I.J.S.N., VOL.6 (4) 2015: 606-612 ISSN 2229 – 6441

INTERNATIONAL JOURNAL OF SCIENCE AND NATURE

www.scienceandnature.org

POLLUTION POTENTIAL ASSESSMENT OF MARKANDA RIVER AROUND KALA-AMB INDUSTRIAL TOWN OF HIMACHAL PRADESH, INDIA

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ABSTRACT
Markanda River, during its flow through lower hills of Sirmour district in Himachal Pradesh receives domestic and industrial effluents from different villages around Kala-amb industrial town situated on its bank. To assess pollution potential 96 surface water samples were collected from eight sampling sites from river Markanda during 2014 and 2015. Water quality attributes and 8 heavy metals (Cr, As, Cd, Ni, Pb, Mn, Zn and Fe) were determined for yearly variations, source apportionment and metal pollution indexing. Principal component analysis (PCA) outcome of two factors was indicating both natural and anthropogenic activities as contributing factors of pollutants profusion in the river. During 2014, PCA_1 accounted 85.51% of the total variance and showed high loading of pH, TDS, turbidity, BOD, COD, Ca, Mg, Fe, Zn, Mn, Cd and NO_3. During 2015, PCA_1 registered 78.24% of the total variance and characterized by high loading of pH, TDS, turbidity, BOD, COD, Ca, Mg, Fe, Mn, Pb, Cd and NO_3. PCA outcome of two factors indicated natural and anthropogenic activities as contributing factors for metals profusion in the river during each year. Based on pollution index, in river water Zn, As and NO_3 were slightly polluting, while COD (moderately), BOD (strongly) and Cr (seriously) polluting, respectively. Although, river quality does not pose any serious threat to human health presently. Based on the results of BOD and COD stretch of the river can be categorized as class of stream "D" for which the designated best uses are propagation of wild life fisheries, irrigation, industrial cooling and controlled waste water disposal. It can be attributed to the discharge of untreated domestic waste, industrial effluents at the upstream of all the monitoring stations and urban runoff from Kalaamb town.

KEYWORDS: Pollution potential, principal component analysis, pollution index, Markanda River, Kala-amb.

INTRODUCTION
Water is one of the most important components of life and life without it is impossible. However due to increasing anthropogenic activities and some natural processes the quality of water is decreasing continuously and is posing a great threat to all forms of life including humans. Water pollution is an acute problem in all the major rivers of India (CPCB, 2010). In the wake of increasing urbanization and industrialization, the pollution potential of rivers are gaining momentums day by day. Polluted water is the major cause for the spread of many epidemics and some serious diseases like cholera, tuberculosis, typhoid, diarrhea etc. However, rivers play a major role in assimilation or transporting municipal, industrial wastewater and runoff from agricultural and mining land (Singh *et al.,* 2008). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metals containing fertilizer and pesticides in agricultural fields (Nouri *et al.,* 2006). Although many attempts have been made by a number of researchers (Sharma and Kansal, 2011; Gupta *et al.,* 2013; Avvannavar and Shrihari, 2008; Bhardwaj and Singh, 2011, Patil *et al.,* 2012; Dwivedi and Pathak, 2007) to study various aspects of water quality and the factors responsible for its degradation in order to formulate a significant control strategy all over the globe yet the problem is on rise.

Markanda River originates at Baraban in the hills of Katasan in district Sirmour of Himachal Pradesh. It flows from south-east to south-west direction and it passes on to the Ambala district, Haryana at Kala-amb. Areas of Bajora, Kala-amb the lands of Shambhuwala, Rukhri, fields of Bir Bikrambag and the Khadar Bag are irrigated by its water. River plays a significant role to meet the demand of farmers for irrigation in this particular region. The Kala-amb region in district Sirmour has about 350 industrial units and most of the units are situated around Markanda River. The major industries in these areas include pharmaceutical, chemicals, ghee industry, food industry, ferroalloy, paper & pulp etc. These industries, although developed with proper planning, but are discharging their effluents in the nearby natural drains and are being ultimately collected in Markanda river. Increasing industrialization and urbanization in these areas are resulting in the degradation of natural resources. The disposal of effluents generated by the industries into river, can pose a great threat to life. It was felt must to take an initiative in to the same line in order to gain some kind of knowledge about the said problem. Keeping the same in view the present study was taken into consideration in which an attempt was made to access the water quality of Markanda River around Kala-amb and it is believed that this study would be helpful in formulating pollution control strategy in near future.

