Threat to water resources due to landuse change of low hills of North – West Himalayas

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Abstract- The water quality has started to deteriorate due to change in landuses even in hilly areas. This necessitated to carry out investigation regarding status of water quality in the hilly region by assessing the seasonal water quality parameters namely like pH, turbidity, EC, TDS, DO, BOD, COD, Ca, Mg, chlorides, nitrates, heavy metals (Ar, Cd, Pb, Cr, Zn, Hg), total coliform under four different landuses categorised as agriculture, urban, peri-urban and forest at 24 representative locations in low hilly region. The results shown that the surface water quality parameter like pH, turbidity, EC, TDS, COD, Mg, chlorides, nitrates, heavy metals (Ar, Cd, Pb, Cr, Zn), total coliform were within the permissible limits whereas, DO, BOD and Ca ranged from 4.10 to 5.67 mg/l, 2.97 to 6.76 mg/l and 38.53 to 82.44 mg/l respectively were above the permissible limits laid down by CPCB. The ground water quality parameters like pH, turbidity, EC, TDS, COD, Mg, chlorides, nitrates, heavy metals (Cd, Pb, Zn, Cr), total coliform were within the permissible limits whereas, the parameters such as DO, BOD, Ca and Ar, ranged from 4.62 to 6.61 mg/l, 2.81 to 6.37mg/l, 35.36 to 93.69 mg/l, 0 to 0.082 mg/l respectively, were above the permissible limits as per CPCB standards. The GIS was incorporated to generate a map that integrated information relating to water quality and its distribution over the study area.

Index Terms- Water Quality, dominant landuses, water quality parameters, WQI, GIS mapping.

I. Introduction

Landuse refers to occurrence of anthropogenic actions on land such as agriculture, forest, urban, peri-urban, pasture etc. The changes in landuse at local and global scales are one of the important driving factors of global climate change (Foley *et al.*, 2005 and Pielke, 2013). Rapid industrialization and massive use of chemical fertilizers and pesticides in agriculture are causing deterioration of water quality. Urban runoff often contains nutrients, sediment and toxic contaminants can cause water pollution. Different types of landuses affect the quality of water quality through point and non point sources.

Global ground water storage is roughly equal to the total amount of fresh water stored in the snow and ice pack, including north and south poles, but with increasing population and improving living standards, the pressure on water resources is increasing and per capita availability of water resource is decreasing drastically (Sampath *et al.*, 2001 and Supriya *et al*., 2019). Our planet Earth, has plenty of water in the oceans (97.7%), however only 2.7 % is available as the fresh water (Todd, 1970 and Supriya *et al.*, 2018, Supriya *et al.*, 2019), the major quantum (70%) of which is being used for irrigation, 20% for industry, whereas, 10% is being used for domestic purpose. Landuse changes have significant effect quality and quantity of water. Landuses affect the rate of runoff, infiltration, water quality and vegetation (Tideman, 1996). Discharge of sewage, domestic waste, industrial effluents and agrochemicals resulted variety of changes in the hydrology and water quality (Mahadev and Gholamis, 2010) and create difficulties for macro invertebrates to survive in high polluted water bodies. The hilly area of developing countries are lesser polluted as compared to cities in plains. Hence, water quality analysis becomes a neccesity to ensure the safety and health of the people residing in study area. So in the present study, the impacts of different landuse water quality status were assessed in low hilly region.

II. Material and Methods

Study Area

In order to assess the impact of landuses change on water quality, the present study has been conducted in some selected regions of Bilaspur, Kangra and Hamirpur districts in lower hill area of Himachal Pradesh which is completely mountainous with altitude ranging from 350 to 6975 meter above mean sea level (Table 1). Bilaspur having an area of 1,167 km^2 is located at 31.34° N to 76.68° E, lies at the foot hill of Bandla Hills, near the reservoir of Govind Sagar on the Sutluj River. Kangra district of Himachal Pradesh having an area of 5,739 km^2 is located at 32.5° N to 77.45° E and Hamirpur district having an area of 1,118 km sq located between 31.68° N and 76.52°E. Two locations (municipal committees) in each of three regions had been selected under four dominant landuses (urban, peri-urban, agriculture and forest) and periodic sampling was done during pre-monsoon, monsoon and post monsoon seasons (Figure 1). Water quality of selected areas was monitored by geospatial mapping (ERDAS software) for different water quality parameters. For this, Water Quality Index (WQI) was calculated by following method outlined by Batabyal and Chakraborty (2015).

$\boldsymbol{WQI = \Sigma S_{i\_n}}$
$\boldsymbol{SI_i = W_i \times q_i}$
Where,

SI_i is the sub index of ith parameter;
W_i is relative weight of ith parameter;
q_i is the rating based on concentration of ith parameter, and
n is the number of chemical parameters.

$$w_i = \frac{w_i}{\Sigma w_i}$$

Where,

W_i is the relative weight,
w_i is the weight of each parameter, and

$\boldsymbol{q_i = (C_i / S_i) \times 100}$

Where,
q_i is the quality rating,
C_i is the concentration of each chemical parameter in each water sample in mg/L, and
S_i is the Indian drinking water standard for each chemical parameter in mg/L.
The computed WQI values were classified into five categories: excellent (WQI= 0-25); good (WQI= 26-50); bad (WQI= 51-75); very bad (WQI= 76-100); and unsuitable for drinking (WQI ≤ 100).

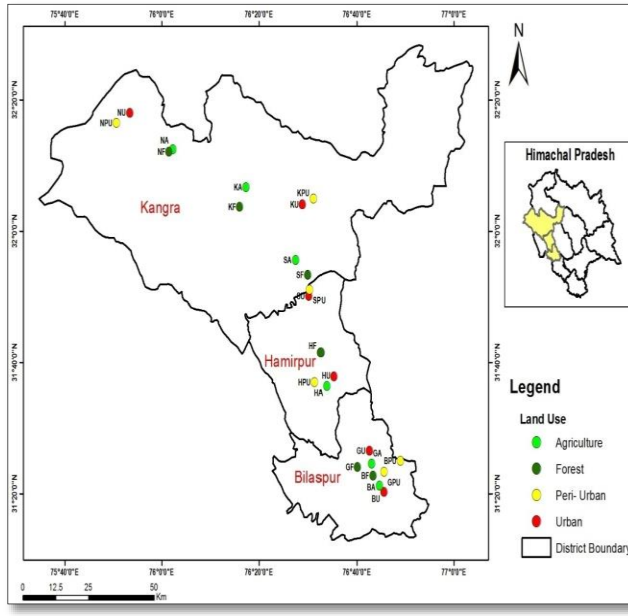


Figure 1: Map of study area

Table 1: Details of selected locations for water sampling in study area.

