found to be above the BIS-2012 acceptable limit for drinking water. High value of TDS may be due to paper mill effluent release into Krishni river (Girt *et al.* 2014). However, high TDS in the drinking water sample also reported in different parts of India (Jangwan *et al.* 2019, Kumar 2017, Kumar and Agarwal 2019, Sharma 2014).

COD: The chemical oxygen demand for the Krishni river water obtained in the range 98.6-1015 mg L^{-1}, which indicate the presence of high amount of chemical in the river water. The entire river water sample has COD value above the WHO-2017 recommendation.

Table 3 Concentration of various physiochemical parameters in River Krishni water samples

Locations	Physico-chemical Parameters												
	Colour	pH	E.C	BOD	COD	Turbidity	TDS	Cl^-	T.H	SO_4 -S	PO_4 – P	T.A	F
Units	Hazen	-	µmhos cm^{-1}	($mg\ L^{-1}$)									
Saharanpur													
KR1	456	6.9	230	15	98.3	57.9	346	88.7	150	65	16	800	0.16
KR2	561	6.5	617	89	286	54.5	520	175.6	380	45	13	950	0.32
KR3	561	7.8	858	126	358	71.6	956	203	320	150	16	1100	0.97
Shamli													
KR4	617	8.0	1078	108	288	92.6	632	170	450	242	48	1400	1.4
KR5	700	7.9	1067	165	388	75.6	744	242	480	194	52	1340	1.2
KR6	857	8.1	904	281	576	71.1	656	306	560	50	14	1200	0.90
KR7	1043	7.5	1087	220	744	64.9	1044	542	640	61	14	1000	1.3
KR8	986	7.8	851	256	1015	53.4	970	526	620	56	15	1200	1.8
KR9	1025	6.9	768	442	572	57.2	984	319	840	42	13	900	1.03
KR10	842	7.5	1082	89	644	61	837	206	560	34	11	1500	1.4
KR11	752	7.3	956	62	556	54.3	786	126	750	103	32	1350	0.63
Baghpat													
KR12	889	6.6	896	48	448	48.6	648	245	580	53	16	1500	1.06
KR13	883	7.6	891	52	424	56.9	862	189	600	59	18	1100	1.4
KR14	956	7.8	932	46	396	75.2	821	126	440	48	21	1700	0.86
KR15	786	8.0	953	65	373	60.3	738	145	550	62	29	1300	2.1
KR16	674	7.3	779	85	415	58.2	698	227	320	96	43	1650	2.3
KR17	657	6.5	627	61	365	78.4	664	186	380	86	34	1500	1.9
KR18	603	7.8	684	73	382	65.1	576	205	300	57	16	1300	2.3
KR19	700	7.9	893	40	532	70.6	686	296	260	73	21	1020	1.6
KR20	611	7.8	745	32	689	76.5	774	173	320	94	32	1400	1.3

Phosphates: Phosphate concentration in the river water samples obtained in the range 13-52 $mg\ L^{-1}$, so all the river water sample crosses the EPA-2001 limit.

T.H: Hardness is the presence of chloride, nitrates and sulphates of calcium and magnesium in the water samples. The hardness value in the river water samples obtained in the range 150-840 $mg\ L^{-1}$, which strongly indicate that 95% of The Krishni river samples cross the WHO-2017 limits.

T.A: Alkalinity is the measurement of OH^- , $CO_3^{-}$and HCO_3^- in the water samples. The total alkalinity of the river water samples found in the range 800-1700 $mg\ L^{-1}$. The entire samples of Krishni river cross the recommendations given by WHO-2017 and BIS-2012.

