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Impact of cropping systems on physico-chemical characteristics of surface water during different seasons in Shimla region of Himachal Pradesh

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Abstract: The present investigations were carried out in the year 2014 with an objective to find out the impact of different cropping systems on nearby surface water resources in Shimla region of Himachal Pradesh. The aim of the study was to monitor the surface water bodies for pollution caused by nearby cropping systems in the Shimla area. In this study fruit, fruit + vegetable, vegetable and cereal based cropping systems were selected along with control (uncultivated land) and sampling was done during winter, summer and rainy seasons. The estimated water quality parameters revealed very less organic pollution and pH values were within the BIS prescribed limits of 6.5-8.5. Under vegetable based cropping system EC (500.23 µS cm^{-1}), TDS (329.17 mg/l), BOD (1.48 mg/l), COD (31.09 mg/l), Cl^- (25.66 mg/l), Ca (75.59 mg/l) and Mg (11.14 mg/l) were in high concentration, whereas No_3- content were high under fruit + vegetable based cropping system. DO were maximum (8.61mg/l) under uncultivated land. Calcium and COD were high in some samples, which could be from anthropogenic sources, rest of the parameters were within the desirable limits prescribed by Bureau of Indian Standards (BIS). The experimental data were statistically analysed through Analysis of variance (two way classification of data) indicated positive correlation among most of the physical and chemical parameters. Study reveals that cropping systems as well as seasonal changes has affected the water quality. The study carried out for water quality parameters, revealed the correlation of each parameter with one another under different cropping systems.

Keywords: Agriculture, Cropping system, Intensive farming, Seasons, Water quality

INTRODUCTION

Cropping systems, an important component of a farming system, represents a cropping pattern used on a farm and their interaction with farm resources, other farm enterprises and available technology. The intensive uses of agriculture inputs and continuous cropping often contribute to environmental deterioration, degrading soil and water resources (Warren *et al*. 2008). Water quality in agricultural systems is associated with the amount of soil lost as runoff into surface water and with the amount of plant nutrients and pesticides that reach surface waters (Nafziger, 2009). Intensive agriculture and growing demands for energy during the last few decades has affected the physical, chemical parameters and biological attributes of the surface water (Jain *et al*. 2007). A cropping system affects water quality to the extent that it keeps soil in place, releases little pesticide, and takes up nutrients that would otherwise leave fields in drainage or runoff water. Use of agrochemicals in Himachal Pradesh on various horticultural crops has increased the production and contributed a lot to the economy of the state. But indiscriminate uses of agrochemicals are also responsible for polluting our water resources (Thakur *et al*. 2012). In the Shimla region the major cropping systems being followed are fruit, vegetable, fruit + vegetable and cereal based cropping systems. Intensive agriculture practices like use of agro chemicals along with other agricultural inputs such as capital and labour are likely to cause degradation of the soil and water quality adjoining to selected cropping

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systems. Studies on effect of cropping system on water quality in Shimla have not been done so far; therefore this study was conducted to identify the pollution present in the surface water resources from nearby farmlands. Water quality in Shimla area has been viewed as un-polluted, however in recent years due to land use change for agriculture practices, pollution due to non-point sources have become evident.

MATERIAL AND METHODS

Water samples were collected under different cropping systems viz., Fruit -T_1, Fruit + Vegetable-T_2, Vegetable -T_3, Cereal-T_4 and uncultivated land -T_5 was taken as Control. Each treatment was replicated thrice. Sampling was done during winter, summer and rainy seasons. Surface water samples were collected in one litre plastic bottle from streams, springs, Bawri and Nalas. Sampling, preservation and transportation of the samples to the laboratory were done as per standard methods (APHA, 2005). The water samples were analyzed for physical and chemical parameters. SPSS Statistics 17.0 software was used for statistical analysis.

Parameter	Method/ Instrument
Physical parameters	
pH	EUTECH instrument pH 510
EC/TDS	Microprocessor based conductivity meter
Turbidity	Digital turbidity meter
Temperature	Mercury thermometer
Chemical parameters	
DO	Winkler's titration method
BOD	BOD-System Oxidirect System incubation for five days at 20°C
COD	Reflux $K_2Cr_2O_7$ (TR320 Spectroquant)
Ca, Mg,No_3^- and Cl	Colorimetry (Spectroquant pharo 300 Merck made)