Code	District	Municipal Committee	Locations	Surface Water		Ground Water	
				Latitude	**Longitude**	**Latitude**	**Longitude**
BU	Bilaspur	Bilaspur	Bilaspur	31°20’40”N	76°45’20E	31°20’18”N	76°45’34”E
BPU			Barmana	31°25'17”N	76°49’58E	31°24’59”N	76°48’56”E
BA			Talwar	31°21’05”N	76°44’44E	31°21’13”N	76°44’38”E
BF			Auhar	31°22’29”N	76°43’36E	31°22’45”	76°43’19”E
GU		Ghumarwin	Ghumarwin	31°26’46”N	76°42’18E	31°26’31”N	76°42’36”E
GPU			Kandrauar	31°23’37”N	76°45’26E	31°23’20”N	76°45’35”E
GA			Panol	31°24’26”N	76°42’51E	31°24’34”	76°43’02”E
GF			Sunhani	31°24’02”N	76°40’01E	31°24’02”N	76°40’09”E
HU	Hamirpur	Hamirpur	Hamirpur	31°37’48”N	76°35’23E	31°37’52”N	76°35’17”E
HPU			Bhota	31°37’17”N	76°33’38E	31°36’25”N	76°33’52”E
HA			Taal	31°37’48”N	76°35’18”E	31°36’25”N	76°33’52”E
HF			Bhated Khas	31°41’31”N	76°32’41"E	31°41’30”N	76°32’39”E
SU		Sujanpur	Sujanpur	31°50’19”N	76°30’45”E	31°50’04”N	76°30’16”E
SPU			Alampur	31°52’08”N	76°29’44”E	31°51’01”N	76°30’25”E
SA			Thural	31°54’54”N	76°27’08”E	31°55'32”N	76°27’31”E
SF			Tikkar	31°53’33”N	76°29’41”E	31°53'19”N	76°30’03”E
KU	Kangra	Kangra	Kanga	32°05’13”N	76°29’35”E	32°04’02”N	76°28’57”E
KPU			Thakurdwara	32°04’56”N	76°31’27”E	32°04’56”N	76°31’10”E

KA		Matour (Birta)	32°07'51"N	76°17'34"E	32°06'41"N	76°17'21"E
KF		Palwana	32°04'03"N	76°15'47"E	32°03'39"N	76°16'01"E
NU	Nurpur	Nurpur	32°17'12"N	75°58'11"E	32'18'02"N	75°53'23"E
NPU		Jassur	32°16'54"N	75°50'40"E	32°16'28"N	75°50'39"E
NA		Kaldun	32°12'22"N	76°02'6"E	32°12'26"N	76°02'14"E
NF		Theru	32°12'07"N	76°01'13"E	32°12'05"N	76°01'29"E

(BU= Bilaspur urban, BPU= Bilaspur peri-urban, BA=Bilaspur agriculture, BF= Bilaspur Forest, GU= Ghumarwin urban, GPU= Ghumarwin peri-urban, GA= Ghumarwin agriculture, GF= Ghumarwin forest, HU=Hamirpur urban, HPU= Hamirpur peri-urban, HA= Hamirpur agriculture, HF= Hamirpur forest, SU= Sujanpur urban, SPU=Sujanpur peri-urban, SA= Sujanpur agriculture, SF= Sujanpur forest, KU= Kangra urban, KPU= Kangra peri-urban, KA= Kangra agriculture, KF= Kangra Forest, NU= Nurpur urban, NPU= Nurpur peri-urban, NA= Nurpur agriculture, NF= Nurpur forest)

Water sampling

Surface water and ground water samples were collected in plastic bottles of one litre capacity during pre-monsoon, monsoon and post-monsoon seasons. The surface water samples were collected from 10 to 12 cm below the water surface for detailed physico- chemical and biological analysis. For the ground water samples, the water was pumped from the hand pump for 5-7 minutes till the water temperature was stabilized and then the samples were collected as per APHA (2012).

III. Results and Discussions

The water quality parameters like pH, turbidity, EC, TDS, DO, BOD, COD, Ca, Mg, Cl^-, NO3-, heavy metal and total coliform of surface and ground water samples were found to vary with landuses and seasons. The pH in surface water ranged from 6.4 to 6.8 in the order of urban and forest (6.8) > agriculture (6.5) > peri-urban (6.4) landuses (Table 2). The pH of ground water ranged from 6.3-6.9, in the order of peri-urban (6.8) > forest (6.7) > urban (6.5) > agriculture (6.4) landuses (Table 3).

The electrical conductivity (EC) of surface water under different landuses ranged from 0.224 to 0.496 dS/m in the order of urban (0.496 dS/m) > agriculture (0.458dS/m) > peri- urban (0.444 dS/m) > forest (0.224dS/m) landuses (Table 2). Among the seasons, the highest (0.443dS/m) EC was found in monsoon followed by pre-monsoon (0.412 dS/m) and lowest (0.362 dS/m) in post-monsoon season. The highest EC in monsoon might be due to contamination of water by sewage, domestic waste, and high built up of salts. These findings are in conformation with Thresh *et al*. (1949) who reported increased ions concentration during rainy season, which resulted high electrical conductivity. Singh *et al.* in 2010 also reported maximum EC during rainy season in the rivers of Manipur. The EC of ground water ranged from 0.293 to 0.494 dS/m in the order of urban (0.494 dS/m) > peri-urban (0.461dS/m) > agriculture (0.451 dS/m) > forest (0.293 dS/m) landuses.

The turbidity of surface water under different landuses ranged from 2.6 to 6.0 NTU in the order of agriculture (9.9 NTU) > peri-urban (8.6 NTU) > urban (7.7 NTU) > forest (5.0 NTU) landuses (Table 2). The the turbidity of ground water ranged from 2.5 to 6.0 NTU in the order of urban (6.0 NTU) > peri-urban (5.5 NTU) > agriculture (5.3 NTU) > forest (2.6 NTU) landuses. Among the seasons, the highest (5.9 NTU) turbidity was found in monsoon followed by pre-monsoon (4.8 NTU) and lowest (3.9 NTU) in post-monsoon season. These results resemble with the findings of Chauhan (2012), Trivedi *et al.* (2010), Supriya *et al.*, 2018 and Yones *et al.* (2012) who observed maximum turbidity in rainy season (Table 3).

Among the seasons, the highest (131.58 mg/l) TDS was found in monsoon followed by pre-monsoon (119.94 mg/l) and minimum in post-monsoon with respective value of 114.92mg/l. The results resemble with the findings of Chauhan (2012), Supriya *et al.*, 2018, Camara *et al.* (2019), Bundela *et al.* (2012), Batabyal and Chakraborty (2015) who reported highest TDS in rainy season. The TDS of ground water ranged from 37.50 to 163.67 mg/l,in the order of urban (163.67mg/l) >peri-urban (152.59mg/l) >agriculture (134.83 mg/l)> forest (37.50 mg/l) landuses. Among the seasons, the highest (131.58 mg/l) TDS was found in monsoon followed by pre-monsoon (119.94 mg/l) and minimum in post-monsoon with respective value of 114.92mg/l, which are in line with Raut *et al.* (2011) who observed highest TDS in monsoon and lowest in post monsoon.

The DO in surface water under different landuses, ranged from 4.10 to 5.67 mg/l, in the order of forest (5.67 mg/l)> peri-urban (4.47 mg/l) >agriculture (4.31 mg/l)> urban (4.10 mg/l) landuses. Among the seasons, maximum (5.55 mg/l) DO concentration was found in post- monsoon followed by pre-monsoon (4.39 mg/l) and minimum (3.96 mg/l) in monsoon season. Similar findings have been reported by Welch (1952) and Adkins (1970). The interaction effect of landuse and season was found to exert statistically significant influence on DO in the surface water as well as in ground water. The DO in ground water ranged from 4.62 to 6.61 mg/lin the order of forest (6.61 mg/l)> peri-urban (4.97 mg/l) >agriculture (4.79 mg/l)> urban (4.62 mg/l) landuses. Among the seasons, the highest (6.09 mg/l) DO concentration was found to be in post-monsoon followed by pre-monsoon and minimum in monsoon season with respective values of 5.14 mg/l and 4.39 mg/l (Table 3). The results are also in line with the findings of Ding *et al.* (2015) who reported that forested land was positively associated with dissolved oxygen and found maximum in post-monsoon season. The DO level was found to be enhanced which means the surface and ground water quality is deteriorating under different landuse changes of low hill region.