BOD: It is the measurement of total oxygen require by water for the oxidation of biological impurities. Its value lays 15-44.2 $mg\ L^{-1}$. All the sample of the river water has the BOD value above the EPA-2001 and WHO-2017 limitations. High amount of BOD in the water leads to the decomposition of organic matter under the anaerobic condition that produces highly objectionable

Table 4 Concentration of various trace elements in River Krishni water samples

Locations	Trace / Heavy Metals									
	As	Cd	B	Na	Fe	Ca	Mn	Mg	K	Se
Units	($mg\ L^{-1}$)									
	Saharanpur									
KR1	BDL	0.02	10.3	3.6	0.06	15.3	0.29	13	14.3	13.6
KR2	0.08	0.05	18.8	36.5	5.11	42.8	0.71	17	24.9	16.9
KR3	0.61	0.05	17.8	22.4	2.13	24.7	0.50	21	17.7	21.8
	Shamli									
KR4	2.1	0.03	17.2	17.8	1.16	16.7	0.53	7	19.8	22.1
KR5	3.9	0.03	18.0	12.4	1.21	10.9	0.82	4.1	11.4	22.9
KR6	2.1	0.06	19.4	34.3	1.20	38	0.46	22.2	62.5	18.9
KR7	0.41	0.07	20.1	25.4	2.03	32.9	0.41	18.8	53	20.0
KR8	0.03	0.07	18.0	21.9	0.23	19.2	0.56	21.6	29.1	17.9
KR9	0.35	0.06	19.8	18.1	0.71	10.6	0.32	11.8	33.9	17.9
KR10	0.13	0.05	17.3	49.4	0.21	29.8	0.28	23.4	40.3	17.2
KR11	0.09	0.05	15.6	15.8	3.08	19.6	0.26	15	25.4	15.9
	Baghpat									
KR12	0.03	0.02	14.9	21.5	0.49	25.8	0.25	25	21.6	13.5
KR13	0.05	0.03	11.5	27.9	0.12	27.3	1.06	16.3	30.8	18.6
KR14	0.21	0.04	17.6	19.8	0.26	19.7	0.49	21.1	32.7	17.8
KR15	0.15	0.07	19.5	32.8	1.18	21.8	0.32	24.5	28.4	19.2
KR16	0.26	0.06	11.7	27.6	2.09	18.6	0.75	10.3	26.3	21.8
KR17	0.35	0.06	15.4	21.3	1.18	21.3	0.26	21.2	27.9	20.9
KR18	0.12	0.04	14.6	19.8	0.21	20.8	0.34	16.5	35.6	19.7
KR19	0.27	0.07	17.8	25.7	0.38	21.7	0.20	17.9	32.7	18.6
KR20	0.23	0.05	17.3	22.8	0.27	25.6	0.24	23.6	34.6	19.4

products including Methane (CH_4), Ammonia (NH_3) and Hydrogen Sulphide (H_2S) gases (Chaudhary and Arora 2011).

Chlorides: The value of chloride in the river sample obtained in the range 88.7-542 mg L^{-1}. 25% of the samples cross the limitations given by EPA-2001, WHO-2017 and BIS-2012. As a result of high amount of chlorine in drinking water, it can form Trihalomethane on combine with the natural organic matter present in water, It is considered a potential health hazard (Bose *et al.* 2012).

Fluoride: Its concentration found in the range 0.63-2.3 mg L^{-1}, which indicate that 25%, 30% and 70% of the river water sample cross the limitations of EPA-2001, WHO-2017 and BIS-2012 acceptable limits respectively, where 30% samples have the fluoride value above the BIS-2012 permissible limit.

Table 5 Range of concentration of various parameters along with the percentage of sample cross the different standards

