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Original Research Paper

Impact of Land Uses and Seasons on Physico-chemical Characteristics of Surface Water in Solan District of Himachal Pradesh

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ABSTRACT

It has been widely accepted that there is a close relationship between the land use type and water quality. Streamwater is affected by several processes in the watershed, including anthropogenic activities that result in changes in the quality of water and its functioning. In year 2012, investigations on impact of land uses on physico-chemical properties of surface water was carried out during different seasons (rainy, winter and summer) in adjoining to Kandaghat block situated between latitude 30°57'994" N and longitude 77°06'470" E and 1458 metre above mean sea level in Solan District of Himachal Pradesh. The estimated water quality parameters were pH, electrical conductivity (EC), temperature, calcium (Ca), magnesium (Mg), nitrate (NO_3^-), chloride (Cl^-), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) from 39 sampling sites under different land uses (agriculture, forest and urban). The experimental data were statistically analysed through Factorial Randomized Design and significance of each treatment was calculated. The maximum pH (7.69), EC (266.39 µS/cm), Ca (66.08 mg/L), temperature (19.25°C), BOD (1.45 mg/L) and COD (18.33 mg/L) of surface water were recorded under urban land use, whereas Mg (12.90 mg/L), Cl^- (3.05 mg/L) and NO_3^- (4.19 mg/L) were maximum under agricultural land use. Maximum pH (7.79), temperature (22.58°C), BOD (1.71 mg/L), COD (17.41 mg/L), Ca (64.61mg/L), Mg (13.87 mg/L) and Cl^- (3.39 mg/L) were recorded during summer season, whereas EC (264.75 µS/cm) and NO_3^- (3.91 mg/L) were maximum during rainy season. The water quality index (WQI) for selected land uses ranged between 1.0782 to 1.0919, whereas season wise water quality index (WQI) ranged from 1.0757 to 1.0956, which shows excellent water quality; small variations in water quality indices were seasonal and linked to land use practices.

INTRODUCTION

Water is one of the most precious resources on earth without which there would be no life on earth (Yadav & Kumar 2011). About 97 per cent of the total water is present in the oceans and seas which is saline water, and is not useful while freshwater makes up only 2.6 per cent and 4/5 of that is immobilized as ice (Karthick & Ramachandra 2006). India is rich in water resources, being endowed with a network of rivers and blessed with snow cover in the Himalayan range that can meet a variety of water requirements of the country. Water quality problems remain ubiquitous around the world and in many locations, are growing in severity. Nutrient enrichment of freshwater from a variety of human activities including agricultural runoff, sewage and industrial sources is the most prevalent type of water quality problem (Kling et al. 2014). Land conversion for agricultural and urban development impacts stream and river ecosystem dynamics by changing hydrological regimes and increasing sediment and pollution loads (Zhang et al. 2010). Water quality index was calculated for the selected sites with an aim to provide a single number that expresses an overall water quality for a particular location based on various water quality parameters.

The Kandaghat, Solan is located between North latitude 30° 57' 994" and East longitude 77° 06' 470" at an elevation of 1458 meter above mean sea level. The land use changes in Kandaghat, Solan, like construction of roads, establishment of educational institutes, deforestation, change in cropping pattern and excessive use of agrochemicals for better crop production is expected to affect surface water quality. Therefore, monitoring of water quality is necessary so that appropriate prevention and remedial measures can be undertaken. The present study investigates the hypothesis that there is no significant difference in the occurrence of physical and chemical properties of water with special reference to nitrate, chloride, calcium, magnesium, COD and BOD, and design used for the analysis was Factorial Randomized Block Design.

MATERIALS AND METHODS

Water samples were collected during three seasons i.e., winter, summer and rainy. Surface water samples were collected in a clean transparent plastic bottle of one litre capacity. Pres-

Table 1: Methods used for estimation of physico-chemical parameters of water.