Table 2: Seasonal variations of surface water quality parameters under different landuses in low hills

Seasons					
Landuses	**Pre-monsoon**	**Post-monsoon**	**Monsoon**	**Mean**	**CD(p=0.05)**
pH					
Agriculture	7.1	6.2	6.2	6.5	L = 0.34
Urban	6.4	6.0	6.8	6.4	S = NS
Peri-urban	6.7	6.6	6.9	6.8	L x S = 0.59
Forest	6.7	6.9	6.9	6.8	
Mean	6.7	6.4	6.7		
EC					
Agriculture	0.373	0.488	0.514	0.458	L = 0.051
Urban	0.471	0.502	0.515	0.496	S = 0.044
Peri-urban	0.393	0.426	0.515	0.444	L x S = NS
Forest	0.213	0.231	0.227	0.224	
Mean	0.362	0.412	0.443		
Turbidity					
Agriculture	9.2	8.2	12.3	9.9	L = 0.63
Urban	7.7	7.5	7.8	7.7	S = 0.55
Peri-urban	7.4	7.7	10.8	8.6	L x S = 1.09
Forest	4.0	3.5	7.6	5.0	
Mean	7.1	6.7	9.6		
Total Dissolved Solids (TDS)					
Agriculture	140.62	114.43	149.43	134.83	L = 23.45
Urban	143.15	161.48	153.15	152.59	S = NS
Peri-urban	163.50	146.25	181.25	163.67	L x S = NS
Forest	32.50	37.50	42.50	37.50	
Mean	119.94	114.92	131.58		
Dissolved oxygen (DO)					
Agriculture	4.09	4.89	3.94	4.31	L = 0.31
Urban	3.68	5.32	3.31	4.10	S = 0.26
Peri-urban	4.48	5.26	3.68	4.47	L x S = 0.53
Forest	5.35	6.74	4.93	5.67	
Mean	4.39	5.55	3.96		
Biological oxygen Demand (BOD)					
Agriculture	5.22	5.05	5.69	5.32	L = 0.29
Urban	6.72	6.237	7.33	6.76	S = 0.25
Peri-urban	5.91	6.48	7.39	6.59	L x S = 0.51
Forest	2.68	3.00	3.22	2.97	
Mean	5.13	5.19	5.91		
Chemical oxygen Demand (COD)					
Agriculture	67.33	57.33	78.42	67.69	L = 6.77
Urban	98.58	87.83	129.83	105.42	S = 5.87
Peri-urban	91.00	84.50	106.92	94.14	L x S = NS
Forest	61.50	55.33	77.50	64.78	
Mean	79.60	71.25	98.17		
Calcium (Ca)					
Agriculture	77.00	81.42	88.92	82.44	L =11.26
Urban	68.00	69.83	72.17	70.00	S = NS
Peri-urban	68.17	86.83	80.17	78.39	L x S = NS
Forest	39.50	41.17	34.92	38.53	
Mean	63.17	69.81	69.04		
Magnesium (Mg)					
Agriculture	22.935	25.449	25.996	24.793	L = 1.37
Urban	19.302	21.117	20.296	20.239	S = 1.19
Peri-urban	21.908	24.198	25.255	23.787	L x S = NS
Forest	9.992	10.131	9.797	9.973	
Mean	18.534	20.224	20.336		
Nitrates (NO_3^-)					

Agriculture	17.73	18.63	26.92	21.09	L = 1.76
Urban	10.60	13.75	16.78	13.71	S = 1.52
Peri-urban	19.03	12.07	14.83	15.31	L x S = 3.04
Forest	2.25	2.22	2.63	2.37	
Mean	12.40	11.67	15.29		
Chlorides (Cl^-)					
Agriculture	82.65	71.73	94.25	82.88	L = 6.60
Urban	56.03	57.67	58.84	57.511	S = 5.70
Peri-urban	48.37	41.15	49.31	46.28	L x S = NS
Forest	16.43	16.31	20.47	17.74	
Mean	50.87	46.72	55.72		
Arsenic (Ar)					
Agriculture	0.002	0.002	0.004	0.003	L = 0.001
Urban	0.005	0.004	0.008	0.006	S = 0.001
Peri-urban	0.004	0.005	0.007	0.005	L x S = 0.001
Forest	0	0	0	0	
Mean	0.003	0.003	0.005		
Cadmium (Cd)					
Agriculture	0.001	0	0.002	0.001	L = 0.001
Urban	0.003	0.003	0.004	0.003	S = 0.000
Peri-urban	0.003	0.004	0.004	0.003	L x S = NS
Forest	0	0	0	0	
Mean	0.002	0.002	0.002		
(Lead) Pb					
Agriculture	0.001	0.002	0.005	0.003	L = 0.000
Urban	0.005	0.005	0.008	0.006	S = 0.000
Peri-urban	0.004	0.005	0.007	0.005	L x S = 0.001
Forest	0	0	0	0	
Mean	0.003	0.003	0.005		
Chromium (Cr)					
Agriculture	0.002	0.002	0.004	0.003	L = 0.001
Urban	0.005	0.004	0.008	0.006	S = 0.001
Peri-urban	0.004	0.005	0.007	0.005	L x S = 0.001
Forest	0	0	0	0	
Mean	0.003	0.003	0.005		
Zinc (Zn)					
Agriculture	0.001	0	0.001	0.001	L = 0.001
Urban	0.003	0.003	0.006	0.004	S = 0.000
Peri-urban	0.003	0.003	0.005	0.004	L x S = 0.001
Forest	0	0	0	0	
Mean	0.002	0.002	0.003		
Total Coliform					
Agriculture	81.92	68.83	93.58	81.44	L = 17.56
Urban	183.75	144.00	259.00	195.58	S = 15.23
Peri-urban	179.83	144.00	238.50	187.44	L x S = NS
Forest	22.83	19.00	27.42	23.08	
Mean	117.08	93.96	154.63		

Table 3: Seasonal variations of ground water quality parameters under different landuses in low hills

Seasons					
Landuses	**Pre-Monsoon**	**Post-Monsoon**	**Monsoon**	**Mean**	**CD(p=0.05)**
pH					
Agriculture	6.8	6.2	6.1	6.4	0.24
Urban	6.3	6.2	7.0	6.5	0.21
Peri-urban	6.9	6.6	6.9	6.8	0.42
Forest	6.7	6.6	6.8	6.7	
Mean	6.7	6.4	6.7		

EC					
Agriculture	0.426	0.380	0.546	0.451	0.049
Urban	0.512	0.416	0.553	0.494	0.042
Peri-urban	0.439	0.408	0.537	0.461	NS
Forest	0.259	0.292	0.327	0.293	
Mean	0.409	0.374	0.491		
Turbidity					
Agriculture	5.5	3.7	6.6	5.3	L = 0.34
Urban	6.0	5.2	6.9	6.0	S = 0.29
Peri-urban	4.7	4.3	7.6	5.5	L x S = NS
Forest	2.8	2.5	2.3	2.6	
Mean	4.8	3.9	5.9		
TDS					
Agriculture	179.33	159.89	286.73	208.65	L = 30.41
Urban	313.50	337.66	501.99	384.38	S = 26.34
Peri-urban	257.58	311.84	438.67	336.03	L x S = 52.67
Forest	73.54	52.36	114.50	80.13	
Mean	205.99	215.48	335.47		
Dissolved oxygen (DO)					
Agriculture	4.78	5.17	4.39	4.78	L = 0.27
Urban	4.93	4.97	3.97	4.62	S = 0.23
Peri-urban	5.09	5.56	3.79	4.82	L x S = 0.46
Forest	5.75	8.67	5.42	6.61	
Mean	5.14	6.09	4.39		
BOD					
Agriculture	5.41	5.16	6.23	5.60	L = 0.29
Urban	6.34	6.12	6.64	6.37	S = 0.25
Peri-urban	6.38	5.73	6.66	6.26	L x S = 0.51
Forest	2.49	2.89	3.05	2.81	
Mean	5.16	4.98	5.64		
COD					
Agriculture	69.67	57.42	80.17	69.08	L = 6.70
Urban	98.83	88.83	131.67	106.28	S = 5.80
Peri-urban	91.75	84.75	107.00	94.50	L x S = NS
Forest	61.67	56.25	79.25	65.72	
Mean	80.48	71.81	99.39		
Ca					
Agriculture	80.25	95.83	105.00	93.69	L = 9.75
Urban	78.33	101.58	75.25	85.06	S = NS
Peri-urban	73.67	73.83	63.00	70.17	L x S = NS
Forest	36.08	32.42	37.58	35.36	
Mean	67.08	75.92	70.21		
Mg					
Agriculture	22.40	29.96	23.29	25.22	L = 1.01
Urban	22.51	28.43	23.07	24.67	S = 0.87
Peri-urban	20.39	23.94	19.59	21.31	L x S = 1.74
Forest	9.31	10.98	9.658	9.99	
Mean	18.65	23.33	18.90		
NO_3^-					
Agriculture	17.43	18.61	24.09	20.04	L = 2.09
Urban	19.63	16.47	16.11	17.40	S = 1.81
Peri-urban	16.89	17.58	16.48	16.99	L x S = 3.13
Forest	2.73	2.57	9.60	4.97	
Mean	14.17	13.81	16.57		
Cl^-					
Agriculture	65.32	59.41	55.99	60.24	L = 4.39
Urban	47.36	43.60	49.26	46.74	S = NS
Peri-urban	37.37	30.94	38.43	35.58	L x S = NS
Forest	15.14	16.02	19.05	16.74	