RESULTS AND DISCUSSION

It is evident from Table 1 that pH of the surface water in Shimla area ranged from 6.69 to 8.41. Amongst all cropping systems highest pH (7.64) was recorded under fruit based cropping system followed by fruit + vegetable (7.53), vegetable (7.47), cereal (7.28) and control (7.09). Use of chemical fertilizers and their runoff into surface water bodies may have resulted high pH of surface water. Slightly acidic pH during rainy season may be due to dilution of surface water by rainfall. Fruit and fruit + vegetable based cropping system were statistically at par ($p < 0.05$) with each other. All the cropping systems differed significantly from control (7.09). Mean values of EC of surface water samples fluctuated between 454.6 µS cm^{-1} and 500.23 µS cm^{-1}. There were no significant difference in EC of surface water among the fruit, fruit + vegetable and vegetable based cropping systems. However EC recorded under different farming systems were significantly different ($p > 0.05$) from control. The study indicated that pH and EC were slightly higher in fruit and fruit + vegetable based cropping systems which may be due run off agrochemicals in the nearby water bodies. These findings confirm the findings of Lamptey *et al.* (2013) who reported that pH (5.1 to 7.2) and EC (200-8300 µS cm^{-1}) of Keta Lagoon, Ghana in West Africa were influenced by intensive agriculture and agrochemicals runoff from nearby farmlands.

TDS of surface water ranged from 290.08 mg/l to

Table 1. Influence of intensive agriculture on physico-chemical parameters of surface water in Shimla.

Seasons	Cropping system						
	F	F+ V	V	C	UL	Mean	CD (*p=0.05*)
				pH			
Winter	7.77	7.74	7.85	7.50	7.15	7.60	S = 0.11
Summer	8.41	8.16	7.85	7.34	7.11	7.77	T = 0.14
Rainy	6.74	6.69	6.73	6.99	7.02	6.83	S*T = 0.25
Mean	7.64	7.53	7.47	7.28	7.09	7.40	
				EC(µS cm^{-1})			
Winter	514.34	514.18	514.36	502.40	456.90	500.43	S = 9.79
Summer	518.66	519.17	530.70	505.63	465.68	507.97	T = 12.64
Rainy	457.45	456.09	455.63	452.03	441.22	452.48	S*T = NS
Mean	496.82	496.48	500.23	486.69	454.6	486.96	
				TDS(mg/l)			
Winter	338.23	340.40	337.48	331.54	300.15	329.56	S = 6.54
Summer	343.32	341.47	350.43	331.73	305.99	334.59	T = 8.44
Rainy	300.89	300.51	299.60	298.25	290.08	297.86	S*T = 14.63
Mean	327.48	327.46	329.17	320.51	298.74	320.67	
				Temperature (^{o} C)			
Winter	8.33	7.50	8.16	6.83	7.50	7.66	
Summer	24.33	23.16	23.66	21.33	24.00	23.30	
Rainy	20.16	21.33	22.66	20.50	20.83	21.10	
Mean	17.61	17.33	18.16	16.22	17.44	17.35	

Where: F= Fruit; F + V = Fruit + Vegetable; V =Vegetable; C = Cereal and UL = Uncultivated land

Table 2. Influence of intensive agriculture on physico-chemical parameters of surface water in Shimla.

Seasons	Cropping system						
	F	**F+ V**	**V**	**C**	**UL**	**Mean**	**CD (*p=0.05)***
	Turbidity (NTU)						
Winter	0.46	0.35	0.29	0.25	0.23	0.32	S = 0.45
Summer	3.00	1.33	0.86	0.82	0.74	1.35	T = 0.64
Rainy	4.66	3.00	2.00	0.99	0.92	2.31	S*T = 1.1
Mean	2.71	1.56	1.05	0.69	0.63	1.33	
	Biochemical Oxygen Demand (mg/l)						
Winter	0.34	0.32	0.53	0.22	0.13	0.31	S = 0.54
Summer	0.78	1.00	1.29	0.33	0.28	0.74	T = 0.70
Rainy	1.66	1.99	2.63	0.37	0.27	1.38	S*T = NS
Mean	0.93	1.10	1.48	0.31	0.23	0.81	
	Dissolve oxygen (mg/l)						
Winter	8.43	8.14	7.30	8.66	8.93	8.29	S = 0.27
Summer	7.96	7.95	7.13	8.30	8.46	7.96	T = 0.35
Rainy	7.94	7.85	6.97	8.20	8.43	7.87	S*T = NS
Mean	8.11	7.98	7.13	8.38	8.61	8.04	
	Chemical Oxygen Demand (mg/l)						
Winter	19.73	21.59	26.70	14.45	8.25	18.14	S = 2.08
Summer	19.91	21.78	27.70	15.19	9.00	18.71	T = 2.69
Rainy	25.19	26.90	38.89	22.85	16.30	26.03	S*T = NS
Mean	21.61	23.42	31.09	17.49	11.18	20.96	

