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Full Length Research Paper

Assessment of spatio-temporal variations in surface water quality of Ghaggar River (North-Western, India) utilized for drinking and agricultural purposes

Sukhdev Kundu[1]*, G. S. Gill[2], Naval Kishore[2], Ram Ratan Singh[2] and Aditya Kumar[1]

[1]School of Biological and Environmental Sciences, Shoolini University, Solan, H.P.- 173229, India.
[2]Department of Geology (CAS), Panjab University, Chandigarh-160014, Panjab, India.

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In the present study, statistical analyses (descriptive and principal component analysis) were applied to Ghaggar River surface water data set monitored in the month of June 2006 and 2007 to check spatio-temporal variations in water quality. From these, two summer observations were taken into consideration because in summer season, high concentrations are observed for different water constituents. The various physico-chemical constituents like pH, total dissolved solids (TDS), electrical conductivity (EC), temperature, $Cl^–$, HCO_3^-, $CO_3^{2–}$, Na^+, K^+, Ca^{2+}, Mg^{2+}, $F^–$, SO_4^{2-} and $PO_4^{3–}$ were analyzed. Statistical results revealed that water quality variables were totally different during the two summer observations.

Keywords: Principal component analysis, spatio-temporal variations, water quality, summer season.

INTRODUCTION

Today, clean water has become a precious commodity and its quality is threatened by over exploitation and insensitivity to conservation, inappropriate agricultural practices, inadequate treatment of the municipal/industrial wastes and deforestation. India is a land of major rivers and abundant monsoon rain, but most regions today face a serious water crisis. The rivers are the lifeline of a country. The rivers and canals in India have a total length of about 27,500 and 112,500 km, respectively (MOWR, 2006).

Ghaggar River is one of the major seasonal rivers passing through two most fertile states (Punjab and Haryana) of India. It receives domestic, industrial and municipal wastewaters/effluents all along its course. The base flow generated in the river system is utilized at various points for various purposes like drinking, irrigation and industrial. Water is pumped directly from the Ghaggar River and tributaries at several places for irrigational and drinking activities along its journey from upstream to downstream. Some industrial regions along with municipal councils/committees/corporations are discharging their wastewaters and effluents directly or indirectly into the Ghaggar River water through different channels. Therefore, it is necessary that the quality of water should be monitored at regular time intervals. Furthermore, the protection and maintenance of water quality is emerging as a great public concern in all over the world.

There have been few studies on the assessment of the Ghaggar River water quality in terms of physico-chemical and heavy metals characterization in Haryana and Punjab regions (Kaur et al., 2000; Kaushik et al., 2000). Garg (2002) has also linked the fluctuation in physical and chemical characteristics of river water with seasonal variation. Of late, multivariate statistical techniques such as cluster analysis (CA), factor analysis/principal component analysis (FA/PCA) and discriminant analysis (DA) has been considered useful for the evaluation and interpretation of large complex water quality data sets and apportionment of pollution sources/factors with a view to getting better information about the water quality and design of monitoring networks for effective management

*Corresponding author. E-mail: drkundu24@yahoo.co.in.