Mean	41.29	37.49	40.68		
Ar					
Agriculture	0.006	0.002	0.005	0.004	L = 0.018
Urban	0.003	0.008	0.007	0.006	S = 0.015
Peri-urban	0.008	0.082	0.007	0.032	L x S = 0.031
Forest	0	0	0	0	
Mean	0.004	0.023	0.005		
Cd					
Agriculture	0.001	0	0.001	0.001	L = 0.000
Urban	0.002	0.002	0.004	0.003	S = 0.000
Peri-urban	0.003	0.003	0.005	0.003	L x S = 0.001
Forest	0	0	0	0	
Mean	0.001	0.001	0.003		
Pb					
Agriculture	0.001	0.002	0.005	0.003	L = 0.000
Urban	0.005	0.005	0.008	0.006	S = 0.000
Peri-urban	0.004	0.005	0.007	0.005	L x S = 0.001
Forest	0	0	0	0	
Mean	0.003	0.003	0.005		
Cr					
Agriculture	0.006	0.002	0.005	0.004	L = 0.018
Urban	0.003	0.008	0.007	0.006	S = 0.016
Peri-urban	0.009	0.082	0.007	0.033	L x S = 0.031
Forest	0	0	0	0	
Mean	0.005	0.023	0.005		
Zn					
Agriculture	0.001	0	0.001	0.001	L = 0.000
Urban	0.002	0.002	0.004	0.003	S = 0.000
Peri-urban	0.003	0.003	0.005	0.003	L x S = 0.001
Forest	0	0	0	0	
Mean	0.001	0.001	0.003		
Total Coliform					
Agriculture	30.17	26.67	35.67	30.83	L = 3.20
Urban	73.83	72.67	89.00	78.50	S = 2.80
Peri-urban	72.00	70.67	81.67	74.78	L x S = NS
Forest	19.00	14.17	21.00	18.06	
Mean	48.75	46.04	56.83		

Table 4: Surface and ground water quality index under selected landuses in low hills

Landuse	Districts	Water Quality Index (WQI)	
		Surface Water	**Ground Water**
Agriculture	Bilaspur	54.26	43.32
Urban		63.24	51.95
Peri-urban		60.94	45.02
Forest		29.05	20.70
Agriculture	Hamirpur	43.32	45.67
Urban		58.21	51.81
Peri-urban		52.51	49.30
Forest		24.47	19.78
Agriculture	Kangra	45.63	42.59
Urban		59.86	52.15
Peri-urban		55.96	47.78
Forest		29.46	22.40

Figure 2: Surface water quality index (WQI) under different landuses in Bilaspur district

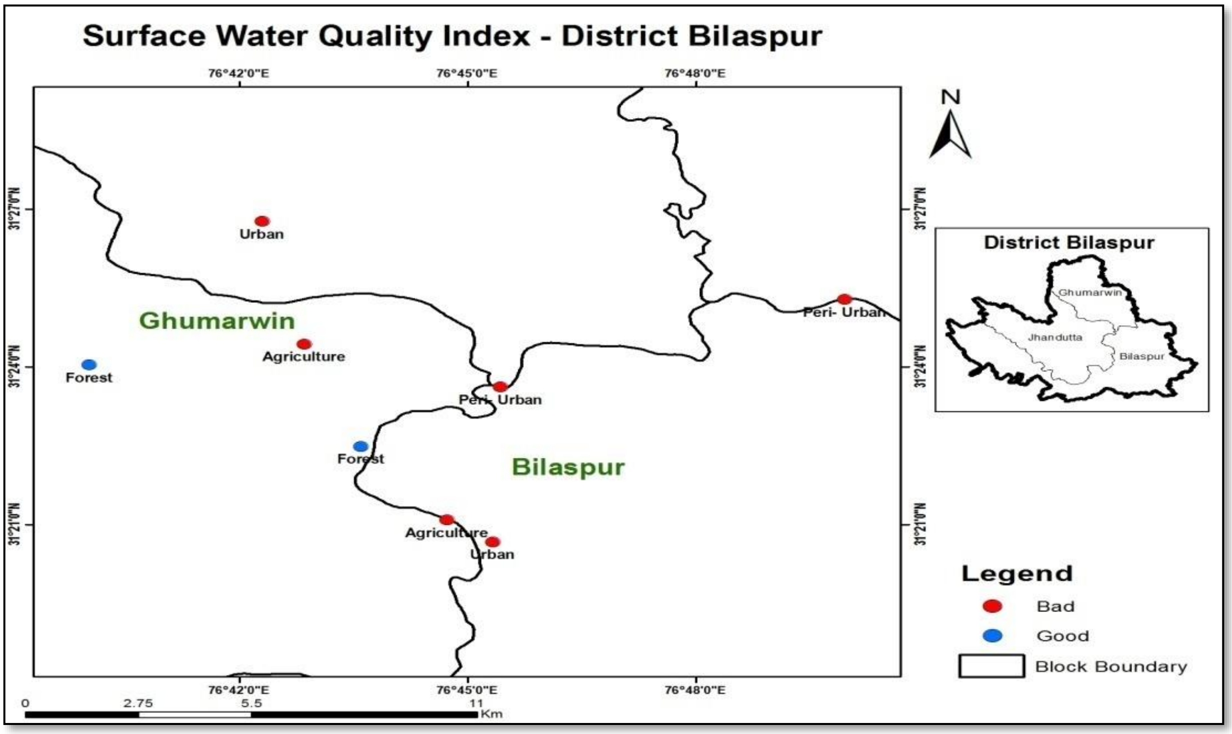


Figure 3: Surface water quality index (WQI) under different landuses in Hamirpur district.