Parameter	Instrument/Method
	Physical Parameters
pH	EUTECH instrument pH 510
EC	Microprocessor based conductivity meter
Temperature	Mercury thermometer
	Chemical Parameters
BOD	BOD-System OxidirectSystemincubation for five days at 20°C
COD	Dichromate titration method
Ca and Mg	EDTA titrimetry
$No_3^-$and Cl^-	(Photometrically Spectroquantpharo 300 Merck made)

ervation, transportation to the laboratory and physico-chemical analysis of the water samples were as per standard methods (APHA 2005) (Table 1). The pH and temperature of water sample were recorded at sampling site. The samples were stored in a refrigerator at 4°C for further analysis. For calculating the water quality index, the most important parameters viz. pH, BOD, COD, calcium, magnesium, nitrate and chloride were used. The overall WQI was calculated using the method proposed by (Harkins 1974).

Where,

Qn = Vn-Vio/Sn-Vi0 × 100

Qn = Quality rating for the n^{th} water quality parameter

Vn = Estimated value of the n^{th}parameter at a given sampling station

Sn = Standard permissible value of n^{th}parameter

Vi0 = Ideal value of n^{th} parameter in the pure water. All the ideal values (Vi0) were taken as zero for the drinking water except for pH = 7.0

Wn (Unit weight) = *K*/*S*n

K (constant) $1/ Vs_1+1/Vs_2$------ + $1/VS_n$

The suitability of WQI values for human consumption, according to Mishra & Patel (2001) is given in Table 10. Total seven parameters were used to calculate WQI.

RESULTS AND DISCUSSION

It is revealed in Table 2 that the maximum pH of surface water was recorded under urban land use (7.69) and minimum under forest land use (7.34). The highest pH was recorded during summer season (7.79) and lowest during rainy season (7.28). The highest pH of surface water was recorded under urban land use which may be due to the dumping of waste, sewage and increased concentrations of ions due to evaporation losses. The lowest pH was recorded under forest land use which may be due the effect of thick forest vegetation. These findings corroborate the findings of Calmelset al. (2006), who reported that thick forest vegetation produces

Table 2: Physico-chemical properties of water under selected land uses and seasons in Kandaghat, Solan.

	Seasons				
Land Uses	Rainy	Winter	Summer	Mean	CD (p = 0.05)
		pH			
Agriculture	7.32	7.41	7.78	7.50	L = 0.08
Forest	7.03	7.24	7.71	7.34	S = 0.08
Urban	7.51	7.66	7.89	7.69	L×S = 0.14
Mean	7.28	7.45	7.79	7.51	
		EC (µS/cm)			
Agriculture	265.25	256.25	260.00	260.50	L = 0.24
Forest	261.00	219.00	220.78	233.59	S = 0.24
Urban	268.00	261.25	269.92	266.39	L×S = 0.41
Mean	264.75	245.50	250.23	253.49	
		Temperature (ºC)			
Agriculture	22.00	8.50	23.25	17.92	
Forest	21.25	7.75	19.75	16.25	
Urban	23.75	9.25	24.75	19.25	
Mean	22.33	8.50	22.58	17.80	
		BOD (mg/L)			
Agriculture	1.70	0.61	1.48	1.26	L = 0.10
Forest	1.00	0.49	1.20	0.90	S = 0.10
Urban	1.12	0.77	2.45	1.45	L×S = 0.18
Mean	1.27	0.63	1.71	1.20	

Table 3: Chemical properties of water under selected land uses and seasonsin Kandaghat, Solan.

