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Effects of national highway expansion activities on physicochemical characteristics of surface water along NH-22, India

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Abstract
The development of highway infrastructure contributes to environmental contamination, specifically surface water bodies in close proximity to the roads. A study was conducted to assess the effects of road expansion on physicochemical parameters of surface water by collecting 72 samples during Pre-monsoon, monsoon and post-monsoon seasons from 4 study sites. The water quality parameters such as pH, EC, TDS, Turbidity, BOD, COD, Cl^- and NO^-_3 were analysed. The water was found to be slightly alkaline in nature. The mean values of analytes were: pH (7.40,7.20,7.24), EC (0.28 ds m^{-1},0.23ds m^{-1},0.25 ds m^{-1}), Turbidity (3.15NTU, 3.53NTU, 2.96NTU), TDS (144.67 mgl^{-1}, 110.9367 mgl^{-1}, 129.69 mgl^{-1}), BOD (2.57 mgl^{-1}, 2.3767 mgl^{-1}, 2.12 mgl^{-1}), COD (48.20 mgl^{-1},42.27 mgl^{-1},35.05 mgl^{-1}), Cl^- (27.12 mgl^{-1}, 21.25 mgl^{-1}, 19.46 mgl^{-1}) and No^-_3 (3.62 mgl^{-1}, 4.26 mgl^{-1}, 4.22 mgl^{-1}) recorded during pre-monsoon, monsoon and post-monsoon seasons respectively. The turbidity has highly significant positive correlation with BOD ($r = 0.844$, $p < 0.01$), COD ($r= 0.730$, $p < 0.010$) and Cl^- ($r = 0.813$, $p < 0.01$). The concentration of pH, EC, TDS, BOD, COD and Cl^- was higher during pre-monsoon whereas turbidity and No^-_3 were higher in monsoon. The highway expansion activities have started affecting the surface water quality henceforth, highway construction impacted parameters can be considered as potential indicator for biological relevance of surface water bodies.

Keywords: Seasons, physical, chemical, construction, concentration, dilution

Introduction

Water is an indispensable natural gift, acts as an integrated system for all metabolic reactions occurred in macro and micro aquatic organisms (Singh *et al*. 2016) [32]. Water is a vital component for socio-economic development globally (Kumar *et al*. 2017) [37], as urbanization proceeds, new highways are constructed for transportation and development. During construction of highways, stream bodies near the roads are susceptible to the impact of construction activities ultimately affect stream biotic and non-biotic conditions (Barton, 1977, Chisholm and Downs, 1978, Cline *et al*. 1982, Taylor and Roff, 1986, Anderson and Potts, 1987, Stout and Cburn, 1989, Wellman *et al*. 2000, Hedrick *et al*. 2007) [7, 8, 35, 39, 15]. Due to rapid anthropogenic activities and unplanned industrialization and urbanization, water pollution became one of the most global threats for human kind (Sharma *et al*. 2018) [31]. The development of road construction and infrastructure activities are the primary source for environmental contamination specifically suspended sedimentation(Hornbeck and Reinhart, 1964), as sedimentation restricts the penetration of sunlight, chocking out aquatic life (Houser and Pruess, 2009) [17], habitat degradation, changing of leaf processing and input of toxins from construction material (Eldin, 2002) [12]. The major pollutants loaded during construction of roads are propellants, lubricants, tannin, silicates, exhaust gases produced by combustion of fuels, abrasive products, asphalt, ashes, dust and organic bituminous compounds (Shabir *et al*. 2016) contribute to road runoff that might be entered into nearby surface water bodies, which in turn leads to degradation of physical and chemical characteristics of water. Certain factors like rainfall, nature of pavement material, nature and concentration of pollutants as well as seasonal changes as a result of variation in precipitation (Vega *et al*. 1998) [38] affect quality of surface water bodies (Yannopulos *et al*. 2013). Surface water bodies particularly vulnerable to pollution as they engulf discharge from point and non- point sources (Young *et al*.1996) [42]. Pollutants generated from major sources like soil erosion, diesel and petrol, paint solvents, cleaner, harmful chemicals, construction debris and dirt at construction sites entered directly or indirectly into adjacent aquatic bodies ultimately caused detrimental effect on stream quality (USEPA, 1993 and Williams *et al*. 2001) [36, 40]. The pollutant level in water bodies near to roads during or after construction is often increases when road construction coupled with forest harvest as well as hauling (Arismendi *et al*. 2017) [6]. It has been emphasized that both natural and anthropogenic activities including hydrological precipitation and climate change profoundly influence the water quality status (Akpe et. al. 2018) [2]. The good quality of water depends upon magnitude of physico-chemical parameters which are to be assessed, helps to determine the productivity of aquatic bodies (Kamal et. al. 2007). To certain extent, seasons has been shown to correlation with mobility of pollutants in pre-monsoon because of higher temperature observed during the dry season which increased the rate of evaporation and facilitated dissolution, ion exchange capacity and desorption of water which increases the ion concentration in surface water and in monsoon might be due to dilution of water during rains (Ngabirano *et al*. 2016) [23].