MATERIAL & METHODS

Study sites, sample collection and analysis

Eight water sampling stations (Rukhri, Shambhuwala, Markanda temple, dewani, Moginand, Ogli, Excise colony, Kalaamb situated in between 30º 30' 56. 75" to 30º 29' 44. 64" N and 77º 20' 20. 56" to 77º 12' 39. 33" E at an altitude 504 to 338 m amsl) were selected around Kalaamb industrial hub/ municipal town to assess the overall river quality. Water quality was monitored for a period of two years by taking samples from each sampling station (Figure: 1) once in pre-monsoon and post-monsoon. Water samples were taken from 5 to 10 cm below the water surface using acid washed plastic container to avoid unpredictable changes in characteristic as per standard procedures (APHA, 2011). The collected samples were brought to laboratory and analyzed within 24 hours, except the biological oxygen demand, which require a period of five days for incubation at a temperature of 200ºC using standard methods (APHA, 2011). pH, total dissolved solids (TDS), turbidity (TBU) and chemical oxygen demand (COD) were measured by eutech instrument pH 510, microprocessor based TDS meter, nephlometer and TR320 spectroquant respectively. BOD was calculated by using BOD-System Oxidirect. 152 ml of sample was poured into the BOD bottles before addition of 5-6 drops of nitrification inhibitor (ATH) with one magnetic stirrer. BOD bottles loaded on BOD system was kept in incubator for five days at 20° C. The readings were recorded after 5 days (Rana, 2012). Sharma and Kansal, 2011; Gupta *et al.,* 2013; Kashyap and Verma, 2015 has been given procedures for physico-chemical analysis of water.

For the analysis of heavy metals water samples (200 ml) were digested with 5 ml of di-acid mixture (HNO3:HClO4=3:1 ratio) on a hot plate and filtered by Whatman No. 1 filter paper and made up the volume to 50 ml by double distilled water. The analysis of the heavy metals i.e. Fe, Zn, Mn, Cd, As were done using inductively coupled plasma emission spectrophotometer (ICP-ES- 6000 series) (Kashyap and Verma, 2015; APHA, 2011). Methodology followed for ICP-ES technique was same as described by Kashyap *et al.,* (2015). Mean of three replicates were taken for each observation.

Statistical analysis

The samples were analyzed in triplicate, using statistical program XLSTAT-2012 to calculate mean concentrations, ranges, standard deviations, total seasonal mean concentrations, correlation coefficient (r-values) of physico-chemical parameters in water samples collected between 2014 and 2015 for testing significant relation at 5% level of significance. The principal component analysis PCA was also performed on normalized (z-scale transformation) on 16 variables after sorting out the highly correlated variable from the data sets individually for each year. The Bartlett's sphericity test was applied to the correlation matrix of variables for assessing the adequacy of (PCA) in water quality studies (Lambarkis *et al.,* 2004). The principal components with eigenvalues > 1 were retained and are used to assess the compositional and spatial variations in the river quality due to anthropogenic activities domiciled along the river course (Singh *et al.,* 2008; Sundaray, 2009; Amadi, 2012).

Pollution index

Pollution index (PI) is a technique which shows the pollution status of water/soil quality parameters. It identifies the contribution of individual parameters on overall water quality (Aboud and Nandini, 2009). The pollution index was calculated only for chemical parameters of water as per the formula of Amadi (2012).

$$PI = \frac{\sqrt{\left[\frac{Ci\ max}{Si}\right]^2 - \left[\frac{Ci\ min}{Si}\right]^2}}{2}$$

Where PI = pollution index; Ci = respective maximum and minimum concentration of quality parameters; Si = standard permissible limit of surface water quality. The water quality and its suitability for drinking purpose were examined by determining its metal pollution index (Prasad and Kumari, 2008). The interpretation of PI was based on different classes and their values i.e. class-I = <0.3 (non-polluting), class-II = 0.3-0.5 (slightly polluting), class-III = 0.5-1.0 (moderately polluting), class-IV = 2-3 (strongly polluting) and class-V = >5 (seriously polluting) given by Amadi (2012).