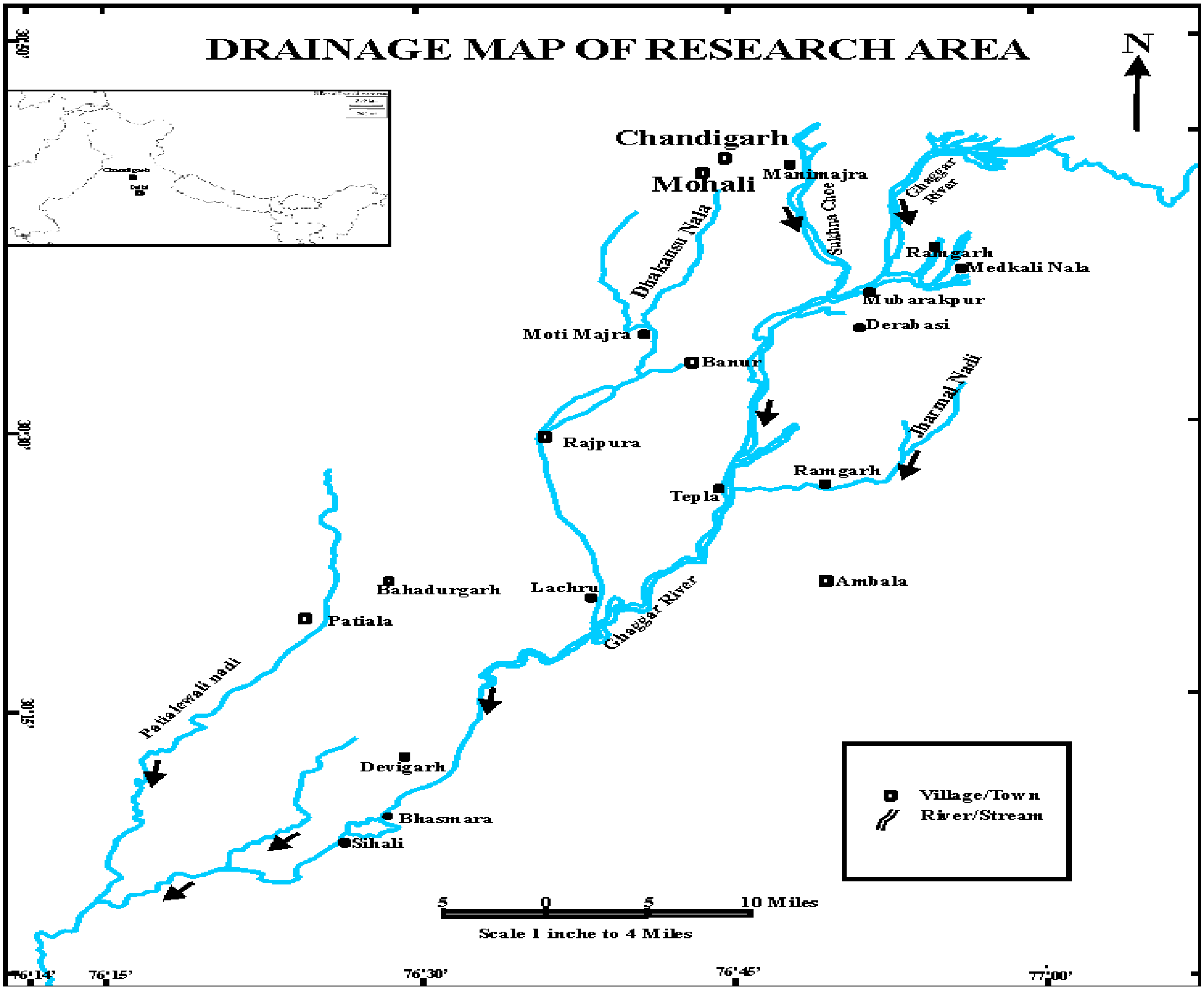

Figure 1. Site map of study area.

of water resources. However, such an analysis about the Ghaggar River is lacking. Therefore, the present study was undertaken to check the spatio-temporal variations in the surface water quality of the Ghaggar River using PCA and FA.

MATERIALS AND METHODS

Description of the study area

The area under investigation lies between North latitudes 30°00′00″ to 30°50′00″ and East longitudes 76˚11′24″ to 77°07′20″ and falls in the survey of India Toposheet No. 53B and 53F, covering a distance of 135 km (Figure 1). The research area falls within the boundaries of several states and covers some parts of different districts of Himachal Pradesh, Haryana and Punjab, India.

The chosen Ghaggar River originates from the Siwalik Hills of Himachal Pradesh and Haryana. It runs along the foot of the Siwaliks and flows through Haryana and Punjab to Rajasthan and then disappear itself in the sands of the Thar Desert. The Ghaggar River flows from east to west and then takes a southwesterly course. During its westward journey, a number of streams, stream-lets, drains and tributaries debouch their load into the Ghaggar. After flowing through Morni Hills before entering the plains, the Ghaggar River is joined by the Kaushalya Nadi in the foothills zone. The small streams viz. Kaushalya, Jhajra and Ghaggar get combined together near Chandimandir to form the main Ghaggar River. Furthermore, at downstream sites various point and non-point sources are joining the Ghaggar River and discharging their untreated effluents into it.