Where: F= Fruit; F + V = Fruit + Vegetable; V =Vegetable; C = Cereal and UL = Uncultivated land

350.43 mg/l in Shimla region under different cropping systems (Table 1). TDS of surface water samples from vegetable based cropping system showed maximum mean value of 329.17 mg/l followed by fruit (327.48 mg/l), fruit + vegetable (327.46 mg/l), cereal based cropping system (320.51 mg/l) and uncultivated land (298.74 mg/l). Fruit, fruit + vegetable, vegetable based cropping system differed significantly ($p > 0.05$) with cereal and uncultivated land. The high concentration of TDS in water bodies may be due to addition of Cl^-, No_3^-, Ca and Mg from nearby farm lands. Similar findings were reported by Esmaeili and Johal (2005) in Gobindsagar reservoir, India, who reported that dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, nitrates, calcium, magnesium, phosphates, sulphates etc.

Temperature of surface water resources varied between 6.83 °C to 24.33 °C (Table 1) in Shimla region under different cropping systems. Season wise highest temperature were recorded during summer (23.30 °C), followed by rainy (21.10 °C) and winter season (7.66 °C). The variation in the water temperature may be due to different timings of collection of water samples, influence of seasons and atmospheric temperature. These findings are in the confirmations with the findings of Trivedi *et al.* (2010) who have reported seasonal variation in physical and chemical propertied of drinking water at Kanpur, India.

Turbidity of surface water under fruit based cropping system revealed maximum mean value (2.71 NTU) (Table 2) in the Shimla area, followed by fruit+ vegetable (1.56 NTU), vegetable (1.05 NTU), cereal based cropping system (0.69 NTU) and uncultivated land (0.63 NTU). The turbidity recorded under fruit based cropping system differed significantly (p values > 0.05) from rest of the cropping systems and control. Season wise turbidity was maximum during rainy season (2.31 NTU) followed by summers (1.35 NTU) and winter season (0.32 NTU). During the rainy season higher value of turbidity observed due to influx of rain water from nearby farmlands, washes silts, sand and cloudiness area. These findings are in confirmation with the findings of Tripathi *et al.* (2014) who reported anthropogenic impacts on physico- chemical parameters of river Ganga and found highest turbidity during rainy season at Shringverpur, Allahabad.

BOD of surface water under different cropping systems in Shimla region ranged between 0.13 mg/l to 2.63 mg/l (Table 2). Mean values for BOD in surface water under fruit based cropping system (0.93 mg/l) was statistically at par (p values < 0.05) with fruit + vegetable (1.10 mg/l) and vegetable (1.48 mg/l) based cropping systems and differed significantly from cereal (0.31 mg/l) based cropping system and control (0.23 mg/l). Seasonally BOD was maximum during rainy season (1.38 mg/l) and minimum during winters (0.31 mg/l).

DO in water samples ranged between 6.97 mg/l to 8.93 mg/l (Table 2). Maximum mean value of DO in surface water was obtained under fruit based cropping system (8.11 mg/l) followed by fruit + vegetable (7.98 mg/l), vegetable (7.13 mg/l), cereal (8.38 mg/l) and uncultivated land (8.61 mg/l). Seasonally maximum DO was recorded during winter season (8.29 mg/l) and minimum during rainy season (7.87 mg/l). DO of surface water under cereal and control were statistically at par ($p < 0.05$) with each other. These findings are in agreement with the findings of Oterler

Table 3. Influence of intensive agriculture on chemical parameters of surface water in Shimla.