The purpose of present study is to assess the effects of highway expansion activities on water quality. Specifically the objectives of present study are: 1) to asses physico-chemical characteristics of water in three different seasons associated with road pollutants. 2) to establish the correlation between the parameters. The results of the study may be helpful to control the degradation level of water quality due to road expansion activities.

Methodolgy

Study area

The study area located in Mashobhra division of District Shimla which lies in between 31º05'10" to 32 º10'50" North latitude and 76º57'05" to 70º07 '45" East longitude in the adjoining forest of Shogi- Shimla - Dhalli bypass realignment under NH-22 and part of this also falls under the jurisdiction of district Solan in Himachal Pradesh (Fig.1) at altitude ranges from1493 to 2250 m and slope range is between 300m to 400 m per km in Shimla district and 100 to 300 per Km in Solan district. The forest road is 51m wide and 27 km long. The Mashobhra is part of Shimla water catchment act wildlife Sanctuary located in Northern India. The Climate of both the districts through which the project road is passing is subtropical in the valley and tends to be temperate in hilltops. The average annual rainfall in the districts Solan and Shimla is 1450 & 1253 mm respectively. The temperature during summer ranges from 14ºC to 28ºC while temperature during winter ranges from 1.7ºC to 14.8ºC. Relative Humidity range is between 33-91%. The land use along the Shoghi- Shimla – Dhali bypass is open barren and partly cultural wasteland. The topography of project road is undulating and hilly which becomes medium to highly undulating in Shoghi – Shimla –Dhali bypass alignment. The drains that are crossed by the project road are KathuluKaNalla (km 131.8), SamriKaNala (Km 137.500), KarKaNala (Km 147.57) and KalaliKaNalla (Km156.115). The soil of project area in district Solan is sandy loam in valley areas and alluvium in District Shimla.

Experimental description

The effects of expansion activities of NH-22 (now NH-5) Shogi- Shimla - Dhalli bypass on water quality were assessed during the years 2018-2019. The study area was divided into 4 equal stretch of 7Km each namely Shunghal, Raghanv, Majjhar, and Dhali. In order to assess the effect of various construction activities on water quality, surface water samples from each site were collected during pre-monsoon (April and May), monsoon (June, to September) and the post-monsoon (October and November) seasons. In total there were 12 treatment combinations (4×3) which were replicated three times in randomized block design.

Sample collection and parameter measurement

Surface (stream) water samples were collected in plastic bottles of 1 litre capacity from 20 cm below the water surface for detailed chemical analysis. The samples were analysed for the parameters such as pH, electric conductivity (EC), turbidity, total dissolved solids (TDS) biological oxygen demand (BOD) and chemical oxygen demand (COD) immediately as per the standard guidelines and procedure. The Physicochemical parameters were assessed by suitable method (Table 1) and results were compared with permissible limits (Table 2).

Statistical analysis

The observations recorded on various parameters of surface water were subjected to statistical analysis under Randomized Block Design. Analysis of variance (ANOVA) was worked out and critical difference at 5% level of significance following Cochran and Cox (1967). Analysis of variance was done as per the model suggested by Panse and Sukhatme (2000). The data was analysed using MS-Excel, OPSTAT as per design of the experiment and the mean values, standard deviation Pearson correlation (r) value of the data were obtained.