RESULTS & DISCUSSION

Spatial variations of physico-chemical attributes of Markanda river during 2014 and 2015

The pH of water is extremely important. The fluctuations in optimum pH ranges may lead to an increase or decrease in the toxicity of pollutants in water bodies (Mishra, 2010). During 2014, maximum pH value 8.12 was at Kalaamb (L8) downstream of river Markanda and minimum 7.46 was at Rukhri (L1). Similar trend was observed during 2015. Maximum 8.19 and minimum 7.53 was recorded at Kalaamb (L8) and Rukhri (L1), respectively. However, pH ranged from 7.78±0.26 and 7.87±0.29 in the river stretch along industrial town Kalaamb during 2014 and 2015 respectively. The higher range of pH indicated high qualitative pollution load in river water. It correspond results of our previous work on water quality of Rewalsar Lake (Kashyap et al, 2015). Total dissolved solids (TDS) and turbidity are often termed pollutant of conservative nature. Dissolved solids neither react readily with many other materials in the water; nor does it settle down readily. Thus, dissolved solids cause turbidity in water. During 2014, maximum TDS, turbidity (TUB) was 100.50 mg/L, 17.50 NTU at Kalaamb (L8), respectively. In 2015 similar observations was recorded. Both are often a very good indicator of the aggregate amount of anthropogenic materials dumped into the river from all sources especially mining and soil erosion as well. TDS ranged between (87.10±12.17 mg/L) to (88.22±10.77 mg/L) and turbidity varied between (13.55±2.79 mg/L) to (17.46±3.74 mg/L) during 2014 and 2015 in selected stretch of river Markanda. Results were in confirmation with findings of (Kumar *et al.,* 2008).

Biological oxygen demand (BOD) and Chemical oxygen demand (COD) are widely used parameter to measure water quality and also in the design of effluent treatment plants (Kar *et al.,* 2003). BOD ranged between (9.974±2.368 mg/L) to (10.406±2.345 mg/L) and COD varied between (19.311±4.857 mg/L) to (21.882±4.310

mg/L) during 2014 and 2015, respectively. The values noticed were contrary to the BOD and COD permissible limit of fresh water (CPCB, 2010). According to CPCB, the BOD, COD standard for fresh waters of unpolluted rivers is less than 5.0 mg/L and 20 mg/L respectively. In 2014, highest BOD 13.50 mg/L and COD 25.51 mg/L was at Kalaamb (L8). In 2015, highest BOD 14 mg/L and COD 27.50 mg/L was also recorded at Kalaamb (L8) (Table 1, 2). The high level of BOD, COD might have been attributed to the severe discharge of pollutants into the river through washing, sewage contamination and industrial effluents. Kumar *et al.,* 2008; Dwivedi and Pathak, 2007, also reported high values of these attributes in polluted rivers of India.

Calcium and magnesium are most abundant ions in fresh water and is important in shell construction, bone building and precipitation of lime. Both enter in river through surface run-off from agricultural land use. Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally lower than the calcium. Highest Ca (61.00 mg/L) and Mg (13.58 mg/L) during 2014 was recorded downstream at Kalaamb (L8). Similarly Ca (40.50 mg/L) and Mg (12.87 mg/L) was also highest at Kalaamb during 2015. The calcium and magnesium of river stretch varied from (47.10±8.09 mg/L) to (33.90±5.15 mg/L), (9.30±2.62 mg/L) to (8.32±3.18 mg/L) during 2014 and 2015, respectively (Table 1, 2). Hardness of water in river is directly related to amount of calcium and magnesium present in water. Since its calcium and magnesium did not exceed 120 mg/L. This agreed with (Patil *et al.*, 2012; Dwivedi and Pathak, 2007) observation on the abundance of these ions in fresh waters.