	Seasons				
Land Uses	Rainy	Winter	Summer	Mean	CD (p = 0.05)
		COD (mg/L)			
Agriculture	16.05	15.25	16.75	16.02	L = 0.39
Forest	14.55	12.78	15.99	14.44	S = 0.39
Urban	18.75	16.75	19.50	18.33	L×S = 0.67
Mean	16.45	14.93	17.41	16.26	
		Calcium (mg/L)			
Agriculture	62.93	60.11	64.18	62.41	L = 0.35
Forest	63.00	55.20	62.40	60.20	S = 0.35
Urban	67.00	63.98	67.25	66.08	L×S = 0.61
Mean	64.31	59.76	64.61	62.89	
		Magnesium (mg/L)			
Agriculture	10.05	14.15	14.50	12.90	L = 0.65
Forest	9.70	12.00	13.75	11.82	S = 0.65
Urban	9.80	13.85	13.35	12.33	L×S = 1.12
Mean	9.85	13.33	13.87	12.35	
		Chloride (mg/L)			
Agriculture	2.12	2.05	4.99	3.05	L = 0.11
Forest	2.13	1.15	2.17	1.82	S = 0.11
Urban	3.06	2.92	3.00	2.99	L×S = 0.19
Mean	2.44	2.04	3.39	2.62	
		Nitrate (mg/L)			
Agriculture	5.53	2.20	4.85	4.19	L = 0.35
Forest	2.20	1.18	2.41	1.93	S = 0.35
Urban	4.00	2.28	4.00	3.43	L×S = 0.60
Mean	3.91	1.88	3.75	3.18	

surplus soil CO_2 by root respiration and by organic decay. The highest pH (7.79) of surface water during summer season may be due to decreased volume of water by evaporation and higher atmospheric temperature, which leads to increase in concentration of ions in the water body. Similar to present findings, Sharma & Capoor (2010) also reported maximum pH during summer season in lake water of Patna bird sanctuary. Whereas the lowest pH during rainy season may be due to the influence of runoff water entering into the water bodies and dilution effects of rain water.

The highest electrical conductivity was recorded under urban land use (266.39 µS/cm) and minimum under forest land use (233.59 µS/cm) (Table 2). Seasonally, the highest EC of surface was recorded during rainy season (264.75 µS/cm) and lowest during winter season (245.50 µS/cm). The higher EC recorded under urban land use may be due to inorganic pollution from dumping of waste and household waste, which increases the concentration of ions. The present findings are in conformation with the findings of Nkwocha et al. (2011) who also observed maximum EC under urban/suburban land use and reported that higher EC under urban land use may be due to dumping of urban waste in the river in the Nigeran tropical environment. In the present findings, higher EC was observed during rainy season which may be due to runoff of materials by rain such as organic waste. Bhatt et al. (1999) also reported increased ions concentration during rainy season, which resulted high electrical conductivity. These findings are in conformation with the findings of Singh et al. (2010) who reported maximum EC during rainy season in the rivers in Manipur.

The temperature ranged between 8.50°C and 22.58°C (Table 2). The variation in the water temperature may be due to different timings of collection of water samples and influence of seasonal and atmospheric temperature and it is a normal feature of water body of the region. These findings are in the conformations with the findings of Trivedi et al. (2010). It is evident from Table 2 that the BOD of surface water was recorded maximum under urban land use (1.45 mg/L) and minimum under forest land use (0.90 mg/L). The highest value of BOD was recorded during summer season (1.71 mg/L) and minimum during winter season (0.63 mg/L). BOD depends upon temperature, extent of biochemical activities and concentration of organic matter. Maximum BOD during summer season may be due to maximum biological activity at elevated temperature, which reduces the oxygen content of water and low in winter due to low temperature which lowers the biological activity (Ghavzan et al. 2006).

Results from Table 3 show that the maximum COD was recorded under urban land use (18.33 mg/L) and minimum under forest land use (14.44 mg/L). The highest value of COD was recorded during summer season (17.41 mg/L) and minimum during winter season (14.93 mg/L). Chemical oxygen demand is a measure of the oxygen equivalent of organic matter content of water that is susceptible to oxidation by the strong chemical oxidant. In the present findings, higher COD under urban land use may be due to the dumping of solid waste, sewage waste and runoff of chemicals. Similar to present findings, Boyd (1981) also reported that COD of water increases with increasing organic content. Maximum COD recorded during summer season may be due to decreased volume of water due to evaporation and high temperature, which leads to increase the concentration of organic content. Such seasonal variation was observed by many workers (Fokmare & Musaddiq 2002).