Results

The surface water quality was determined in terms of the mean values of physical parameters which were compared with their WHO, CPCB and ICMR recommended limits for proper functions of biological system of living organisms.

pH

pH followed a decreasing trend from pre-monsoon, post monsoon and to monsoon season with respective values of 7.40, 7.24 and 7.20 (Table 3). Statistical analysis suggested that pH do not differ significantly at 0.05% level among sites in surface water while it showed significant difference at 0.05% level among seasons as well as season and sites (Table 6). The season x sites interaction showed significant impact as the highest pH of 7.46 recorded at Shunghal in pre- monsoon season and a lowest of 7.09 at Majjhar in the monsoon season (Table 5).

Electrical Conductivity of surface water bodies

The electrical conductivity of surface water in the study area revealed that the EC followed a decreasing trend as pre-monsoon > post –monsoon > monsoon season with respective values of 0.28 dsm^{-1}, 0.25dsm^{-1} and 0.23 dsm^{-1}(Table 3). Further, the season x site interaction revealed that the highest EC of 0.30 dsm^{-1} was noticed in pre-monsoon at Majjhar and Dhali while, the lowest of 0.21 dsm^{-1} was noticed in monsoons at Dhali (Table 5). Statistical analysis suggested that EC do not differ significantly at 0.05% level among sites in surface water while it showed significant difference at 0.05% level among seasons as well as season and sites (Table 6).

Turbidity of surface water bodies

The turbidity of surface water in the study area indicated that turbidity followed a decreasing trend in the order of monsoon pre-monsoon > post-monsoon with respective values of 3.53 mg l^{-1}, 3.15 mg l^{-1} and 2.96 mg l^{-1}(Table 3). Statistical analysis suggested that turbidity differed significantly at 0.05% level among sites as well as seasons in surface water while it showed non-significant difference at 0.05% level among season x sites (Table 6). The scrutiny of data further indicated that among different sites, the highest turbidity of 3.25 mg l^{-1} was recorded in water sources at Dhali while the lowest (3.17 mg l^{-1}) was evidenced at Raghanv (Table 4).

Total Dissolved Solids (TDS) in the surface water bodies

TDS of surface water in the study area indicated that TDS followed a decreasing trend in the order of pre-monsoon > post-monsoon > monsoon with respective values of 144.67 mg l^{-1}, 129.69 mg l^{-1} and 110.93 mg l^{-1}(Table 3). The scrutiny of data further indicated significant variation among the sites as the highest TDS of 133.84 mgl^{-1} was observed in surface water at Majjhar followed by 129.02 mg l^{-1} (Shunghal), 128.91 mg l^{-1} (Dhali) and lowest of 121.95 mg l^{-1} at Raghanv (Table 4). The season x site interaction indicated that the maximum TDS of

152.59 mg l^{-1} was observed in pre-monsoon season at Majjhar, whereas the minimum of 105.91 mg l^{-1} was observed in the monsoon season at Shunghal (Table 5). Statistical analysis suggested that TDS differed significantly at 0.05% level among sites as well as seasons in surface water while it also showed significant difference at 0.05% level among season x sites (Table 6).

Biological Oxygen Demand (BOD) of surface water bodies
The BOD in surface water further indicated a similar trend with respective of seasons. The average highest BOD was observed in the pre-monsoon which was statistically at par with monsoon and lowest in post-monsoon with respective values of 2.57 mg l^{-1}, 2.37 mg l^{-1} and 2.12 mg l^{-1} and followed a decreasing trend in the pattern of pre-monsoon > monsoon>post monsoon (Table 3). The scrutiny of data further reported that irrespective of season the maximum (2.48 mgl^{-1}) BOD was recorded at Shunghal followed by 2.36 mg l^{-1} at Dhali, 2.32 mg l^{-1} at Raghanv and minimum of 2.25 mg l^{-1} was recorded at Majjhar (Table 4). The two way interaction influence of season x site indicated that the highest BOD of 2.78 mg l^{-1} was recorded at Shunghal in pre monsoon while the lowest of 2.06 mg l^{-1} was noticed at Majhhar in post monsoon (Table 5). Statistical analysis suggested that BOD differed significantly at 0.05% level among sites as well as seasons in surface water while it also showed significant difference at 0.05% level among season x sites (Table 6).