Iron in water may be present in varying quantities depending upon the geology of the area and ferrous and ferric ions are the primary forms of concern in aquatic environment (Kashyap *et al.,* 2015). Iron increased significantly from Rukhri (L_1) to Kalaamb (L_8). Last sampling location of river Markanda was having highest Fe (0.240 mg/L) in 2014 and (0.220 mg/L) in 2015. Iron ranged from (0.19±0.043 mg/L) to (0.16±0.044 mg/L) in river water during 2014 and 2015 respectively. Gupta *et al.,* (2013) also reported the similar results in Yamuna river at Agra, India. The water runoff may carry higher concentrations of these attributes, which arise from anthropogenic activities such as municipal waste water, use of chemical fertilizers and pesticides in agriculture (Gupta *et al.,* 2013; Avvannavar, and Shrihari, 2008).

The major industrial sources for Mn and Pb can be attributed to iron and steel related industries, power plants and coke ovens, paper and newsprint mills, manufacturing of heating equipment, fossil fuel power generation and welding industries (Bhardwaj and Singh, 2011). In river Markanda, Pb was (0.023±0.004 mg/L) in 2014 and (0.024±0.006 mg/L) in 2015 whereas, Mn was (0.024±0.006 mg/L) in 2014 and (0.023±0.009 mg/L) in 2015. High values of Mn (0.035 mg/L), Pb (0.028 mg/L) and Zn (1.930 mg/L) was recorded at Kalaamb (L8) in 2014. Similar trend was observed during 2015. Zinc registered overall mean value (1.594±0.283 mg/L) in 2014 and (1.551±0.366 mg/L) in 2015. Zinc is an essential micronutrient in traces to sustain life but its high concentration in water bodies may be phototoxic to aquatic flora and fauna (Kashyap and Verma, 2015; Kashyap *et al.,* 2015). It is a common contaminant in industrial effluents (Gupta *et al.,* 2013). Arsenic occurs naturally or is possibly aggravated by over powering aquifers by phosphorus from different type of chemical fertilizers industrial and sewage effluents reported by Macklin *et al.,* (2003). As was (0.093±0.014 mg/L) and (0.045±0.007 mg/L) during 2014 and 2015. Maximum As (0.112 mg/L) in 2014 and (0.050 mg/L) in 2015 was recorded at Kalaamb (L8) downstream along river course. Significant increase in arsenic concentration may be because of pollution from industrial or sewage effluents directly entering into river water. Landfill leachates are also an important source of arsenic in the environment (Vinodhini and Narayanan, 2008).

Cadmium is a poisonous metal and can cause serious health problems even if ingested in small concentration. Effluents from industries like battery making, dye making, pigment making, alloy making are the major sources of Cd into the water bodies reported by (Kashyap *et al.,* 2015). Cd was (0.002±0.002 mg/L) observed with same concentrations irrespective of years in water of Markanda river. However Ni, was (0.025±0.007 mg/L) in 2014 and (0.041±0.002 mg/L) in 2015 recorded in river water. Maximum Cd (0.005 mg/L), Ni (0.036 mg/L) observed at L8 during 2014 as that of other attributes (Table1, 2). Cd were attributed to industries dealing with electrical equipment, household appliances, catalysts, pigments, paints and batteries (Ni-Cd) are sources of Ni, Cd contamination in the river Yamuna (Bhardwaj and Singh, 2011). Chromium reaches the aquatic environment chiefly from mines and a large number of industrial processes like agricultural chemicals, paints, etc. Chromium varied from (0.019±0.014 mg/L) to (0.025±0.013 mg/L) in river water during 2014 and 2015 respectively. Cr was maximum (0.045 mg/L) during 2015 and (0.035 mg/L) during 2014 at Kalaamb (L8). It may be attributed to the discharge of large amount of agricultural chemicals and sewage into the river water. NO_3 varied from (11.09±2.25 mg/L) to (9.806±3.619 mg/L) in river water during 2015 and 2014 respectively. Source of NO_3 may be agricultural runoff or industrial discharge of ammonia into river Markanda. During each year values of NO_3 were also significantly high at downstream sampling location (L8) as compared to others.