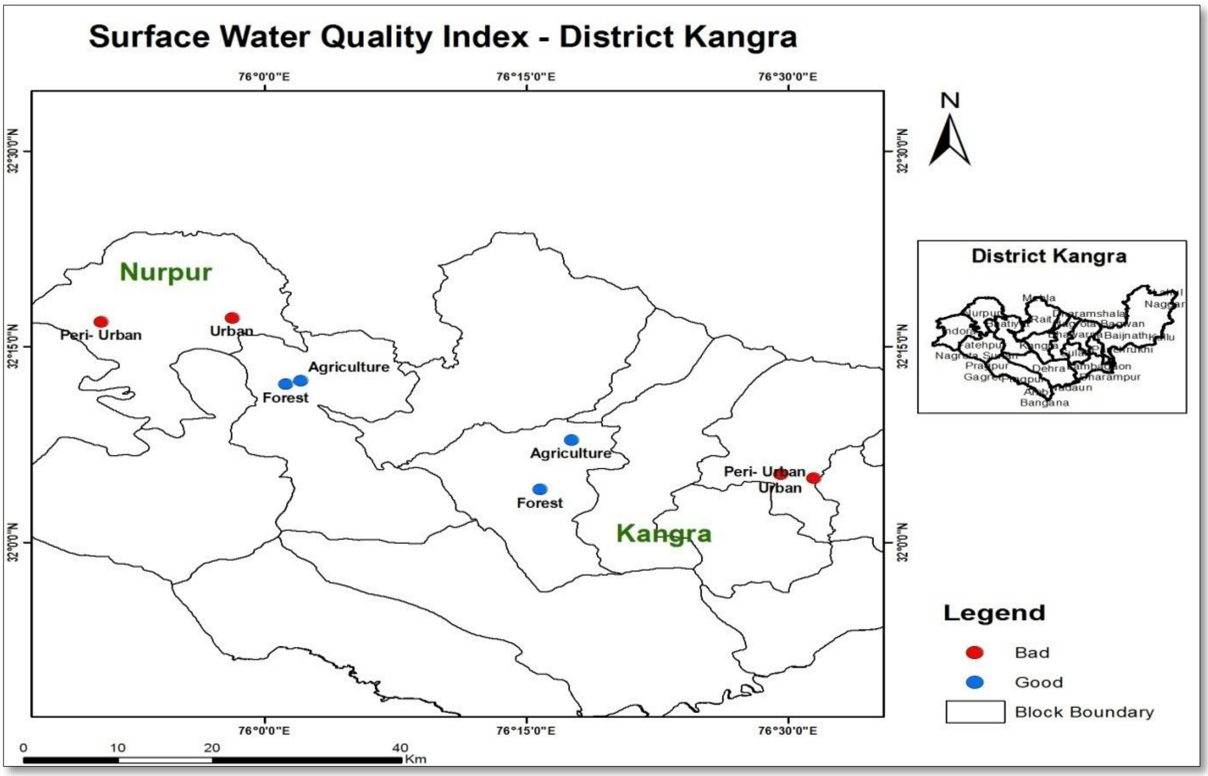


Figure 4: Surface water quality index (WQI) under different landuses in Kangra district.

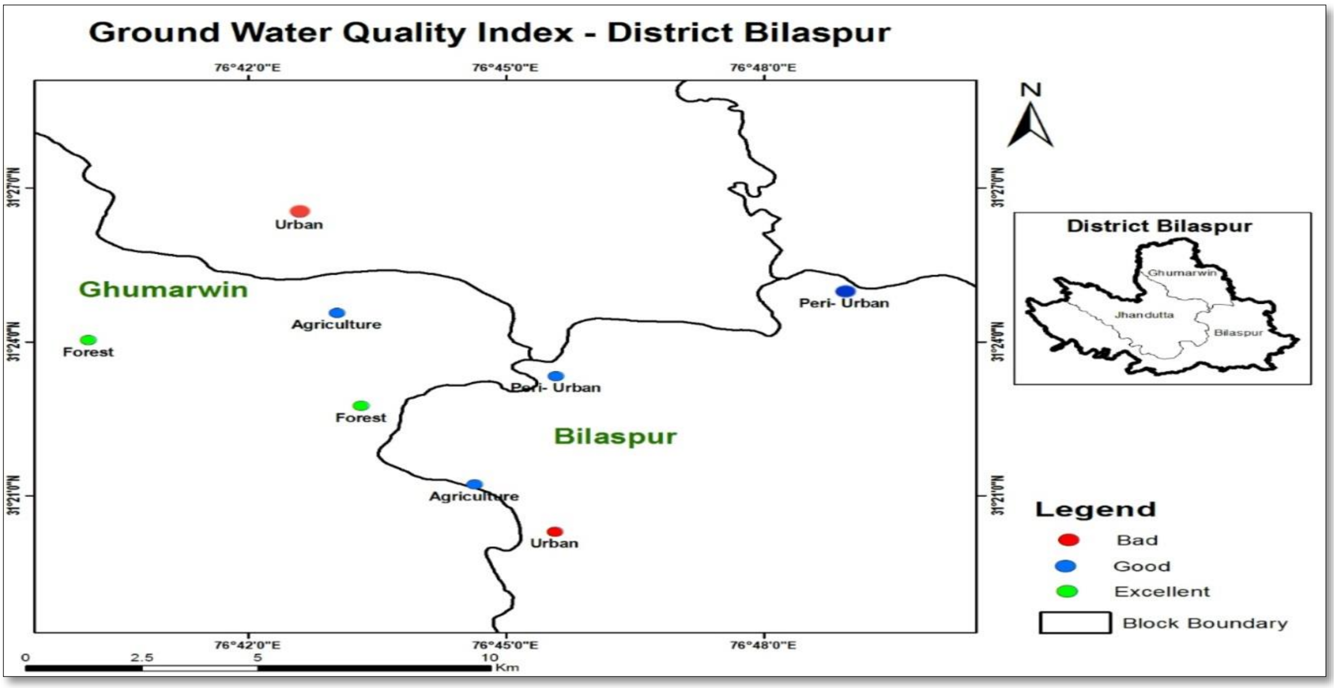
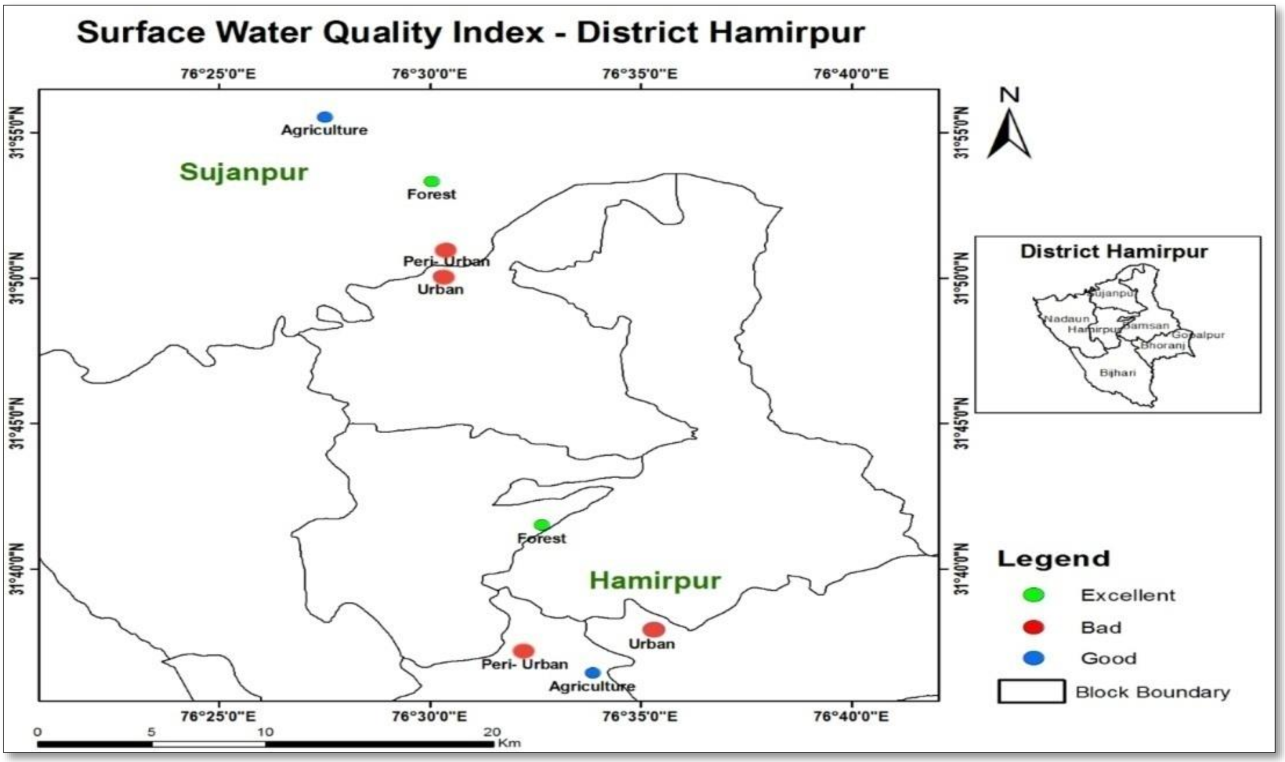