Chemical Oxygen Demand of surface water bodies
The surface water COD showed that seasons followed a decreasing trend from Pre-monsoon > monsoon > post-monsoon with respective values of 48.2 mg l^{-1}, 42.27 mg $l^{-1}$and 35.05 mg l^{-1} (Table 3). The data further showed that the highest COD of 48.50 mg l^{-1} was recorded in surface water bodies at Shunghal which was statistically at par with 41.90 mg l^{-1} (Dhali), 40.63 mg l^{-1} (Raghanv) and lowest of 36.36 mg l^{-1} in surface water bodies at Majjhar (Table 4). The two way interaction influence of season x site indicated that the highest COD of 52.16 mg l^{-1} was recorded at Shunghal in pre monsoon while the lowest of 29.55 mg l^{-1} was noticed at Majhhar in post monsoon (Table 5). Statistical analysis suggested that COD differed significantly at 0.05% level among sites as well as seasons in surface water while it also showed significant difference at 0.05% level among season x sites (Table 6).

Chloride concentration in the surface water bodies
The highest chloride (27.12 mg l^{-1}) was observed in pre-monsoon while lowest (19.46 mg l^{-1}) concentration of chloride in post monsoon followed the trend pre monsoon > monsoon > post-monsoon (Table 3). Whereas, among different sites highest (25.00 mg l^{-1}) concentration of chloride was registered at Raghanv while lowest (20.40 mg l^{-1}) was recorded at Majjhar (Table 4). Statistical analysis suggested that Cl^- content differed significantly at 0.05% level among sites as well as seasons in surface water while it also showed non-significant difference at 0.05% level among season x sites (Table 6).

Nitrate concentration in the surface water bodies
The highest nitrate (4.26 mg l^{-1}) concentration was noticed in monsoon while the lowest (3.62 mg l^{-1}) in pre-monsoon followed the trend monsoon > post-monsoon > pre-monsoon (Table 3). While among different sites highest (4.18 mg l^{-1}) concentration of nitrate was noticed at Shunghal while the lowest (3.88 mg l^{-1}) was reported at Majjhar (Table 4). The average interaction among season and sites was observed to be significant. The highest (4.42 mg l^{-1}) concentration of nitrate was observed in monsoon season at Shunghal while the lowest (3.40 mg l^{-1}) was noticed in pre-monsoon at Shunghal (Table 5). Statistical analysis suggested that nitrate content differed significantly at 0.05% level among sites as well as seasons in surface water while it also showed significant difference at 0.05% level among season x sites (Table 6). The minimum, maximum and overall average value of all the parameters were shown in Fig 2.

Correlation between water parameters
The data presented in Table 7 revealed that pH has highly significant positive correlation with TDS (r= 0.758, p < 0.01), BOD (r= 0.663, p < 0.05) and Cl^- (r= 0.771, p < 0.01) The EC has moderate significant positive correlation with TDS (r = 0.650, p < 0.05). The turbidity has highly significant positive correlation with BOD (r = 0.844, p < 0.01), COD (r= 0.730, p < 0.010) and Cl^- (r = 0.813, p < 0.01). The BOD showed significantly positive correlation with COD (r= 0.756, p < 0.01) and Cl^- (r= 0.756, p < 0.01). The COD has highly significant positive correlation with Cl^- (r= 0.616, p < 0.05). The NO_3^- has significantly negative correlation with pH (r = -0. 650), TDS (r = -0.670) and Cl^- (r = -0.604) at 0.05 % level whereas at 0.01% level, NO_3^- showed negative correlation with turbidity (r = -0.733).
During pre-monsoon season, strong degree positive correlation between (pH & BOD r = 0.814), (pH & COD r = 0.886), (EC & TDS r = 0.926), (EC & turbidity, r = 0.809), (BOD & COD r = 0.745) and moderate degree positive correlation between (Cl- & NO_3^- r = 0.642) has been estimated (Table 8). The strong degree positive correlation between (Cl^- & pH r = 0.791), (EC & COD, r = 0.878), (NO_3^- & BOD r = 0.908) and (COD & NO_3^- r = 0.860) has been observed. The moderate degree positive correlation between (EC & NO_3^- r = 0.662) and low degree positive correlation (BOD & COD r = 0.580) has been observed during monsoon season (Table 9). There is strong degree positive correlation between (TDS & pH, r = 0.938), (BOD & EC r = 0.827), (Cl^- & EC r = 0.728) and (COD & NO_3^- r = 0.806). The moderate degree positive correlation between (COD & turbidity r = 0.669), (BOD & NO_3^- r = 0.609) and low degree positive correlation between (COD & BOD, r = 0.579) was observed in post monsoon season (Table 10)