Seasons	Cropping system						
	F	**F+ V**	**V**	**C**	**UL**	**Mean**	**CD (*p=0.05)***
				Nitrate (mg/l)			
Winter	10.00	12.00	9.33	6.33	3.33	8.20	S = 0.64
Summer	12.00	13.66	14.66	7.66	4.33	10.46	T = 0.82
Rainy	7.33	7.66	8.33	6.66	3.33	6.66	S*T = 1.43
Mean	9.77	11.11	10.77	6.88	3.66	8.44	
				Chloride (mg/l)			
Winter	16.00	24.00	32.50	14.51	13.60	20.13	S = 2.08
Summer	27.50	32.00	34.50	18.66	14.50	25.43	T = 2.79
Rainy	7.46	7.70	10.00	5.93	3.36	6.89	S*T = 4.66
Mean	16.98	21.23	25.66	13.03	10.51	17.48	
				Calcium (mg/l)			
Winter	74.66	69.66	95.33	57.00	14.00	62.13	S = 8.02
Summer	84.66	84.93	99.11	67.66	38.33	74.94	T = 10.35
Rainy	12.66	19.33	32.33	13.00	5.00	16.46	S*T = 17.92
Mean	57.33	57.97	75.59	45.88	19.11	51.18	
				Magnesium (mg/l)			
Winter	10.97	10.70	11.56	4.66	4.43	8.46	S = 0.95
Summer	12.56	12.56	16.43	11.36	8.96	12.38	T = 1.22
Rainy	5.96	4.46	5.43	3.26	2.13	4.25	S*T = 2.12
Mean	9.83	9.24	11.14	6.43	5.17	8.36	

Where: F= Fruit; F + V = Fruit + Vegetable; V =Vegetable; C = Cereal and UL = Uncultivated land

et al. (2014), who reported that BOD was lowest and DO were highest during winter season in Tundzha river in Turkey and these parameters were influenced by surrounding farms where cultivation of fruits, vegetables and rice were followed.

COD of surface water under different cropping systems ranged between 8.25 mg/l to 38.89 mg/l (Table 2). Maximum mean value for COD were detected in surface water under vegetable based cropping system (31.09 mg/l) followed by fruit + vegetable (23.42 mg/l), fruit (21.61 mg/l), cereal (17.49) and uncultivated land (11.18 mg/l). Seasonally, COD were maximum (26.03 mg/l) during rainy season and minimum (18.14 mg/l) during winters, which were significantly at par ($p < 0.05$) with COD recorded during summer season (18.71 mg/l) in Shimla region. COD of surface water under vegetable based cropping systems differed significantly ($p > 0.05$) with rest of the cropping systems along with control i.e. uncultivated land. COD were high during rainy season (26.03 mg/l) which may be due to surface runoff of organic waste from nearby farms. These findings are in confirmation with the findings of Upkar and Vyas, (1992) who also reported that high value of COD may be due to high degree of organic pollution in Mansarovar reservoir, Bhopal.

Maximum mean value of NO_3^- in surface water in Shimla area under different cropping systems was observed under fruit + vegetable based cropping system (11.11 mg/l) (Table 3), followed by vegetable (10.77 mg/l), fruit (9.77 mg/l), cereal (6.88 mg/l) and uncultivated land (3.66 mg/l). Seasonally maximum

Table 4. Pearson correlations between water quality parameters under different cropping systems.

Parameter	pH	EC	TDS	Turbidity	COD mg/l	BOD mg/l	Ca mg/l	Mg mg/l	No3 mg/l	Cl mg/l	DO mg/l	Temp^r °C
pH	1											
EC	.827**	1										
TDS	.832**	.997**	1									
Turbidity	-.262	-.223	-.213	1								
COD mg/l	-.110	.010	.017	.352*	1							
BOD mg/l	-.281	-.111	-.104	.442**	.564**	1						
Ca mg/l	.841**	.907**	.905**	-.254	.109	-.082	1					
Mg mg/l	.740**	.828**	.818**	-.137	.100	-.006	.869**	1				
No3 mg/l	.679**	.748**	.759**	.089	.457**	.217	.775**	.776**	1			
Cl mg/l	.819**	.835**	.827**	-.232	.076	-.080	.875**	.875**	.746**	1		
DO mg/l	-.072	-.200	-.202	-.231	-.792**	-.586**	-.303*	-.337*	-.486**	-.341*	1	
Temperature °C	-.138	-.186	-.185	.477**	.249	.371*	-.113	.120	.135	-.057	-.323*	1

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed).

NO_3^- (10.46 mg/l) content were observed during summers, which were significantly different ($p > 0.05$) from rainy season (6.66 mg/l) as well as winter season (8.20 mg/l). NO_3^- content of surface water under fruit + vegetable and vegetable based cropping systems was statistically at par with each other and differed significantly from rest of the cropping systems and control. NO_3^- may arise from the excessive application of fertilizers, leaching and runoff of wastewater or other organic wastes into surface water bodies (WHO 2006).