Parameters	Concentration Range in Krishni River Water (mg L^{-1}) Except, Colour-Hazen, E. C- µmhos cm^{-1}		Percentage of sample cross the BIS, 2012 Recommendations for Drinking water		Percentage of sample cross the EPA, 2001 limit	Percentage of sample cross the WHO, 2017 limit
	Min.	Max.	Acceptable Limit	Permissible Limit		
Colour	456	1043	100 %	100 %	100 %	100 %
pH	6.5	8.1	Nill	-	Nill	-
TDS	346	1044	95 %	Nill	-	85 %
E. C	230	1087	75 %	Nill	20 %	95 %
Turbidity	48.6	92.6	100 %	100 %	-	100 %
Sulphates	34	242	5 %	Nill	5 %	5 %
Phosphates	13	52	-	-	100%	-
F	0.63	2.3	70 %	30%	25%	30 %
T.H	150	840	95 %	20 %	-	95 %
Cl^-	88.7	542	25 %	Nill	25 %	25 %
T.A	800	1700	100 %	100 %	-	100 %
COD	98.6	1015	-	-	-	100 %
BOD	15	442	100 %	-	100 %	100 %
Mn	0.20	1.06	100 %	70 %	65 %	100 %
Fe	0.6	5.11	65 %	-	25 %	65 %
Mg	7	24.5	Nill	Nill	-	-
Na	3.6	49.4	-	-	Nill	Nill
Ca	10.6	42.8	Nill	Nill	-	-
K	11.4	62.5	-	-	-	-
Cd	0.02	0.07	100 %	-	100 %	100 %
Se	13.5	22.9	100 %	-	100 %	100 %
B	10.3	20.1	100 %	100 %	100 %	100 %
As	BDL	3.9	95 %	85%	85 %	95 %

Sulphates: The sulphates concentration in the river water samples obtained in the range 34-242 mg/L, which indicate that 5% samples cross the EPA-2001, WHO-2017 and BIS-2012 acceptable limits.

As shown in the physiochemical parameters analysis the quality of the Krishni river water is beyond the standard for each parameter. Apart from this heavy metal/ trace metal also reported by many researchers in the surface water as well as ground water aquifers (Devi and Bhattacharyya 2013, Mensah *et al.* 2013). This analysis were also performed for the Krishni river water samples as-

Mn: Manganese concentration obtained in the range 0.20-1.06 mg L^{-1}. 65% and 70% sample cross the EPA-2001 and BIS-2012 permissible limits respectively, while all the river water sample