Discussion
pH is an important parameter which explains the acid- alkaline nature of water as it is considered as index for the degree of pollution. Higher pH in pre-monsoon might be due to increased photosynthetic activity by autotrophs as they assimilate dissolved carbon dioxide and bicarbonates which increase the alkalinity of water. The results are in collaboration with Patil (2012) who observed higher pH in pre-monsoon and lowest in the post-monsoon season. The lower value of pH during monsoons might be due to the dilution of alkaline substances (Kumar et. al. 2017). The results showed similarity with the findings of Gupta *et al*. (2017) who also recorded a fall in pH value in monsoon season.
The ability of an aqueous solution to carry a current is depending upon total dissolved ions. The amount of ions in water directly proportional to dissolved solids (Bhatt *et al*.1999). The highest

EC in pre monsoon season might be due to accumulation of salts as they break into positive and negative ions like Na^+, Ca^+ and K^+ at higher temperature and increases the mobility of ions due to high rate of evaporation (Makineci et. al. 2015). Similarly, in monsoon season dilution of the ions occurs due to rain resulting in decreased EC (Venkatesharaju *et al*. 2010). The electrical conductivity was directly proportional to pH and alkalinity (Gupta and Saharan, 2009).

Turbidity determined the condition and productivity of natural water bodies. It is caused by suspended and colloidal matter such as clay, slit and finely divided organic and inorganic matter. The highest turbidity in monsoon might be due to the presence of suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter where as in pre-monsoon sedimentation was found to be responsible for lower value of turbidity (Venkatesharj et.al. 2010). The results are in conformity with the findings of Singh *et al*. (2013) who have indicated that higher turbidity in monsoon season due to high dilution in water sources.

Total dissolved solids generally depend upon many factors like rainfall and amount of surface runoff. The highest TDS in pre-monsoon might be due to higher temperature observed during the dry season which facilitated dissolution, ion exchange capacity, desorption, weathering processes and evaporation of water which increased the ion concentration in surface water. Decrease in TDS in monsoons might be due to dilution of water because of rainfall. The results are in conformity with the findings of Ngabirano *et al*. (2016) who also reported higher TDS in pre-monsoon.

The amount of oxygen in the water which is required by the aerobic organisms is measured by BOD. The highest BOD in pre monsoon might be due to higher evaporation of water from the surface water bodies and rapid utilization of oxygen for the decomposition of organic matter comes from precipitation (Ololade and Ajayi, 2009). The results are in collaboration with the finding of (Radhika and Gangaderr, 2004) who also reported highest BOD in pre-monsoon season.

The COD act as an indicator of organic pollution in surface water bodies (King *et. al.*, 2003 and Faith, 2006) as it measure the amount of organic compounds in water. The highest COD in pre –monsoon might be due to increasing rate of evaporation at higher temperature which ultimately facilitates dissolution of ion in surface water and decrease in COD in monsoon might be due to dilution of water due to rains. The results showed similarity with the findings of (Ngabirano *et al*. 2016) who also reported higher COD in pre-monsoon season.

Chloride is generally considered as a major factor to equalize cation and anion balance of an aquatic system. Higher concentration of chloride in pre-monsoon may probably be because of increased temperature that causes high evaporation rate of water and thus decreasing the water level (Lashari *et al*. 2009). The results are in conformity with the findings of Sahni and Yadav (2012) who also noticed highest chlorides (42.58 mg l^{-1} to 1735.24 mg l^{-1}) during pre-monsoon season while lowest (12.6 mg l^{-1} to 1402.96 mg l^{-1}) in the post monsoon season.

Nitrates generally assessing the potential biological productivity of surface water The Higher concentration of nitrates in monsoon might be due to the presence of algae, bacteria and other suspended particles in the water. The results are in collaboration with the findings Manjare *et al.* (2010) who also noticed highest (3.75 mg l^{-1}) nitrate concentration during monsoon season while the lowest (4.40 mg l^{-1}) in the pre- monsoon season. A strong and positive relationship was observed between water parameters in pre-monsoon and post -monsoon season as the results showed similarity with the findings of Sharma *et al.* (2018).