Figure 5: Ground water quality index (WQI) under different landuses in Bilaspur district



The BOD in surface water under different landuses ranged from 2.97 to 6.76 mg/l, in the order of urban (6.8 mg/l) > peri-urban (6.6 mg/l) > agriculture (5.3 mg/l) > forest (2.9 mg/l) landuses. The interaction effect of landuse and season was also found to exert significant influence on BOD in the surface water. The BOD in ground water ranged from 2.81 to 6.37 mg/l,in the order of urban (6.4 mg/l) > peri-urban (6.3 mg/l) > agriculture (5.6 mg/l) > forest (2.8 mg/l) landuses. The higher BOD in ground water in monsoon season was probably due to runoff and its further percolation down to profile from non-point sources which is in conformity with the findings of Phiri *et al.* (2005), (Supriya *et al.,* 2019). The BOD level was found to be enhanced above the prescribed limit indicating that the quality of the surface and ground water is deteriorating under different landuse changes.

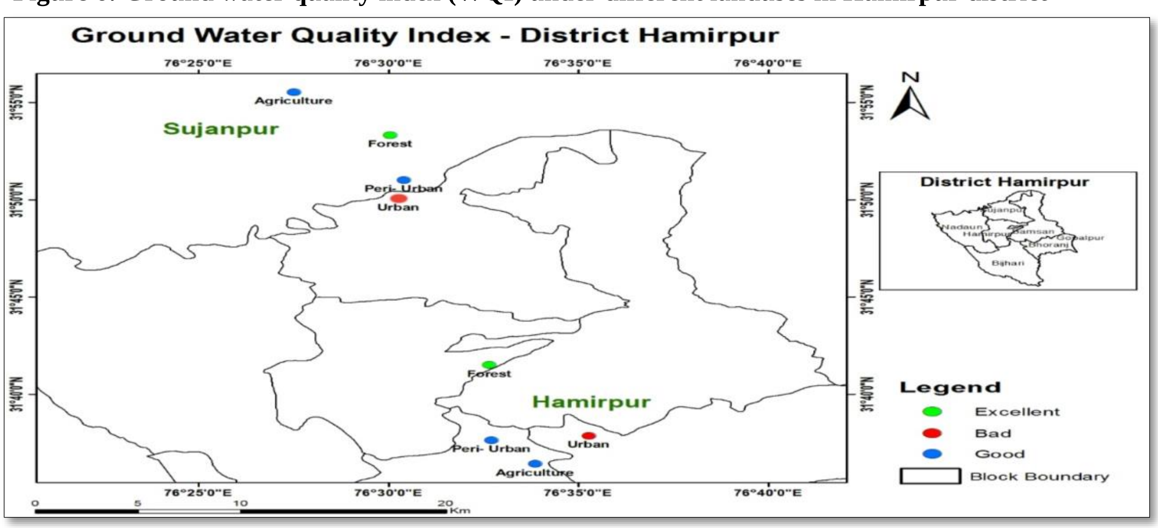
The COD in surface water under different landuses ranged from 64.78 to 105.42 mg/l, in the order of urban (105.42 mg/l) > peri-urban (94.14 mg/l) > agriculture (67.69 mg/l) > forest (64.78 mg/l) landuses (Table 2). The COD in ground water ranged from 65.72 to 106.28 mg/l, in the order of urban (105.42 mg/l) > peri-urban (94.14 mg/l) > agriculture (67.69 mg/l) > forest (64.78 mg/l) landuses (Table 3). Among the seasons, the maximum COD concentration was found in monsoon followed by pre-monsoon and lowest in post-monsoon with respective values of 98.17, 79.60 and 71.25 mg/l. Joseph and Jacob (2010) and Chattopadhyay *et al.* (2005) also reported similar results where they found maximum COD under urban landuse.

The concentration of calcium in surface water ranged from 35.53 to 82.44 mg/l, in the order of agriculture (82.44 mg/l)> peri-urban (78.39 mg/l) > urban (70.00 mg/l) > forest (38.53 mg/l) landuses (Table 2). Among the seasons, the highest (69.81mg/l) Ca was found in post- monsoon followed by monsoon (69.04 mg/l) and minimum in pre-monsoon season with respective values of 63.17 mg/l. The present findings are in line with the findings of Yones *et al.* (2012) and Shaikh and Mandre (2009), where they found highest Ca concentration under agriculture landuse.

The concentration of Ca in ground water ranged from 35.36 to 93.67 mg/l, in the order of agriculture (93.69 mg/l)> urban (85.00 mg/l) >peri-urban (70.17 mg/l)) > forest (35.36 mg/l) landuses. Among the seasons, the highest (75.92 mg/l) Ca was found in post-monsoon followed by monsoon (70.21 mg/l) and minimum in pre-monsoon season with respective value of 67.08 mg/l. The present findings are in confirmation with the findings of Gupta and Paliwal (2010) who also recorded that landfill leachates were enriched in $Ca^{2+}$and other anions and cations. Therefore, the calcium concentration was found to be higher than permissible limit indicating the threat to quality of surface and ground water under different landuse changes. Among the seasons, maximum concentration was found in monsoon followed by post-monsoon and lowest in pre-monsoon season with respective values of 20.34, 20.22 and 18.53 mg/l. The higher Mg content under agriculture landuse as well as under urban landuse was due to the dumping of garbage, sewage discharge, urban runoff, agrochemicals, effluents containing the residues from soap and detergents. These results are in the conformation with the findings of Shaikh and Mandre (2009) who recorded highest Mg concentration under agriculture landuse. The Mg concentration in surface water ranged from 9.97 to 24.79 mg/l, in the order of agriculture (24.79 mg/l) > peri-urban (23.78 mg/l) > urban (20.24 mg/l) > forest (9.97 mg/l) landuses. The Mg concentration in ground water ranged from 9.99 to 25.22 mg/l, in the order of agriculture (25.22 mg/l) > urban (24.67 mg/l) > peri-urban (21.31 mg/l) > forest (9.99 mg/l) landuses. Among the seasons, the highest Mg concentration was found in post- monsoon followed by monsoon and minimum in pre-monsoon season with respective values of 23.33, 18.90 and 18.65 mg/l (Table 3). These findings are in agreement with Balamurgan and Dheenadayalan (2012) who have reported highest values of magnesium under agriculture landuse in post-monsoon season.

The concentration of nitrates under different landuses in surface water ranged from 2.37 to 21.09 mg/l, in the order of agriculture (21.09 mg/l) > peri-urban (15.31 mg/l) >urban (13.71 mg/l) > forest (2.37 mg/l) landuses. Similar results corroborated the findings of Gupta *et al*. (2010), Shaikh and Mandre (2009) and Yones *et al.* (2012) where they found highest nitrates concentration under agriculture site.