Sample collection and analysis

The surface water samples were collected from Badisher-Koti (Panchkula) to Rantanheri (Patiala) stretch. Samples were obtained in the month of May 2006 and May 2007 for summer observations. The physical parameters such as pH, electrical conductivity (EC),

Table 1. Descriptive statistics for surface water for summer observations of 2006 and 2007.

Variable	June 2006 (Summer)				June 2007 (Summer)			
	Mean	Stabdard deviation	Minimum	Maximum	Mean	Standard deviation	Minimum	Maximum
Temp	32.03	2.384	30	40	27.732	1.0410	26.2	30.0
pH	8.032	.3124	7.3	8.6	7.313	.3730	6.8	8.30
EC	807.52	337.86	325	1632	517.19	233.81	248.0	1248.0
TDS	523.23	215.29	212	1052	331.32	144.30	161.0	780.0
CO_3^{2-}	4.68	6.82	0	20	4.35	6.92	.0	20.0
HCO_3^-	247.74	38.79	200	365	245.81	115.95	135.0	680.0
Cl^-	104.06	46.89	42.6	235.8	87.86	63.00	27.8	291.0
SO_4^{2-}	94.10	114.00	20	558	28.13	15.79	10.0	75.0
PO_4^{3-}	7.47	7.56	.8	38.8	7.60	5.70	1.1	21.3
F^-	.353	.274	.02	.96	0.30	0.19	.05	.85
Na^+	76.29	92.3	22	375	66.32	73.74	13.0	438.0
K^+	18.57	16.13	4.0	72.0	11.81	9.92	2.3	50.0
Ca^{2+}	53.57	10.48	34.5	85.5	64.84	21.03	39.3	145.4
Mg^{2+}	26.59	7.49	13.6	48.2	15.01	11.90	6.8	65.7
TH	245.45	45.57	150	381	223.84	97.62	132.0	633.0

Temp = Temperature; EC = Electrical conductivity; TDS = Total dissolved solids; CO_3^{2-} = Carbonate; HCO_3^- = Bicarbonate; Cl^- = Chloride; SO_4^{2-} = Sulphate; PO_4^{3-} = Phosphate; F^- = Fluoride; Na^+ = Sodium; K^+ = Potassium; Ca^{2+} = Calcium; Mg^{2+} = Magnesium; TH = Total hardness.

total dissolved solids (TDS) and temperature were measured in the field using water and soil analysis kit (Electronics India, Model 16 E). The rest of the characteristics of water samples were measured in the laboratory immediately after transportation to the laboratory. Chloride, sulphate, phosphate, fluoride, carbonate, bicarbonate, sodium, potassium, calcium, magnesium and total hardness were estimated using standard procedures (APHA, 1992). To ensure accuracy, analysis was done in triplicates and mean value was taken into consideration.

RESULTS AND DISCUSSION

The obtained surface water results were subjected to statistical analyses (descriptive statistics and principal component analysis) to check spatio-temporal variations in river water quality using SPSS (2000).

Descriptive statistics

In descriptive analysis, variables mean values were taken into consideration as characteristics values to check variations between two different observations of the same season are shown in Tables 1 and 2. Table 1 shows variations between the two months of June (summer) observations of 2006 and 2007. From the table, it was clear that in summer 2006, the average mean values for temperature, pH, EC, TDS, CO_3^{2-}, HCO_3^-, Cl^-, SO_4^{2-}, F^-, Na^+, K^+, Mg^{2+} and TH are recorded higher as compared to summer 2007. Whereas, constituents like PO_4^{3-} and Ca^{2+} are recorded low in 2006 observation as compared to 2007 observation.

Principal component analysis (PCA)

Factor loading of all variables was calculated using principal component analysis (PCA)/factor analysis (FA) performed on 15 variables for 31 different sampling stations in summer observations of 2006 and 2007, in order to identify imperative spatio-temporal water variables. PCA analysis was done to see seasonal variations in the studied parameters. For this all, the analyses were made upon at least three observations each. PCA results along with factor loading values and

Table 2. Factors loading values and explained variance of variables for summer observations of 2006 and 2007.