Cl^- content in surface water in Shimla area under different cropping systems ranged between 3.36 mg/l to 34.50 mg/l. Maximum mean value for Cl^- in surface water was under vegetable based cropping system (25.66 mg/l) followed by fruit + vegetable (21.23 mg/l), fruit (16.98 mg/l), cereal (13.03 mg/l) and control (10.51 mg/l). Seasonally, Cl^- content were maximum (25.43 mg/l) during summers, which were significantly different (p values > 0.05) from rainy season (6.89 mg/l) as well as winter season (20.13 mg/l). Cl^- content of surface water under vegetable based cropping system differed significantly ($p > 0.05$) from all other cropping systems and control. Presence of Cl^- content in water bodies is the indication of organic waste of animal origin and this contamination may be due to nearby agriculture farms. These findings confirm the findings of Kumar *et al*. (2006) who studied the Ranjit Sagar Reservoir, Jammu and Kashmir and reported that Cl^- content in surface water is regarded as an indication of organic load of animal origin.

Data presented in Table 3 for study of impact of cropping systems on physico-chemical parameters of surface water in Shimla region revealed that calcium in surface water samples ranged from 5 mg/l to 99.11 mg/l. Mean values of Ca in surface water under vegetable (75.59 mg/l) based cropping systems differed significantly ($p > 0.05$) from fruit (57.33 mg/l), fruit + vegetable (57.97 mg/l), cereal based cropping system (45.88 mg/l) and control (19.11 mg/l) i.e. uncultivated land. Seasonally, summer season revealed maximum Ca content (74.94 mg/l) which were significantly different from Ca content observed during winters (62.13 mg/l) and rainy season (16.46 mg/l). Mg content was highest (12.38 mg/l) during summer season and lowest (4.25 mg/l) during rainy season, which shows that they significantly differed (p values > 0.05) from each other. Mean values of Mg in surface water were high under vegetable based cropping system (11.14 mg/l) (Table 3) which were statistically different from fruit (9.83 mg/l), fruit + vegetable (9.24 mg/l) cereal (6.43 mg/l) based cropping system and control (5.17 mg/l). The presence of Ca and Mg in surface water may be due to runoff of chemical fertilizers from surrounding farms. These findings corroborate the findings of Agu *et al*. (2014) who reported that chemical fertilizers contain volumes of elements ranging from macro nutrient such as nitrate, phosphate and potassium and trace elements such as calcium, magnesium, iron, copper etc.

Correlation matrix: During the present study this is evident from Table 4 that pH and EC (0.827), EC and TDS (0.997), pH and TDS (0.832) are strongly correlated to each other and negatively correlated to turbidity. EC, pH, TDS are positively correlated to Ca, Mg, Cl^- and No_3-, which means that increase in nutrient content of surface water body has increased pH, EC and TDS, respectively. No_3-, Mg, Ca and Cl^- are positively correlated to each other showing their common source of origin. Agriculturally induced water pollution may occur from point sources as well as through diffuse pollution from farm land. pH shows negative correlation with BOD (-0.281) and COD (-0.110). DO and BOD (-0.586) are negatively correlated to each other which mean increase in demand of DO would decrease the BOD of surface water bodies. Positive loading were observed between Cl^- and Ca (0.875), No_3- and COD (0.457) as well as BOD and COD (0.564). These findings confirm the findings of Manssour and Al-Mufti, (2010) who reported similar findings in Quttina Lake in the middle region of Syria. Temperature is positively correlated to turbidity, COD, BOD and negatively with TDS, Cl^-, No_3-, Mg, and Ca. The pressure of intensive agriculture may impact water quality particularly via nutrient loss from land to water Murphy *et al.* (2015). The nutrients and agrochemicals applied in the fields may reach adjacent surface water bodies over land flows and subsurface flows during precipitation events or, at a slower rate, reach surface water bodies through groundwater discharge (Johannsen and Armitage, 2010).

Conclusion

Impact of cropping systems on physico-chemical characteristics of surface water during different seasons in Shimla region of Himachal Pradesh have revealed the significant impact of cropping systems on water quality. The investigated hypothesis showed significant difference in the occurrence of physical and chemical properties of water. Water quality under vegetable based cropping system was reported with higher concentration of nutrients and under control site there were less organic pollution along with low level of pollutants. Intensive farming under different cropping systems impacted the quality of water and among these, the stresses (agricultural, horticultural and wasteland) are impacting largely on water quality. All the water quality parameters were within desirable limits except Ca according to Bureau of Indian standards (BIS). High content of Ca in surface water during winter and summer seasons under the fruit and fruit + vegetable cropping systems may be due to anthropogenic sources such as from Ca containing fertilizers or it could be from geological origin. Careful planning of land use, shifting towards organic agriculture and minimizing the use of agrochemicals is needed to bring significant reductions in nutrient exports from agriculture land.

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