The increased calcium content of surface water was observed under urban land use (66.08 mg/L) and least contents were observed under forest land use (60.20 mg/L) (Table 3). Seasonally, highest value of calcium was reported (64.61 mg/L) during summer season and minimum during winter season (59.76 mg/L). The calcium is one of the most abundant substances of natural water, being present in high quantities in the rocks. Maximum value of calcium under urban land use may be due to increased rate of decomposition of organic matter because of high temperature, sewage discharge and solid waste from the surroundings. Similarly, the higher calcium content observed during summer season may be due to losses of water by evaporation which increases the concentration of calcium ions besides urban runoff, sewage disposal waste. These results are in conformation with the findings of Gupta & Paliwal (2010) who reported the highest values of calcium during summer season.

The maximum magnesium content was recorded under agriculture land use (12.90 mg/L) followed by urban (12.33 mg/L) and forest land use (11.82 mg/L). Highest value of magnesium was observed during summer season (13.87 mg/L) and minimum during rainy season (9.85 mg/L) (Table 3). The highest magnesium content under agriculture land use as well as urban land use may be due to the dumping of garbage, sewage discharge, urban runoff, agrochemicals, effluents containing the residues from soap and detergents. These findings are in the conformation with the findings of Shaikh & Mandre (2009). The highest chloride content of surface water was recorded under agriculture land use (3.05 mg/L) and lowest under forest land use (1.82 mg/L).

Seasonally, higher chloride content was observed during summer season (3.39 mg/L), and in winter season (2.04 mg/L) it was lowest (Table 3). Chloride in surface water may be due to geological formations of area, runoff of

Table 4: Water Quality Index for Agriculture land use.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.50	0.008	90.909090	0.015668511
EC	300	260.5	0.0002	86.83333	0.000388
BOD	5	1.26	0.013	25.2	0.018218
Calcium	200	62.41	0.0003	31.205	0.000448
Magnesium	100	12.9	0.0006	12.9	0.000666
Chlorine	250	3.05	0.0002	1.22	.000017
Nitrate	45	4.19	0.001	9.311111	0.0000969
					ΣWn.logQn= 0.035502

WQI = Antilog. ΣWn.logQn= Antilog 0.035502= 1.0851

Table 5: Water Quality Index for Forest land use.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.34	0.008	61.818181	0.014328929
EC	300	233.59	0.0002	77.86333	0.00037827
BOD	5	0.9	0.013	18	0.01631854
Calcium	200	60.2	0.0003	30.1	0.00044357
Magnesium	100	11.82	0.0006	11.82	0.00064357
Chlorine	250	1.82	0.0002	0.728	-0.00002757
Nitrate	45	1.93	0.001	4.288889	0.00063234
					ΣWn.logQn =0.032718

WQI = Antilog. ΣWn.logQn= Antilog 0.032718= 1.0782

Table 6: Water Quality Index for Urban land use.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.69	0.008	125.45	0.016787891
EC	300	266.39	0.0002	88.79667	0.00038968
BOD	5	1.45	0.013	29	0.01901117
Calcium	200	66.08	0.0003	33.04	0.00045571
Magnesium	100	12.33	0.0006	12.33	0.00065458
Chlorine	250	2.99	0.0002	1.196	0.000015546
Nitrate	45	3.43	0.001	7.622222	0.00088208
					ΣWn.logQn =0.038197

WQI = Antilog. ΣWn.logQn = Antilog 0.038197= 1.0919

Table 7: Water Quality Index for Rainy season.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.28	0.008	50.90909091	0.013654362
EC	300	264.75	0.0002	88.25	0.00038914
BOD	5	1.27	0.013	25.4	0.01826284
Calcium	200	64.31	0.0003	32.155	0.00045217
Magnesium	100	9.85	0.0006	9.85	0.00059606
Chlorine	250	2.44	0.0002	0.976	-0.00000211
Nitrate	45	3.91	0.001	8.688889	0.00093896
					ΣWn.logQn =0.034291