Conclusion

The present study revealed that due to highway expansion activities water quality become degraded. Pollution parameter indicates that all these parameter vary depending upon the quality and quantity of silt, sediments around the sites. The concentration of pollution parameter was more during pre-monsoon except turbidity and nitrate which was more in monsoon season.However most of the parameter analysed within the permissible limit.

Table 1: Different water physicochemical properties determined and methods

Sr. No.	Parameter	Units	Method and References
1	pH	_	pH meter model 510 of EIA
2	EC	dsm^{-1}	EC meter model 1601 of EIA
3	TDS	mgl^{-1}	Microprocessor based conductivity and TDS meter.
4	Turbidity	NTU	Nephelometric method (APHA, 1998)
5	BOD	mgl^{-1}	5 day BOD test as per 5210B method (APHA, 2005).
6	COD	mgl^{-1}	TR 320 Spectroquant after digesting at 148^{0}C for 120 minutes
7	Chloride (Cl^{-1})		Photometrically by using spectroquant 300 (Merck make) instrument
8	Nitrate (NO^-_3)		Photometrically by using spectroquant 300 (Merck make) instrument

Table 2: Permissible limits of water quality parameters for drinking and domestic purpose lay down by WHO, CPCB, BIS and ICMR

Parameter	CPSB	WHO	BIS	ICMR
pH	6.5-8.5	6.5-8.5	6.5-8.5	7.5-8.5
EC	2000	Not avaliable	2000	Not avaliable
TDS	500	1000	500	Not available
Turbidity	10	Not available	Not available	Not available
BOD	5	5	<2	Not available
COD	Not available	Not available	250	20
Chloride (Cl^{-1})	250	250	250	200
Nitrate (NO^-_3)	45	45	45	45

Table 3: Mean parameter values recorded for Pre-monsoon, Monsoon and Post-monsoon seasons

	Parameters							
seasons	pH	EC	Turbidity	TDS	BOD	COD	Cl^-	No_3^-
Pre-monsoon	7.40 ± 0.05	0.28 ±0.03	3.15 ±0.03	144.67 ±8.41	2.57 ±0.16	48.20 ±5.42	27.12 ±1.62	3.62 ±0.23
Monsoon	7.20 ± 0.07	0.23 ±0.02	3.53 ±0.04	110.93 ±3.35	2.37 ±0.13	42.27 ±5.08	21.25 ±2.39	4.26 ±0.35
Post-monsoon	7.24 ± 0.02	0.25 ±0.02	3.53 ±0.04	129.69 ±6.84	2.12 ±0.04	35.05 ±6.73	19.46 ±2.48	4.22 ±0.13

Values in bold are standard deviation

Table 4: Mean parameter values for each site during study period

	Parameters							
Sites	**pH**	**EC**	**Turbidity**	**TDS**	**BOD**	**COD**	**Cl^-**	**NO_3^-**
Site1	7.30 ± 0.14	0.26 ± 0.01	3.22 ± 0.28	129.02 ± 21.35	2.48 ± 0.32	48.50 ± 4.31	22.12 ±4.69	4.18 ± 0.70
Site2	7.28 ± 0.09	0.24 ± 0.02	3.17 ± 0.29	121.95 ± 10.32	2.32 ± 0.25	40.63 ± 10.16	25 ±.18	3.96 ± 0.31
Site3	7.23 ± 0.12	0.25 ± 0.04	3.22 ± 0.39	133.84 ± 20.09	2.25 ± 0.18	36.66 ± 5.91	20.40 ±4.04	3.88 ± 0.33
Site4	7.31 ± 0.10	0.25 ± 0.04	3.25 ± 0.30	128.91 ± 16.20	2.36 ± 0.19	41.90 ± 7.26	22.92 ±4.58	4.11 ± 0.16