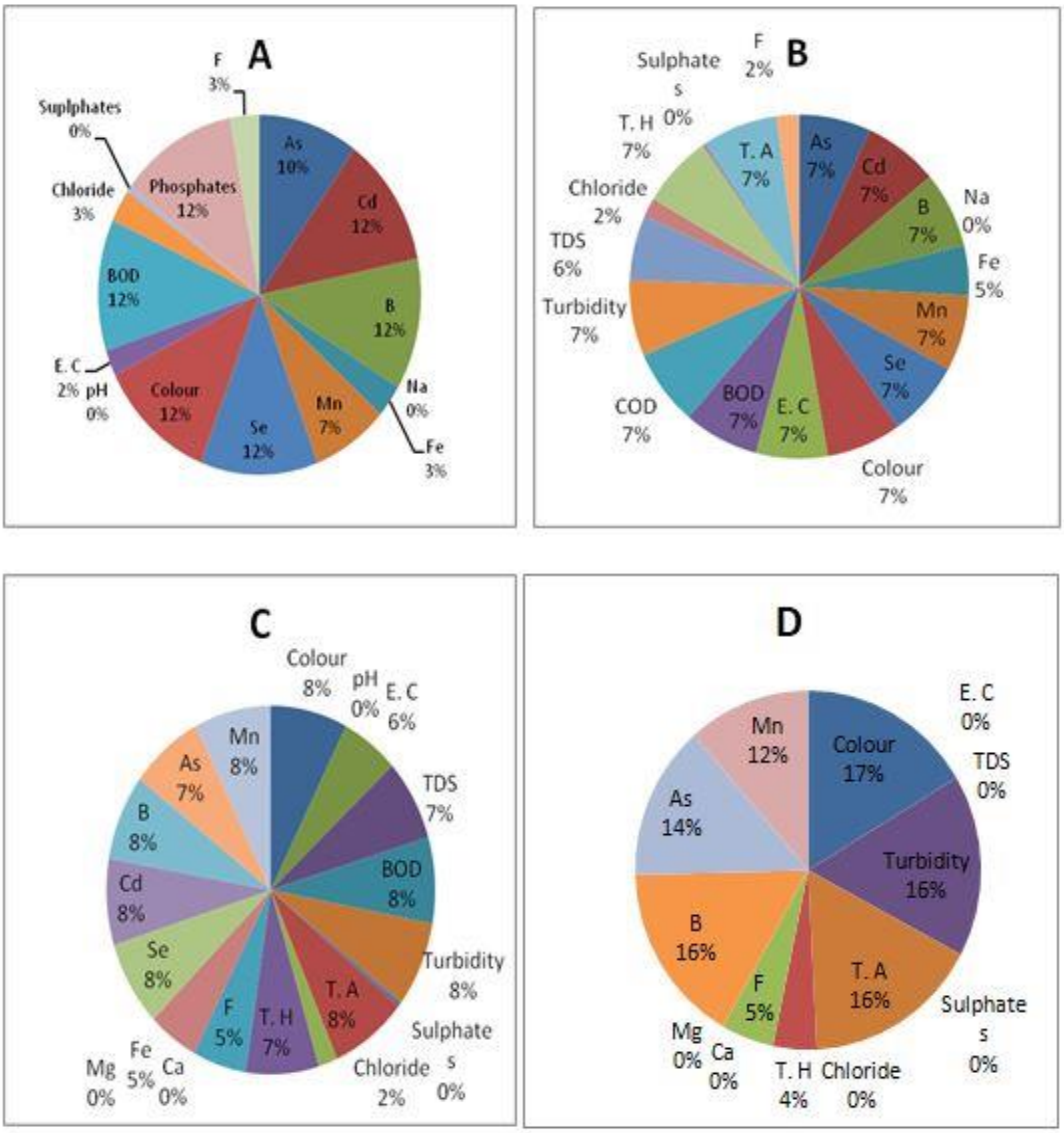

Fig. 3 Pie chart showing percent of sample cross the (a) EPA-2001 recommendations for surface water, (b) WHO-2017 guidelines for drinking water, (c) BIS-2012 acceptable limit for drinking water and (d) BIS-2012 permissible limits for drinking water

have the Mn concentration above the WHO-2017 and BIS-2012 acceptable limits as shown in Table 5.

Fe: Its concentration found in the range 0.6-5.11 mg L^{-1}. The study reveals that 25% sample cross the EPA-2001 limit, while 65% sample cross the both WHO-2017 and BIS-2012 acceptable limits.

Se: Selenium concentrations in the study area obtained in the range 13.5-22.9 mg L^{-1}, which indicate that all the sample, have the Se concentrations above all the drinking water regulations.

Cd: It is a carcinogenic element and its concentration in the river water samples found in the range 0.02-0.07mgL^{-1}. This study indicates that all the river water sample cross all of the recommendations. Cd concentrations in the groundwater's of some district of west U.P. were reported by many authors (Malyan *et al.* 2019, Kumar *et al.* 2019)

As: Arsenic is also carcinogenic in nature. Its value lies in the range from BDL-3.9mgL^{-1}. As contamination in aqueous systems have been reported by many authors (Babak *et al.* 2014, Galimova *et al.* 2012, Melnik *et al.* 2012). 85% of the Krishni river samples cross the EPA-2001 and BIS-2012 permissible limits, where 95% cross the WHO-2017 and BIS-2012 acceptable limits. While Na, Ca, Mg and K concentration in the Krishni river water samples were within the range.

B: Its value found in the range 10.3-20.1mgL^{-1}. All the river water samples cross all the recommendation given by EPA-2001, WHO-2017 and BIS-2012.

The graphical representation of percentage of sample which cross the EPA-2001, WHO-2017, BIS-2012 acceptable limits and BIS-2012 permissible are shown in Fig. 3 as a pie graph.

Heavy metals study reveals that their concentration in the analysis was alarming in the river water samples. They are undesirable and a threat to the health of ecological health of river. Such value show the water is unfit for domestic, bathing as well as agriculture use. So it is necessary to identify the pollution source along the river stretch. Since there are a number of industrial units running in the catchment of Krishni river. So, it can be conclude that untreated/ partially-treated effluent is being discharged by industrial units are major source of pollution in the river. However sewage discharge from nearby city/ town cannot be neglected.