Principal component analysis

During 2014, two principal components were identified to be responsible for the deterioration of the river water and accounts for 92.40% of the overall total variance (Table 3). The first principal component accounts for 85.51% of the total variance and is characterized by high loading for pH, TDS, turbidity, BOD, COD, Ca, Mg, Fe, Zn, Mn, Cd and NO_3. The presence of these parameters showed some degree of mineralization of river water due to high rates of loading and inclusion of organic pollutants as well (Prasad and Kumari, 2008). The second major component accounts for 6.89% and comprises of Pb, Ni, As and Cr with moderate loading. Naturally, chemical weathering of rock-forming minerals may be major source and anthropogenic activities may be minor sources of their enrichment in the surface water (Mohan *et al.,* 1996, Amadi *et al.,* 2010).

River stretch during 2015 also showed high pollution load, because two principal components were identified to be responsible for the deterioration of the river water and accounts for 89.15% of the overall total variance. The first principal component accounts for 78.24% of the total variance and observed high loading for pH, TDS, turbidity, BOD, COD, Ca, Mg, Fe, Mn, Pb, Cd and NO_3 (Table 3). Especially this year disposal of untreated domestic sewage from villages, effluents from industrial area and chemical weathering as well may be the major source of pollution of these parameters in river water (Mohan *et al.,* 1996). Second principal component comprises 10.91% of overall total variance and showed very less loading consists of Zn, Ni, As and Cr in river water. Effluents from industries like battery making, dye making, pigment making, alloy making are the major sources of Ni, Cr into the water bodies (Kashyap *et al.,* 2015). Agricultural, human and industrial activities taking place along the river course could be responsible for the high concentration of all metals at sampling points.

TABLE 1: Spatial variations of physicochemical parameters in water samples at different locations of Markanda River during 2014

Parameters	Locations of water sampling along river stretch								Standards		Grand mean
(mg/L)	L1	L2	L3	L4	L5	L6	L7	L8	CPCB*	WHO*	± SD
pH	7.46	7.48	7.59	7.71	7.90	7.91	8.07	8.12	6.5-8.5	6.5-8.5	7.78±0.259
TDS	70.67	70.83	80.48	86.07	91.26	98.83	98.17	100.50	500	NA	87.101±12.17
*TUB	10.74	11.16	12.65	11.69	11.80	15.58	17.29	17.50	10	NA	13.551±2.793
BOD	7.39	7.54	8.28	9.09	9.75	11.30	12.94	13.50	5	5	9.974±2.368
COD	13.38	14.36	14.99	17.70	20.86	22.80	24.90	25.51	20	20	19.311±4.857
Ca	35.59	39.79	42.24	46.22	48.15	49.95	53.89	61.00	200	NA	47.102±8.097
Mg	6.06	6.48	7.24	9.03	10.22	10.14	11.62	13.58	200	NA	9.295±2.618
Fe	0.128	0.140	0.167	0.207	0.215	0.237	0.217	0.240	1	NA	0.194±0.043
Zn	1.192	1.187	1.515	1.655	1.658	1.718	1.897	1.930	5	5	1.594±0.283
Mn	0.015	0.017	0.021	0.022	0.023	0.027	0.028	0.035	2	0.05	0.024±0.006
Pb	0.018	0.021	0.027	0.021	0.023	0.023	0.027	0.028	0.1	0.05	0.023±0.004
Ni	0.018	0.021	0.027	0.018	0.023	0.028	0.033	0.036	2	0.2	0.025±0.007
Cd	0.001	0.001	0.001	0.001	0.001	0.003	0.004	0.005	2	0.01	0.002±0.002
As	0.077	0.082	0.078	0.083	0.107	0.102	0.105	0.112	0.2	0.1	0.093±0.014
NO_3	5.067	6.217	7.667	8.667	9.833	12.167	13.333	15.502	NA	45	9.806±3.619
Cr	0.010	0.005	0.025	0.028	BDL	0.012	0.035	0.035	0.1	0.01	0.019±0.014

L_1 -Rukhri, L_2- Shambhuwala, L_3- Markanda temple, L_4 -dewani, L_5 -Moginand, L_6- Ogli, L_7- Excise colony, L_8- Kalaamb, BDL- Below detectable limit, NA-Not available, SD- standard deviation, *-Units for TUB are NTU.