Values in bold are standard deviation

Table 5: Seasonal variation among physicochemical parameters in selected sites during study period

		pH	**EC**	**Turbidity**	**TDS**	**BOD**	**COD**	**Cl^-**	**No^{-3}**
Site 1	Pre	7.46	0.28	3.53	148.02	2.78	52.16	26.62	3.40
	Mon	7.21	0.25	3.16	105.91	2.51	49.60	22.48	4.42
	Post	7.24	0.25	2.97	133.13	2.14	43.75	17.26	4.73
Site 2	Pre	7.38	0.23	3.48	132.13	2.66	50.20	28.66	3.66
	Mon	7.24	0.23	3.11	112.42	2.24	41.75	23.44	4.26
	Post	7.21	0.27	2.91	120.51	2.13	29.95	22.91	3.96
Site3	Pre	7.33	0.30	3.53	152.59	2.41	40.18	25.07	3.51
	Mon	7.01	0.23	3.19	112.63	2.28	39.36	17.96	4.12
	Post	7.28	0.22	2.93	136.29	2.06	29.55	18.18	4.02
Site4	Pre	7.42	0.30	3.58	145.14	2.5	50.26	28.14	3.92
	Mon	7.27	0.21	3.16	112.74	2.43	38.38	21.14	4.21
	Post	7.23	0.25	3.02	128.85	2.15	37.07	19.50	4.18

Table 6: Anova Relation of Physicochemical Parameters during study period

Significant level at 0.05%	**Source of Variation**	**pH**	**EC**	**Turbidity**	**TDS**	**BOD**	**COD**	**Cl^-**	**NO_3^-**
	sites	NS	NS	SS	SS	SS	SS	SS	SS
2018-19	season	SS	SS	SS	SS	SS	SS	SS	SS
	Site x season	SS	SS	NS	SS	SS	SS	NS	SS
Minimum value		7.09	0.21	2.91	105.91	2.06	29.55	17.26	3.40
Maximum		7.46	0.30	3.58	152.59	2.78	52.16	28.66	4.73
Overall average		7.28	0.25	3.21	128.43	2.35	41.85	22.61	4.03

SS Significant at 0.05%
NS- Non Significant

Table 7: Correlation between analysed parameters

	pH	**EC**	**TDS**	**Turbidity**	**BOD**	**COD**	**Cl^-**	**No_3^-**
pH	1.000							
EC	0.485	1.000						
TDS	0.758**	.650*	1.000					
Turbidity	0.721**	0.547	0.545	1.000				
BOD	0.663*	0.314	0.250	.844**	1.000			
COD	0.548	0.315	0.189	.730**	.834**	1.000		
Cl^-	0.771**	0.514	0.409	.813**	.756**	.616*	1.000	
No_3^-	-.650*	-0.363	-.670*	-.733**	-0.513	-0.271	-.604*	1.000

**Correlation is significant at 0.01% level
*Correlation is significant at 0.05 % level

Table 8: Correlation between analysed parameter in Pre-monsoon season

	pH	**EC**	**TDS**	**Turbidity**	**BOD**	**COD**	**Cl^-**	**No_3^-**
pH	1							
EC	-0.004	1.000						
TDS	-0.076	0.926**	1.000					
Turbidity	0.308	0.809**	0.542	1.000				
BOD	0.814**	-0.368	-0.233	-0.270	1.000			
COD	0.886**	-0.430	-0.530	0.019	0.794**	1		
Cl^-	0.396	-0.646	-0.869	-0.073	0.262	0.745**	1	

No_3^-	0.042	0.043	-0.332	0.546	-0.432	0.203	0.642*	1

**Correlation is at 0.01% level
*Correlation is significant significant at 0.05 % level

Table 9: Correlation between analysed parameters in monsoon season

	pH	**EC**	**TDS**	**Turbidity**	**BOD**	**COD**	**Cl^-**	**No_3^-**
pH	1							
EC	-0.417	1.000						
TDS	0.214	-0.915	1					
Turbidity	-0.700	0.203	-0.316	1				
BOD	0.330	0.303	-0.661	0.295	1			
COD	0.059	0.878**	-0.925	-0.069	0.580*	1		
Cl^-	0.791**	0.109	-0.135	-0.866	0.192	0.490	1	
No_3^-	0.156	0.662*	-0.902	0.222	0.908**	0.860**	0.293	1