There are 11drains which directly discharge their effluent into the river. Some of these drains are mixed, while some are industrial or domestic. The list of drains is shown in Table 6.

As far as the source of pollution in the Krishni river is concern, the simplest way is to analyse the effluent released by nearby industry into Krishni river. Effluent samples were collected from various industries as well as sewage. The collected effluents were analysed for physiochemical as well as heavy metal analysis as per the APHA standard. The results reveal that the main reason behind the pollution of Krishni river is these drain containing either partially treated or non-treated effluents. Physiochemical as well as heavy metal analysis results of effluents are shown in Table 7.

Table 6 Major drains discharging their effluents into River Krishni

S. No.	Town / Catchment Area	Drains	Type
1.	Saharanpur District	Nanauta Sugar Mill Nallah	Industrial
2.		Nanauta Dairy plant Nallah	Industrial
3.		Nanauta Distillery	Industrial
4.	Shamli District	Thana Bhawan Sewage	Mixed
5.		Bajaj Sugar mill Thana Bhwan	Industrial
6.		Sikka paper mill	Industrial
7.		Sikka Sewage Nallah	Mixed
8.		Shamli Sugar Mill	Industrial
9.		Shamli Distillery	Industrial
10.		Shamli Sewage	Domestic
11.	Baghpat District	Ramala Sugar Mill	Industrial

Table 7 Physiochemical and Heavy metals analysis of some drains discharging their effluents into Krishni River

Parameters	Nanauta Sugar Mill Nallah (Saharanpur)	Nanauta Distillery Efluent (Saharanpur)	Thana Bhawan Sewage (Shamli)	Bajaj Sugar mill effluent Thana Bhwan (Shamli)	Sikka paper mill effluent (Shamli)	Shamli Sugar Mill effluent (Shamli)	Shamli Distillery effluent (Shamli)	Ramala Sugar Mill effluent (Baghpat)
pH	6.3	8.2	7.5	6.7	7.8	7.6	8.3	7.3
E. C	1420	1365	1354	1260	900	1100	936	1000
TDS	2380	2818	2986	2067	1737	1467	1324	1611
BOD	198	534	125	238	308	210	317	120
COD	655	1396	352	623	1110	432	509	532
T. H	230	583	460	534	300	340	370	140
Cl^-	210	293	337	225	213	127	243	142
SO_4^{--}	760	243	372	580	404	105	256	102
Cd	0.032	0.026	0.018	0.045	0.004	0.032	0.061	0.002
As	1.3	0.96	0.38	0.25	0.86	0.23	0.13	0.09
Mn	0.92	0.83	0.69	0.32	0.25	0.43	0.30	0.45

High amount of E.C, TDS, COD, BOD value obtained due to presence of high load of organic components in the effluents of all the sugar mill, paper mill and distillery. The value of COD in effluents obtained in the range 352-1396 mg L^{-1},which is appreciably high compared to BIS standard (250 mg L^{-1}) (Siddiqui and Waseem 2012).

4. Conclusions

Water quality of Krishni river was assessed during the analysis through entire stretch from Saharanpur to Baghpat. The entire stretch of Krishni river is characterized by high pollution load in terms of almost all the physiochemical as well as heavy metals. Detailed study revealed that the ~78 km stretch of the river, from Saharanpur to Baghpat district, is highly polluted owing to industrial and domestic discharge either directly or through drains. Exceedingly high values of these parameters are harmful for the ecological health of the river because it makes survival of aquatic flora and fauna at risk. Moreover, river water is unfit for drinking / bathing / irrigation / propagation of wildlife and fisheries etc. Therefore, consistent efforts and planning should be take place so that these small rivers or tributaries can breathe easily.

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Application of the work

The above study is useful for the people living in the catchment of such a polluted river, regarding their health issue and targeting the health hazardous source. This study is also useful for the policy makers to take strong and needed action against the pollution spreading sources.

Conflict of interest

The authors declare no conflict of interest.

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