TABLE 2: Spatial variations of physicochemical parameters in water samples at different locations of Markanda River during 2015

Parameters	Locations of water sampling along river stretch								Standards		Grand mean
(mg/l)	L1	L2	L3	L4	L5	L6	L7	L8	CPCB*	WHO*	± SD
pH	7.53	7.56	7.59	7.76	8.08	8.11	8.17	8.19	6.5-8.5	6.5-8.5	7.87±0.290
TDS	79.64	70.83	80.48	86.07	91.26	98.83	98.17	100.50	500	NA	88.223±10.771
*TUB	13.07	14.71	13.03	16.07	18.63	20.53	21.13	22.50	10	NA	17.458±3.743
BOD	8.04	8.20	8.66	9.10	10.14	11.84	13.27	14.00	5	5	10.406±2.345
COD	15.76	17.25	19.01	21.08	23.16	25.12	26.18	27.50	20	20	21.882±4.310
Ca	29.15	29.20	27.85	31.34	35.43	37.75	40.00	40.50	200	NA	33.900±5.152
Mg	3.08	5.54	6.10	8.70	10.20	9.48	10.58	12.87	200	NA	8.318±3.183
Fe	0.105	0.105	0.152	0.133	0.155	0.190	0.208	0.220	1	NA	0.159±0.044
Zn	0.852	1.187	1.515	1.655	1.658	1.718	1.897	1.930	5	5	1.551±0.366
Mn	0.013	0.014	0.015	0.021	0.029	0.030	0.031	0.035	2	0.05	0.023±0.009
Pb	0.016	0.019	0.022	0.022	0.025	0.026	0.030	0.035	0.1	0.05	0.024±0.006
Ni	0.041	0.043	0.039	0.039	0.041	0.040	0.041	0.045	2	0.2	0.041±0.002
Cd	0.001	0.001	0.001	BDL	0.001	0.003	0.004	0.004	2	0.01	0.002±0.002
As	0.050	0.048	0.037	0.033	0.043	0.052	0.050	0.050	0.2	0.1	0.045±0.007
NO_3	8.000	9.642	8.500	11.500	11.447	12.170	12.887	14.615	NA	45	11.095±2.251
Cr	0.015	0.010	0.028	0.032	0.015	0.018	0.038	0.045	0.1	0.01	0.025±0.013

L_1 -Rukhri, L_2- Shambhuwala, L_3- Markanda temple, L_4 -dewani, L_5 -Moginand, L_6- Ogli, L_7- Excise colony, L_8- Kalaamb, BDL- Below detectable limit, NA-Not available, SD- standard deviation, *-Units for TUB are NTU.

TABLE 3: Principal component analysis of data set of water quality during 2014 and 2015

Parameters	During 2014		During 2015	
	PCA_1	PCA_2	PCA_1	PCA_2
pH	0.265	-0.155	0.271	-0.010
TDS	0.259	-0.187	0.265	-0.066
Turbidity	0.255	0.216	0.276	0.083
BOD	0.267	0.013	0.279	0.078
COD	0.264	-0.174	0.279	-0.087
Ca	0.265	-0.037	0.275	0.108
Mg	0.263	-0.123	0.267	-0.154
Fe	0.243	-0.295	0.271	-0.054
Zn	0.258	-0.035	0.250	-0.319
Mn	0.266	0.050	0.275	-0.009
Pb	0.221	0.322	0.275	-0.041
Ni	0.244	0.258	0.107	0.521
Cd	0.236	0.188	0.240	0.213
As	0.242	-0.363	0.102	0.672
NO_3	0.270	-0.029	0.269	-0.024
Cr	0.161	0.647	0.196	-0.252
Eigen value	13.682	1.103	12.519	1.746
Variability (%)	85.510	6.893	78.242	10.912
Cumulative (%)	85.510	92.403	78.242	89.154