WQI = Antilog. ΣWn.logQn= Antilog 0.034291= 1.0821

Table 8: Water Quality Index for Winter season.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.45	0.008	81.81818182	0.015302798
EC	300	245.5	0.0002	81.83333	0.00038259
BOD	5	0.63	0.013	12.6	0.01430482
Calcium	200	59.76	0.0003	29.88	0.00044261
Magnesium	100	13.33	0.0006	13.33	0.0006749
Chlorine	250	2.04	0.0002	0.816	-1.766E-05
Nitrate	45	1.88	0.001	4.177778	0.00062095
					ΣWn.logQn =0.031711

WQI= Antilog. ΣWn.logQn= Antilog 0.031711= 1.0757

Table 9: Water Quality Index for Summer season.

Physico-Chemical Parameters	Standard value (Sn)	Observed value (Vn)	Unit wt (Wn)	Quality rating Qn=Vn-Vi0/Sn-Vi0×100	WQI = Wn.logQn
pH	6.6-8.5	7.79	0.008	143.6363636	0.017258115
EC	300	250.23	0.0002	83.41	0.00038424
BOD	5	1.71	0.013	34.2	0.01994234
Calcium	200	64.61	0.0003	32.305	0.00045278
Magnesium	100	13.87	0.0006	13.87	0.00068525
Chlorine	250	3.39	0.0002	1.356	2.6452E-05
Nitrate	45	3.75	0.001	8.333333	0.00092082
					ΣWn.logQn=0.03967

WQI = Antilog. ΣWn.logQn= Antilog 0.03967= 1.0956

Table 10: Suitability of water quality index for human consumption.

Range	Quality
0-24	Excellent
25-49	Good
50-74	Bad
75-100	Very Bad
>100	Unfit for human consumption

agrochemicals, agriculture waste and domestic waste. Maximum chloride during summer season may be due to low water level because of evaporation losses, which leads to increase in the concentration of ions. These findings are in agreement with the findings of Khound et al. (2012) who reported maximum chloride under agriculture land use system. Maximum nitrate content in surface water was recorded under agriculture land use (4.19 mg/L) and minimum under forest land use (1.93 mg/L). The higher concentration of nitrate was recorded under agriculture land use during rainy season (5.53 mg/L). The present findings corroborate the findings of Gupta et al. (2010) who reported high concentration of nitrate during rainy season. Nitrate in surface water depends upon activity of nitrifying bacteria, stream current and catchment characteristics. Nitrate is mainly attributed by anthropogenic activities such as runoff from agriculture lands and discharge from the households. In the present investigations, the sample collection sites were flourished with commercially grown vegetables, as well as floriculture crops in which plenty of agrochemicals are used which leads to increase in nitrate content in surface waters.

Water Quality Index (WQI)

From Table 4 to 9, it is evident that the Water Quality Index for all the land uses and seasons revealed excellent quality of water and small variations may be due to changes in seasons and land used practices. Increasing order of WQI for selected land uses were as follows: 1.0782<1.0851<1.0919 (Forest<Agriculture<Urban), indicating best water quality under forest land use amongst agriculture and urban land uses. Increasing order of WQI for seasons were 1.0757< 1.0821<1.0956 (Winter<Rainy<Summer), indicating superior water quality during winter season than in rainy and summer seasons.

CONCLUSION

All the water quality parameters were found to be within the permissible limits prescribed by Indian Standards specifications for drinking water IS: 10500 (1992). The water quality index (WQI) showed excellent quality of water. In the present study, it was found that seasons and land use influences the water quality parameters. Urban/suburban land uses show the highest values for all the parameters, whereas forest land use shows very less concentration of all the measured parameters, therefore this study raises the need of regular monitoring of water quality so that preventive measures could be undertaken to control any future consequences related to water pollution.

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