Figure 6: Ground water quality index (WQI) under different landuses in Hamirpur district



Among the seasons, the highest (15.29 mg/l) concentration of nitrates was found in monsoon followed by pre-monsoon (12.40 mg/l) and minimum in post-monsoon season with respective value of 11.67 mg/l. The results are in line with Anbazhagan (1988) who also observed maximum concentration of nitrates in surface water in monsoon season. The interaction effect of landuse and season was also found to exert statistically significant influence on the concentration of NO3- in surface water. The maximum (26.92 mg/l) NO3- concentration was observed under agriculture in monsoon season and minimum (2.22 mg/l) under forest landuse in post-monsoon. Irene (1991) also observed highest concentration of nitrates during monsoon season and was of the view that it may be due to runoff of nutrients by rains. The concentration of NO3- in ground water ranged from 4.97 to 20.04 mg/l, in the order of agriculture (20.04 mg/l)> urban (17.40 mg/l) >peri- urban (16.90 mg/l) > forest (4.97 mg/l) landuses (Table 3). Jeyaruba and Thushyanthy (2009) also have similar results.

The concentration of chlorides in surface water ranged from 17.74 to 82.88 mg/l in the order of agriculture (82.88 mg/l)> urban (57.51 mg/l) >peri-urban (46.28 mg/l)> forest (17.74 mg/l) landuses (Table 2). Similar results corroborated the findings of Chauhan (2012), Rana (2012), Jeyaruba and Thushyanthi (2009), where they recorded highest chloride concentration in surface water under agriculture landuse. Among the seasons, maximum (55.72 mg/l) chloride concentration was found in monsoon season followed by post-monsoon (50.87 mg/l) and minimum was found in pre-monsoon (46.72 mg/l). The results corroborate the findings of Khound *et al.* (2012) where they recorded highest chloride concentration in monsoon season.

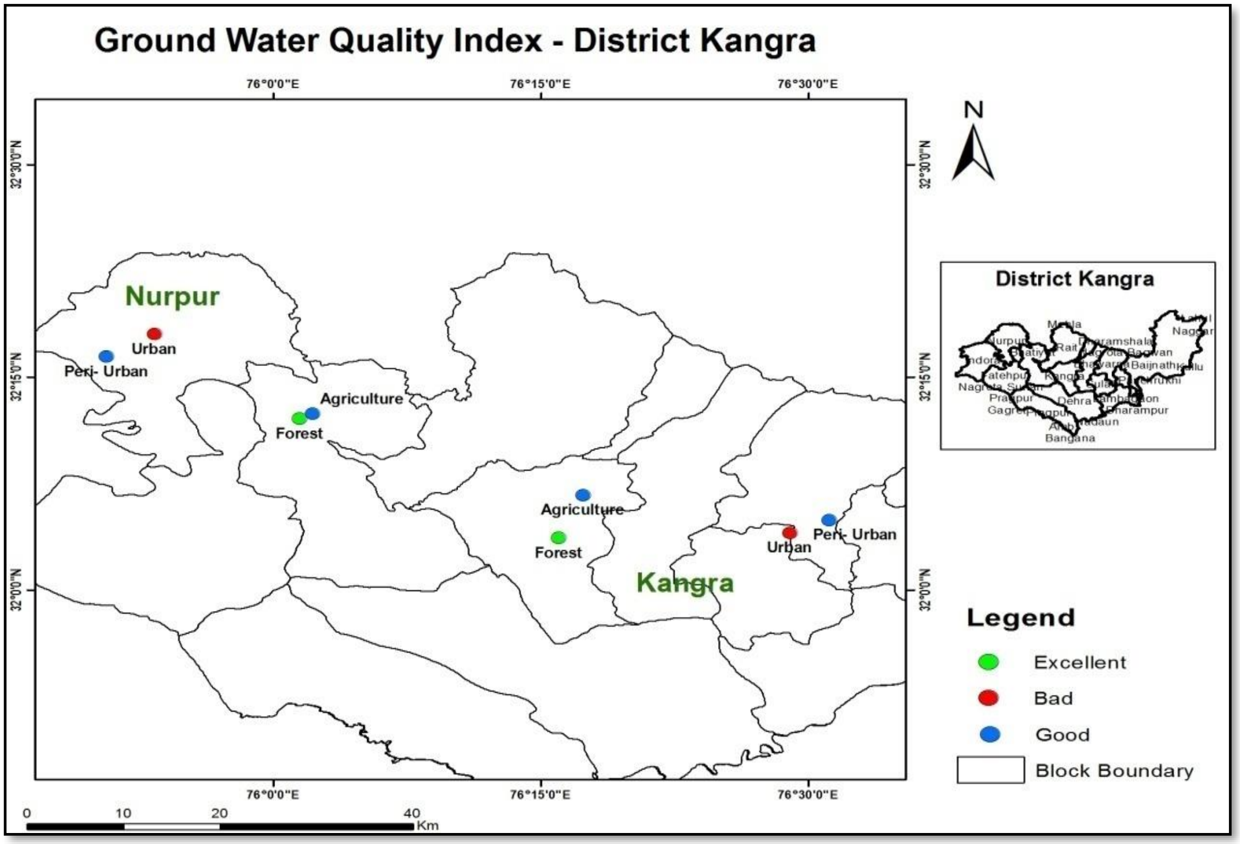
The concentration of chlorides in ground water ranged from 15.82 to 60.26 mg/l, in the order of agriculture (60.24 mg/l)> urban (46.74 mg/l) > peri-urban (35.58 mg/l)> forest (16.74 mg/l) landuses. Similar results resemble with the findings of Thresh *et al.* (1949) where they found maximum chloride concentration in ground water under agriculture landuse. Among the seasons, maximum (41.29, mg/l) chloride concentration was found in pre- monsoon season followed by monsoon (40.68 mg/l) and minimum was found in post-monsoon (37.49mg/l). The results corroborate the findings of Rana *et al.* (2012) who reported maximum chloride concentration in pre-monsoon season.

The Ar concentration in surface water ranged from 0 to 0.006 mg/l, in the order of urban (0.006 mg/l) > peri-urban (0.005 mg/l) > agriculture (0.003 mg/l) and forest landuse does not have Ar concentration (Table 2). This is due to contamination of surface water sources from dumping of waste, effluents release and water sources near landfill sites (Rana, 2012 and Chauhan, 2012). Among the seasons, the highest (0.005 mg/l) Ar concentration was observed in monsoon followed by pre-monsoon and same in post-monsoon season (0.003 mg/l) respectively. These results are also in agreement with the findings of (Rana, 2012) who have also reported maximum Ar during monsoon season. The Ar concentration in ground water ranged from 0 to 0.082 mg/l, in the order of peri-urban (0.032 mg/l) > urban (0.006 mg/l) > agriculture (0.004 mg/l) and no Ar concentration was found under forest landuse. Among the seasons, the maximum concentration was found in post-monsoon followed by monsoon and lowest in pre-monsoon with respective values of 0.023, 0.005 and 0.004 mg/l. These results are also in agreement with the findings of Kar *et al*. (2008) who have also reported maximum Ar concentration during monsoon season in the ground water under peri-urban and urban landuses. The Ar concentration was above the permissible limit indicating deteriorating quality of ground water under different landuses.