**Correlation is significant at 0.01% level
*Correlation is significant at 0.05 % level

Table 10: Correlation between analysed parameters in post-monsoon season

	pH	**EC**	**TDS**	**Turbidity**	**BOD**	**COD**	**Cl^-**	**No_3^-**
pH	1							
EC	-0.999	1						
TDS	0.938**	-0.948	1					
Turbidity	-0.008	-0.043	0.257	1				
BOD	-0.852	0.827**	-0.631	0.502	1			
COD	-0.147	0.121	0.202	0.669*	0.579*	1		
Cl^-	-0.710	0.728**	-0.909	-0.496	0.273	-0.592	1	
No_3^-	-0.455	0.457	-0.191	0.152	0.609*	0.806**	-0.186	1

**Correlation is significant at 0.01% level
*Correlation is significant at 0.05 % level

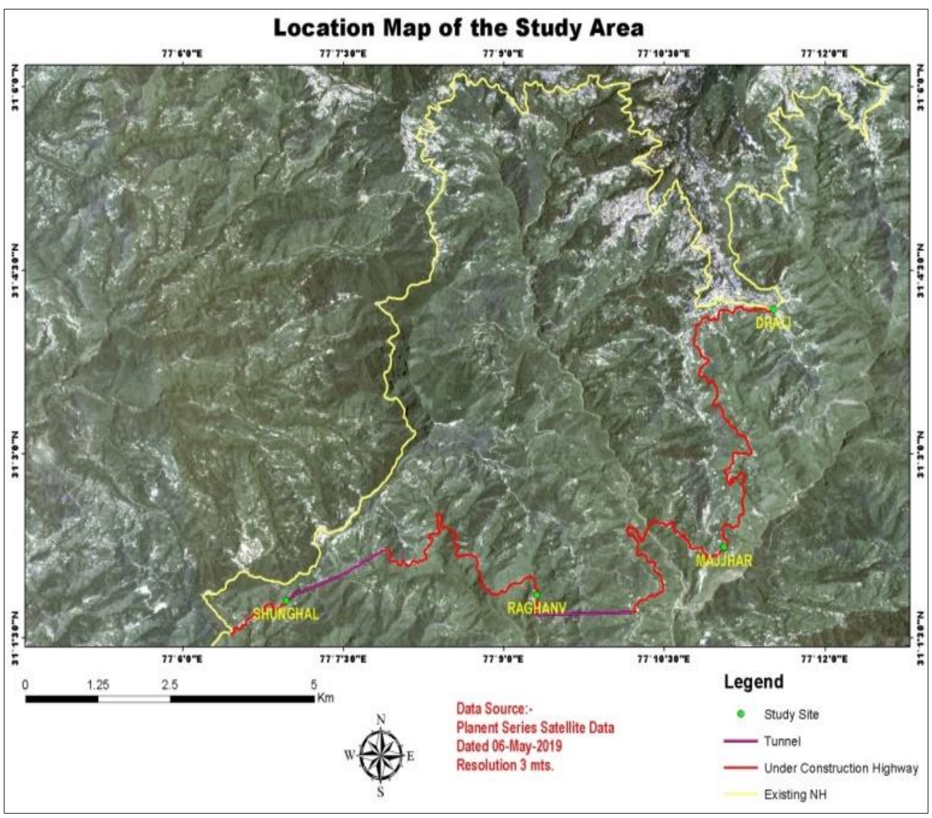

Fig 1: Location map of the study area

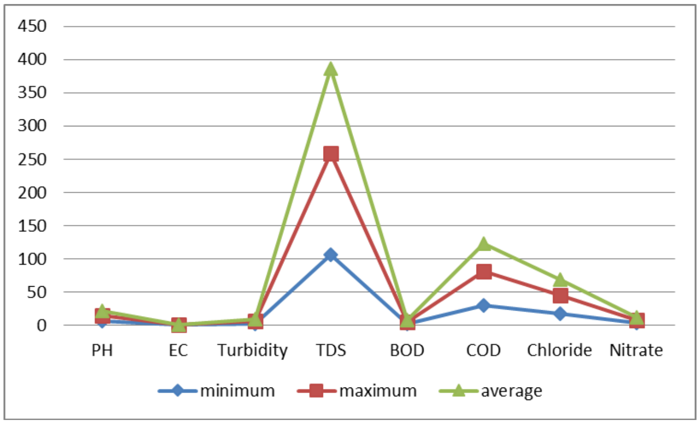

Fig 2: The minimum, maximum and average value of water parameters in study area

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Conflict of interest
There is no conflict of interest for this manuscript.

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