TABLE 4: Calculated individual pollution index (PI) of Markanda river during 2014 and 2015

Parameters	PI 2014	Status	PI 2015	Status
BOD	2.2	Strongly polluting	2.3	Strongly polluting
COD	1.0	Moderately polluting	1.1	Moderately polluting
Ca	0.2	Non polluting	0.2	Non polluting
Mg	0.1	Non polluting	0.0	Non polluting
Fe	0.2	Non polluting	0.2	Non polluting
Zn	0.3	Slightly polluting	0.3	Slightly polluting
Mn	0.0	Non polluting	0.0	Non polluting
Pb	0.2	Non polluting	0.3	Non polluting
Ni	0.0	Non polluting	0.0	Non polluting
Cd	0.0	Non polluting	0.0	Non polluting
As	0.5	Slightly polluting	0.2	Non polluting
NO_3	0.3	Slightly polluting	0.3	Slightly polluting
Cr	24.7	Seriously polluting	32.6	Seriously polluting

FIGURE 1: Downstream flow of Markanda river and water sampling stations around Kala-amb industrial town of (H.P) India (Source: *www.googlearth.com*)

Classification based on Pollution Index

There were significant variations observed in pollution index of surface water of Markanda river. Based on pollution index during 2014 values of Zn, as and NO_3 were slightly polluting and COD was moderately polluting. On the other hand BOD, Cr value was in strongly and seriously polluting category respectively. Rests of the parameters were non-polluting. During 2015 the trend was same as that of 2014, except for index values of as which ware non-polluting (Table 4). Mean values of BOD, COD and Cr were above permissible limits (CPCB, 2010) which were confirming the results of calculated pollution index values. Results are also in line with the findings of Mishra, (2010), who has also reported similar kind of high metal concentrations in eutrophicated and Delhi segment of Yamuna river.

Correlation coefficient (r-values) of physicochemical parameters

pH, TDS, BOD, COD, Ca, Mg, Zn, Mn, Cd, NO_3 and Cr registered positive/highly significant correlation (0.977, 0.969, 0.996, 0.990, 0.913, 0.972, 0.963, 0.916, 0.983, 0.945 and 0.955) (r-values) between 2014 and 2015 respectively. These attributes noticed almost similar concentrations during both years. But other parameters of water quality (turbidity, Fe, Pb, Ni and As) showed non-significant correlation, which implies these were recorded with different or uneven concentrations. The results indicated that the concentrations of the physical/chemical attributes in water had an effect on the quality of river water during study period. Nouri *et al.,* (2006) reported similar findings in their study of water quality of a river catchment.

CONCLUSION

Concentrations of observed attributes in the surface water of Markanda River demonstrated significant variations. Irrespective of years, high values were recorded at downstream sampling location (L8). However when compared to drinking water guidelines established by WHO, India, much greater attention should be paid to pH, BOD and COD though the concentrations were slightly above limits. In fact, concentrations of heavy metals were below permissible limits of surface water quality given by CBCB, India. The results of pollution index (PI) suggested that river water was adversely affected with respect to Cr, BOD and COD during each study year. Two possible sources of pollution to Markanda river water reveled by PCA and they were categorized into natural and anthropogenic factors. Nutshell, it is reasonably justified to conclude that the augmented concentrations of pollutants in Markanda river stretch around Kalaamb industrial town is greatly influenced by direct discharge of industrial, urban and dumping wastes into river and necessitate adequate strategies or management planning to control the intrusion of pollutants in river system.

ACKNOWLEDGEMENTS

The first author is highly thankful to Dean, Dr Kartar Singh Verma, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan-173230 (H.P), India for the guidance and help during the tenure of the study.

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