Variable	June 2006 (Summer)		Variable	June 2007 (Summer)	
	Factor 1	Factor 2		Factor 1	Factor 2
Temp	0.231	0.695	Temp	-0.108	0.715
pH	-0.418	0.732	pH	0.009	0.167
EC	0.762	0.370	EC	0.928	0.102
TDS	0.767	0.351	TDS	0.926	0.098
CO_3^{2-}	0.260	-0.467	CO_3^{2-}	-0.097	-0.805
HCO_3^-	0.682	0.054	HCO_3^-	0.803	0.263
Cl^-	0.799	0.255	Cl^-	0.935	0.067
SO_4^{2-}	0.175	0.717	SO_4^{2-}	0.400	0.800
PO_4^{3-}	0.271	0.738	PO_4^{3-}	0.622	0.497
F^-	0.523	0.750	F^-	0.663	0.475
Na^+	0.650	0.431	Na^+	0.787	0.128
K^+	0.385	0.724	K^+	0.861	0.351
Ca^{2+}	0.624	0.188	Ca^{2+}	0.911	-0.128
Mg^{2+}	0.586	-0.353	Mg^{2+}	0.896	0.105
TH	0.744	-0.155	TH	0.938	-0.016
Variance (%)	40.54	18.69	Variance (%)	57.58	13.6
Cumulative (%)	40.54	59.24	Cumulative (%)	57.58	71.2

Table 3. Comparison of significance of variables of summer observations of 2006 and 2007.

Significance	June 2006 (Summer)	June 2007 (Summer)
Highly	EC, TDS and Cl^-	EC, TDS, HCO_3^-, Na^+, Ca^{2+}, Mg^{2+}, TH, Cl^- and K^+
Moderately	HCO_3^-, F^-, Na^+, Ca^{2+}, Mg^{2+} and TH	PO_4^{3-} and F^-
Weakly	K^+, PO_4^{3-}, SO_4^{2-}, CO_3^{2-}, Temp and pH	SO_4^{2-}, CO_3^{2-}, Temp and pH

percentages of variance for all stations are presented in Table 2 for both the observations. Eigenvalue gave a measure of the significance of the factor, and factor with the highest Eigenvalue was the most significant. Eigenvalue of 1.0 or greater was considered significant and is retained in the table, while those less than 1.0 were omitted. Liu et al. (2003a) categorized the factor loadings as strong, moderate and week corresponding to the absolute loading values of >0.75, 0.75–0.50, and 0.50–0.30, respectively.

Table 2 shows factor loading value for all variables for summer observations of 2006 and 2007. Two factors or PCs explained 59.24 and 71.2% of the total variance for 2006 and 2007, respectively which was adequate to give good prior information regarding the data structure. In summer observation of 2006, factor 1 accounted for 59.24% of total variance, which showed moderate significance. In summer 2006, the variables like F^-, Na^+, HCO_3^-, Mg^{2+}, Ca^{2+} and TH are moderately significant (0.75 to 0.50); EC, TDS and Cl^- are highly significant (> 0.75); and temperature, pH, CO_3^{2-}, SO_4^{2-}, PO_4^{3-} and K^+ were weakly significant (< 0.50) based on Eigen values. In summer observation of 2007, factor 1 accounted for 71.2% of total variance which showed moderate significance. It was observed that the parameters like EC, TDS, HCO_3^-, Cl^-, Na^+, K^+, Ca^{2+}, Mg^{2+} and TH are highly significant with Eigen value > 0.75, moderately significant with Eigen value (0.75 to 0.50) for parameters PO_4^{3-} and F^- and weakly significant with Eigen value < 0.05 for the parameters temperature, pH, SO_4^{2-} and CO_3^{2-}.

In addition, Table 3 shows comparison of significance of all components for summer observations of 2006 and 2007. Thus, variations are evident in various parameters when compared to summer season (2006) factor loadings with summer season (2007) factor loadings.

Conclusion

From the descriptive statistics, it was clear from the observation that during summer 2006, the river water contained the higher concentrations for various parameters as compared to summer 2007 observation. Principal component analysis (PCA) also confirmed changes in surface water parameters concentrations with temporal variations. Hence, it has been concluded that river surface water quality changed within the two different same season observations (summer) also. These observed variations in the present study may likely affect agriculture since this water is used for irrigation purpose, which may in turn have implications on human health. Moreover, since water is used for drinking purpose by local people, the change in quality of surface water may have direct impact on human health. In conclusion, observed changes in surface water quality of the river can have impact on human health both directly or indirectly.

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