The Cd concentration in surface water ranged from 0 to 0.003 mg/l, in the order of urban and peri-urban (0.006 mg/l) > agriculture (0.001 mg/l) and no Cd concentration was found under forest landuse (Table 2). Among the seasons, Cd concentration was same in monsoon, pre- monsoon and post-monsoon seasons (0.002 mg/l).The maximum content of Cd in surface water during monsoon season is in agreement with the findings of Sankar *et al.* (2010) who have also recorded maximum concentration of cadmium during monsoon season. The Cd concentration of ground water ranged from 0 to 0.003 mg/l in the order of urban and peri-urban (0.003 mg/l) > agriculture (0.001 mg/l) and no Cd concentration was found under forest landuse. Among the seasons, maximum concentration was found in monsoon followed by pre-monsoon and post-monsoon seasons with respective values of 0.003, 0.003 and 0.001 mg/l (Table 3).The maximum (0.005 mg/l) Cd concentration was observed under peri-urban landuse in monsoon season and no Cd concentration was found under forest landuse in all the three seasons. The maximum content of Cd in ground water during monsoon season is in agreement with the findings of Sankar *et al*. (2010) who have also recorded maximum concentration of cadmium under urban landuse in monsoon season.

The Pb concentration in surface water ranged from 0 to 0.006 mg/l,in the order of urban (0.006 mg/l) > peri-urban (0.005 mg/l) > agriculture (0.003 mg/l) and no Pb concentration was found under forest landuse (Table 2). Among the seasons, maximum (0.005 mg/l) Pb concentration was found in monsoon followed by pre-monsoon and same in post-monsoon seasons (0.003 mg/l). This was ascribed due to disposal of lead acid batteries, spent petroleum, news print, pigments of paints and combustion of coal containing lead results in higher concentration of surface water bodies Rao *et al.* (2010). The maximum content of Pb in surface water during monsoon season is in agreement with the findings of Kar *et al.* (2008) who have recorded maximum concentration of Pb under urban landuse. The Pb concentration in ground water ranged from 0 to 0.006 mg/l, in the order of urban and peri-urban (0.005 mg/l)> agriculture (0.003 mg/l) and no Pb concentration was found under forest landuse. Among the seasons, maximum Pb concentration was found in monsoon followed by pre-monsoon and post-monsoon with respective values of 0.005, 0.003 and 0.003 mg/l. The present results corroborate the findings of Oyeku and Eludoyin (2010), Walia (2018), Sharma (2018), Sharam (2014) and Gupta (2012) who reported maximum concentration of Pb under urban landuse in rainy season.

Figure 7: Ground water quality index (WQI) under different landuses in Kangra district



The Cr concentration of surface water ranged from 0 to 0.006 mg/l, in the order of urban (0.006 mg/l), peri-urban (0.005 mg/l) >agriculture (0.003 mg/l) and no Cr concentration was found under forest landuse (Table 2).

Among the seasons, maximum (0.005 mg/l) Cr concentration was found in monsoon followed by pre-monsoon and same in post-monsoon seasons (0.003 mg/l). These findings are in agreement with the findings of Chauhan (2012) who reported maximum Cr concentration under urban landuse in monsoon season in surface water. This was due to landfill sites near water bodies, geology of catchment areas and surface runoff.

The Cr concentration in ground water ranged from 0 to 0.033 mg/l in the order of urban (0.033 mg/l), peri-urban (0.006 mg/l) > agriculture (0.004 mg/l) and no Cr concentration was found under forest landuse. Among the seasons, the maximum concentration was found in post-monsoon followed by pre-monsoon and post-monsoon with respective values of 0.023, 0.005 and 0.005 mg/l (Table 3). The results of present findings are confirmation with the findings of Singh *et al.* (2010) who reported maximum Cr concentration in ground water under urban and semi-urban landuses in post-monsoon season.

The Zn concentration in surface water ranged from 0 to 0.004 mg/l, in the order of urban and peri-urban (0.004 mg/l) > agriculture (0.001 mg/l) and no Zn concentration was found under forest landuse (Table 2). Among the seasons, maximum (0.003 mg/l) Zn concentration was found in monsoon followed by pre-monsoon and same in post-monsoon seasons (0.002 mg/l). This was due to geology of catchment areas, surface runoff, municipal waste and sewage waste. These findings are in agreement with the findings of Chauhan (2012) and Rana (2012) who reported maximum zinc concentration under urban landuse in monsoon season. Zn concentration in ground water ranged from 0 to 0.003 mg/l, in the order of urban and peri-urban (0.003 mg/l) agriculture (0.001 mg/l) and no Zn concentration was found under forest landuse. Among the seasons, the maximum (0.003 mg/l) concentration was found in monsoon followed by pre- monsoon and same in post-monsoon (0.001 mg/l). These findings are in agreement with the findings of Woldeab *et al.* (2019) and Singh *et al.* (2010) who reported maximum Zn concentration under urban landuse in monsoon season in ground water.

The Hg concentration in surface and ground water under study area was not found to be influenced by landuses, seasons and their interaction.

The total coliform of surface water ranged from 23.08 to 195.58MPN/100 ml,in the order of urban (195.58MPN/100 ml) > peri-urban (187.44MPN/100 ml) >agriculture (81.44 MPN/100 ml)> forest (23.08MPN/100 ml) landuses. The results are in line with Bundela *et al.* (2019), Kumar *et al.* (2017) and Singh *et al.* (2010) who also detected total coliform in urban site. Among the seasons, the highest (154.63 MPN/100 ml) total coliform was found in monsoon followed by pre-monsoon (117.08 MPN/100 ml) and minimum in post-monsoon season with respective value of 93.96 MPN/100 ml. Similar results are in line with Kumar *et al.* (2017), Singh *et al.* (2010), Woldeab *et al.* (2019) and Shaikh and Mandre (2009) who also observed maximum concentration of total coliform in monsoon and lowest in post monsoon. The total coliform of ground water ranged from 18.00 to 78.78 MPN/100 ml in the order of urban (78.50MPN/100 ml) > peri-urban (74.78MPN/100 ml) >agriculture (30.83MPN/100 ml)> forest (18.03MPN/100 ml) landuses. Similar results are in line with Pullanikkatil *et al*. (2015) who also detected total coliform in ground water under urban landuse. Among the seasons, the highest (56.83 MPN/100 ml) total coliform was found in monsoon followed by pre-monsoon (48.75 MPN/100 ml) and minimum in post-monsoon season with respective value of 46.04 MPN/100 ml.The results are in line with Bundela *et al.* (2019) who also observed highest total coliform in monsoon season.

Water Quality Index (WQI)

a) Surface water

The water quality index (WQI) of surface water ranged from 24.47 to 63.24. In Bilaspur district, the WQI for urban, peri-urban and agriculture landuse remarked as bad and good for forest landuse. In Hamirpur district, the WQI for urban and peri-urban landuse remarked as bad and good for agriculture and excellent for forest landuse. In Kangra, WQI for urban, peri-urban landuses remarked as bad and good for agriculture and forest landuses.

a) Ground water

The water quality index (WQI) of ground water ranged from 19.78 to 52.15. In Bilaspur district, the WQI for urban landuses was remarked as bad, good for peri-urban and agriculture and excellent for forest landuse. In Hamirpur district, the WQI for urban was remarked as bad, good for peri-urban & agriculture andexcellent for forest landuse. In Kangra district, the computed ground WQI for urban remarked bad ground water quality, good for peri-urban andexcellent for forest landuse.

IV. Conclusion

The study revealed that water quality under different landuses (agriculture, urban, peri-urban and forest) in low hills of Himachal Pradesh has deteriorating as the level of DO, BOD and Ca has been enhanced above the permissible limit in surface water. In ground water, the level of DO, BOD, Ca and Ar concentrations were above the prescribed limit. The use of the WQI is useful in identifying pollution hotspots. This is a simple way which could be used in study area to determine the health of water bodies and does not need extensive analysis or large resources. The surface water quality index was rated as bad for urban, peri-urban, agriculture landuses in Bilaspur district, urban and peri-urban in Hamirpur and Kangra districts, whereas, the WQI of ground water rated as bad for urban landuse in all selected regions of study area.

Conflict of interest: There is no conflict of interest

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